

**Potential benefits of a Puzzle Video Game -
Cognitive Enrichment Programme for the
development of critical thinking among first year
BEd students**

BJ Bunt

 **orcid.org / 0000-0002-2102-4381**

Thesis accepted for the degree Doctor of Philosophy in
Learning and Teaching at the North-West University

Promoter: Prof MM Grosser

Graduation: October 2019
Student number: 20172672

DEDICATION

This thesis is dedicated to my wife, Laurel Lydia Bunt, who offered me unconditional love and support throughout the course of this study. I also dedicate this work to my parents, Prof John Reginald Bunt and Erna Bunt, who supported me all the way since the beginning of my studies and are an inspiration to further my academic career. And finally, to my son, Arthur Georg Bunt, who inspires me every day to do better. This study is dedicated to you.

DECLARATION

I, BYRON JOHN BUNT, solemnly declare that this work is original and the result of my own labour. It has never, on any previous occasion, been presented in part or whole to any institution or board for the award of any degree.

I further declare that all information used and quoted has been duly acknowledged by complete reference.



12 August 2019

Signature

Date

ACKNOWLEDGEMENTS

My sincere thanks and gratitude go to the following people whose advice, guidance, support and motivation have helped me to complete this study.

- The Lord God, Jesus Christ my saviour, who has helped and carried me through my studies with love and grace.
- My promoter, Professor M.M. Grosser, for her leadership, patience, guidance and support throughout the study period.
- Mrs Aldine Oosthuyzen for her assistance with the statistical analysis of data and technical editing of this dissertation.
- Dr Rhelda Krugel for the professional language editing of the dissertation.
- The staff of the Ferdinand Postma Library (Vaal Triangle campus), for helping me to find the literature needed for my research.
- My colleagues at the Faculty of Education for their advice and continued support.
- All the students who participated in this research study.
- Grantt Gouws, who acted as the independent person and assisted me with the recruitment of the participants and the observations during the implementation of the intervention programme
- To my parents, Prof John Bunt and Erna Bunt, my brother, Lance, and all my friends for their unconditional love and support.
- A very special word of thanks goes to my wife, Laurel Bunt, for all her patience, love, support and understanding during the completion of this study.
- Open access for the use of Portal images:
https://www.google.com/search?rlz=1C1FERN_enZA671ZA671&q=Portal+video+game+images&tbm=isch&source=univ&sa=X&ved=2ahUKEwjZrr-gyZ_hAhXRC-wKHUirCJ0Q7Al6BAglEA8&biw=1349&bih=559
- And finally, to my son, Arthur Bunt, who inspires me every day to do better.

SUMMARY

The central purpose of this doctoral thesis has been to deepen understanding of the development of critical thinking by using Portal, a puzzle video game.

The study involved embedded mixed method research that employed quantitative experimental research and qualitative, multiple case study research as strategies of inquiry, to investigate the potential benefits of a 13-week Puzzle Video Game-Cognitive Enrichment Programme (PVG-CEP) for the development of critical thinking among a group of first-year BEd students at a university in South Africa. In the context of the study, critical thinking is conceptualised as the integrated development, and application of critical thinking skills (making inferences, recognising assumptions, making deductions, doing interpretations, evaluating arguments), critical thinking dispositions (systematic working ways, accuracy, persistence), and standards for reasoning (logic, clarity, relevancy). The research involved students who were conveniently and purposively sampled, and randomly assigned to an experimental (N = 4) and control (N = 4) group. Only the experimental group took part in the intervention.

Quantitative test data were collected by administering the Watson-Glaser Critical Thinking Appraisal (W-GCTA) prior to, and after the PVG-CEP intervention that involved the application of Portal, a puzzle video game, to assess the development of the participants' critical thinking. In addition, qualitative descriptive data were collected by conducting observations that were accompanied by anecdotal records and video recordings, and guided by a four-point descriptive scale, during the implementation of the PVG-CEP intervention, to establish growth in relation to the critical thinking skills, dispositions and standards for reasoning. After the intervention, semi-structured face-to-face interviews were conducted with the participants of the experimental group to explore their experiences with the Portal puzzle video game.

None of the participants excelled in the application of critical thinking skills during the pre-test and the post-test, and differential growth in relation to the development of the critical thinking skills was noted among the participants after completing the intervention: Based on the post-test results, participants 1, 2, and 4 demonstrated growth for making inferences, only participant 4 achieved growth for making deductions and doing

interpretations, and only participant 2 showcased growth for recognising assumptions. Participant 3 demonstrated no growth for any of the critical thinking skills on which the research focused, and the skill to evaluate arguments did not display any growth among any of the participants. Overall, participants 1 and 3 seemingly entered the intervention programme at practicing levels of thinking, and remained at practicing levels of thinking at the conclusion of the intervention. Participants 2 and 4 appeared to be at beginning level of thinking, and achieved growth to practicing level during the post-test.

Even though the observations did not frequently support the post-test results, the researcher argues that the intervention possibly contributed to the slight improvement that was noted for some of the critical thinking skills. The skills still appear to be fragile, and require more practice to enable the participants to progress towards becoming advanced and master thinkers. The intervention appeared to have been more beneficial for the growth noted in relation to the dispositions and standards for reasoning on which the study focused. All the participants, except participant 2, managed to achieve growth for all the dispositions and standards for reasoning on which the research focused.

Challenges related to the difficulty of the game, and lack of time were mentioned in relation to the intervention. Although the participants experienced fun and enjoyment during the game play, and noted that the PVG-CEP holds benefits in relation to growth in cognitive and emotional abilities, the findings of the study do not conclusively confirm that the intervention contributed to the growth observed for some of the critical thinking skills, dispositions, and standards for reasoning.

The participants in the control group who did not take part in the intervention, also demonstrated some growth in relation to the critical thinking skills on which the research focused, which could probably be linked to the influence of normal academic teaching.

The study is concluded with guidelines to guide and enhance the future implementation of puzzle video games for developing critical thinking.

Key words: critical thinking, critical thinking dispositions, standards for reasoning, puzzle video games, informal learning

TABLE OF CONTENTS

DEDICATION	i
DECLARATION	ii
ACKNOWLEDGEMENTS	iii
SUMMARY.....	iv
TABLE OF CONTENTS.....	vi
LIST OF TABLES	xvii
LIST OF FIGURES.....	xviii
LIST OF GRAPHS	xix
CHAPTER 1 INTRODUCTION AND STATEMENT OF THE PROBLEM	1
1.1 INTRODUCTION.....	1
1.2 THEORETICAL AND CONCEPTUAL FRAMEWORKS	8
1.2.1 Theoretical framework	8
1.2.2 Conceptual framework.....	8
1.3 CONCEPT DEFINITIONS	15
1.3.1 Critical thinking	15
1.3.2 Puzzle video games	15
1.4 PRIMARY AND SECONDARY RESEARCH QUESTIONS	16
1.5 AIM AND OBJECTIVES	17
1.5.1 Variables	18
1.6 EMPIRICAL RESEARCH.....	18
1.6.1 The literature study.....	18
1.6.2 Research framework	18
1.6.3 Research design.....	18
1.6.4 Research strategy	18

1.6.5	Research participants.....	19
1.7	METHODS OF DATA COLLECTION AND QUALITY CRITERIA	19
1.7.1	Quantitative data collection instruments	19
1.7.1.1	Reliability and validity of the quantitative research design.....	20
1.7.2	Qualitative data collection instruments	20
1.7.2.1	Observations	20
1.7.2.2	Interviews	21
1.7.2.3	Rigour of the observations and interviews	21
1.8	DATA ANALYSIS	22
1.8.1	W-GCTA test data	22
1.8.2	Interviews and observations	22
1.9	THE PVG-CEP INTERVENTION	23
1.10	ETHICAL CONSIDERATIONS	23
1.11	DEMARCATON OF THIS STUDY	23
1.12	RESEARCH PROCEDURE	24
1.13	CHAPTER DIVISION	24
1.14	CHAPTER SUMMARY.....	25
CHAPTER 2	CRITICAL THINKING CONCEPTUALISED	27
2.1	INTRODUCTION	27
2.2	THE ORIGINS OF CRITICAL THINKING	29
2.2.1	Introduction.....	29
2.2.2	The origins of critical thinking	29
2.2.2.1	First phase of the critical thinking movement: The work of John Dewey (1910)	30
2.2.2.2	The second phase of the critical thinking movement: The work of Robert Glaser (1941) and Bertrand Russell (1943)	32
2.2.2.3	The third phase of the critical thinking movement: The work of Robert Ennis (1964, 1987), McPeck (1981), Beyer, (1983), Norris and Ennis (1989), and Paul (1990).....	34
2.2.2.4	The recent critical thinking movement: The work of Facione (1990, 2009), Paul and Elder (2006), Halpern (2007) and Sternberg (2007).....	36
2.3	CRITICAL THINKING: A CONCEPT CLARIFICATION	37
2.3.1	The nature of critical thinking.....	37

2.3.2	Core cognitive and meta-cognitive critical thinking skills	38
2.3.3	Critical thinking dispositions	40
2.3.4	Critical thinking intellectual traits	44
2.3.5	The elements of reasoning	45
2.3.6	Universal standards for reasoning	46
2.3.7	The researcher's conceptualisation of critical thinking in the context of the study	49
2.4	CRITICAL THINKING IN ACTION	51
2.4.1	Applying the logical thinking mode	52
2.4.2	Applying the critical questioning mode	53
2.4.3	Applying the creative thinking mode	53
2.4.4	Applying the big picture thinking mode	54
2.5	THE IDEAL CRITICAL THINKER	55
2.5.1	Stage one: The unreflective thinker	55
2.5.2	Stage two: The challenged thinker	56
2.5.3	Stage three: The beginning thinker.....	58
2.5.4	Stage Four: The practicing thinker.....	59
2.5.5	Stage Five: The advanced thinker	61
2.5.6	Stage Six: The master thinker	63
2.5.7	Developing dispositions and standards for reasoning	65
2.6	THE IMPORTANCE OF CRITICAL THINKING FOR TEACHER EDUCATION	66
2.6.1	Critical thinking and the Curriculum and Assessment Policy	66
2.6.2	Critical thinking and teaching and learning in the 21 st century.....	67
2.6.3	Critical thinking as a life skill.....	70
2.7	GATHERING INFORMATION ON STUDENTS' CRITICAL THINKING SKILLS	71
2.7.1	The purpose of critical thinking assessment.....	71
2.7.2	Measuring instruments	73
2.7.2.1	Multiple choice tests	73
2.7.2.2	Direct classroom observation	73
2.7.2.3	Individual interviews	74
2.7.2.4	Student-teacher journals	74
2.7.2.5	Constructed response tests.....	75
2.7.3	Information gathering techniques on critical thinking.....	75
2.7.3.1	Aspect specific techniques	75
2.7.3.2	Comprehensive techniques	76

2.7.3.3	General knowledge techniques	76
2.7.3.4	Subject specific techniques	76
2.7.3.5	Techniques with a variety of tasks.....	77
2.7.4	Commercially available tests to determine critical thinking	77
2.7.4.1	Academic Profile test.....	78
2.7.4.2	Assessment of Reasoning and Communication Test	78
2.7.4.3	The California Critical Thinking Skills Test (CCTST) – college level	78
2.7.4.4	The California Critical Thinking Disposition Inventory Test (CCTDIT)	78
2.7.4.5	Cornell Critical Thinking Test – Level X.....	79
2.7.4.6	Cornell Critical Thinking Test – Level Z.....	79
2.7.4.7	Cambridge Thinking Skills Assessment Test.....	79
2.7.4.8	Ennis–Weir Critical Thinking Essay Test.....	79
2.7.4.9	International Centre for the Assessment of Thinking Critical Thinking Essay Test (ICAT CT)	80
2.7.4.10	The Test of Everyday Reasoning (TER).....	80
2.7.4.11	Watson–Glaser Critical Thinking Appraisal (W-GCTA) UK edition	80
2.8	FACTORS INFLUENCING THE DEVELOPMENT OF CRITICAL THINKING SKILLS	82
2.8.1	Education factors.....	82
2.8.1.1	Classroom atmosphere	82
2.8.1.2	Imbedded or explicit instruction	83
2.8.1.3	The role of the facilitator/teacher	84
2.8.2	Student factors	86
2.8.2.1	Reading ability	87
2.8.2.2	Motivation for success	87
2.8.2.3	Intention to study	88
2.8.3	Personal factors	88
2.8.3.1	Societal and cultural challenges	88
2.8.3.2	Language and critical thinking	90
2.9	CHAPTER SUMMARY.....	91
 CHAPTER 3 TEACHING FOR CRITICAL THINKING: THE PLACE OF FORMAL, INFORMAL AND NON-FORMAL TEACHING AND LEARNING		
3.1	INTRODUCTION.....	95
3.2	TEACHING FOR CRITICAL THINKING IN FORMAL, INFORMAL AND NON-FORMAL LEARNING CONTEXTS	96
3.2.1	Teaching in formal contexts.....	96

3.2.2	Teaching in informal and non-formal contexts	97
3.2.3	Teaching and learning theories and their relation to the development of critical thinking	100
3.2.3.1	Behaviourism	100
3.2.3.2	Cognitivism	101
3.2.3.3	Constructivism	101
3.2.3.4	Transformative learning theory	103
3.2.3.5	Experiential learning theory	104
3.2.3.6	Structural cognitive modifiability theory	105
3.2.3.7	Mediated Learning Theory	105
3.2.3.8	Tangential learning theory	107
3.2.3.9	Transfer of learning theory	108
3.3	TEACHING METHODS AND STRATEGIES TO DEVELOP	
	CRITICAL THINKING	111
3.3.1	Direct teaching methods and related strategies	112
3.3.2	Indirect teaching methods and related strategies	113
3.3.3	Independent teaching methods and related strategies	114
3.3.4	Interactive/participative teaching methods and related strategies	117
3.3.5	Strategies to develop critical thinking dispositions and standards for reasoning	120
3.4	CREATING CLASSROOMS CONDUCTIVE TO THE	
	DEVELOPMENT OF CRITICAL THINKING	122
3.4.1	Frequent evaluative questions	122
3.4.2	Encouragement of active learning	123
3.4.3	Developmental tension	123
3.5	THE ROLE OF GAME-BASED LEARNING TO DEVELOP	
	CRITICAL THINKING	124
3.5.1	Introduction	124
3.5.2	Serious games and game-based learning	124
3.5.3	Video games: A conceptualisation	125
3.5.3.1	History of video games	126
3.5.3.2	Trends in playing video games	128
3.5.3.3	Video game controversies and negative effects	129
3.5.3.4	Positive effects of video games	133
3.5.4	Puzzle video games and its subgenres	136
3.5.4.1	Puzzle video games	137
3.5.4.2	Types of puzzle games	137
3.5.4.3	Portal games	140

3.5.5	Developing critical thinking skills with Portal.....	136
3.6	CHAPTER SUMMARY.....	149
CHAPTER 4 THE PUZZLE VIDEO GAME – COGNITIVE ENRICHMENT		
	PROGRAMME (PVG-CEP).....	153
4.1	INTRODUCTION.....	153
4.2	INTERVENTION RESEARCH.....	154
4.2.1	The purpose of intervention research.....	154
4.2.2	The stages of intervention research	154
4.2.2.1	Stage 1: Problem analysis and project planning.....	154
4.2.2.2	Stage 2: Information gathering and synthesis	156
4.2.2.3	Stage 3: Design.....	158
4.2.2.4	Stage 4: Developing a prototype or preliminary intervention	162
4.2.2.5	Stage 5: Evaluation and advanced development	162
4.2.2.6	Stage 6: Dissemination.....	162
4.3	THE NATURE OF THE PUZZLE VIDEO GAME – COGNITIVE ENRICHMENT PROGRAMME	163
4.3.1	The focus of the PVG-CEP.....	163
4.3.2	The teaching and learning theories underpinning the design and implementation of the intervention programme	164
4.3.3	The teaching methods and strategies utilised during the implementation of the intervention programme	165
4.3.4	The implementation features of the PVG-CEP	167
4.4	GAME INSTRUCTION TO THE RESEARCH PARTICIPANTS.....	167
4.4.1	Mechanics	168
4.4.2	Devices: Handheld portal device	168
4.4.3	Structures: Test Chambers.....	169
4.4.4	Test chamber mechanics	170
4.4.4.1	Portal 1.....	170
4.4.4.2	Portal 2.....	173
4.4.5	Teaching and learning principles underpinning the playing of Portal.....	175
4.5	OBSERVATION CRITERIA	177
4.6	CHAPTER SUMMARY.....	180
CHAPTER 5 EMPIRICAL RESEARCH DESIGN.....		181

5.1	INTRODUCTION	181
5.2	RESEARCH FRAMEWORK	182
5.3	RESEARCH AIM, OBJECTIVES AND VARIABLES.....	184
5.3.1	Aim and objectives	184
5.3.2	Variables	185
5.4	RESEARCH DESIGN.....	185
5.4.1	Embedded mixed method experimental research	185
5.5	STRATEGY OF ENQUIRY.....	187
5.5.1	Quantitative strategy of enquiry: Quasi-experimental research	187
5.5.2	Qualitative strategy of enquiry: Case study	187
5.6	RESEARCH PARTICIPANTS	188
5.6.1	Sampling for the quantitative study.....	188
5.6.2	Participants for the qualitative phase of the study	190
5.6.2.1	Interviews	190
5.6.2.2	Observations	191
5.7	DATA COLLECTION	191
5.7.1	Quantitative data collection instruments	191
5.7.1.1	Watson-Glaser Critical Thinking Appraisal	192
5.7.2	Qualitative data collection instruments	194
5.7.2.1	Observations: Rating scale.....	194
5.7.2.2	Anecdotal records.....	195
5.7.2.3	Semi-structured interviews	197
5.8	ROLE OF THE RESEARCHER	199
5.9	DATA ANALYSIS AND INTERPRETATION	200
5.9.1	Quantitative W-GCTA test data	200
5.9.2	Qualitative observation data	202
5.9.3	Qualitative interview data	203
5.10	RIGOUR	205
5.10.1	Quantitative study: Reliability and validity.....	205
5.10.1.1	Reliability of the W-GCTA.....	205
5.10.1.2	Validity of the quantitative research design	208
5.10.1.3	Validity of the quasi-experimental research.....	209
5.10.2	Qualitative study: Trustworthiness.....	211
5.10.2.1	Trustworthiness of the interviews	211

5.10.2.2	Trustworthiness of the observations	212
5.11	ETHICAL CONSIDERATIONS	214
5.11.1	Ethical issues in terms of the research problem	215
5.11.2	Ethical issues in terms of the purpose and questions.....	215
5.11.3	Ethical issues in terms of data collection	216
5.11.4	Ethical issues in terms of data analysis and interpretation	217
5.11.5	Ethical issues in terms of writing and disseminating the research	217
5.12	CHAPTER SUMMARY.....	217
CHAPTER 6 DATA ANALYSIS AND INTERPRETATION		221
6.1	INTRODUCTION	221
6.2	PILOT STUDY DATA.....	223
6.3	DATA ANALYSIS AND INTERPRETATION: TEST AND OBSERVATION DATA – EXPERIMENTAL GROUP	223
6.3.1	Data analysis: Participant 1	227
6.3.2	Data analysis: Participant 2	242
6.3.3	Data analysis: Participant 3	256
6.3.4	Data analysis: Participant 4	269
6.3.5	Pre- and post-test scores: Experimental group	281
6.4	DATA ANALYSIS AND INTERPRETATION: TEST DATA – CONTROL GROUP.....	287
6.4.1	Participant 5	287
6.4.2	Participant 6	289
6.4.3	Participant 7	290
6.4.4	Participant 8	291
6.5	DATA ANALYSIS AND INTERPRETATION –TEST DATA: COMPARISON – EXPERIMENTAL AND CONTROL GROUP	294
6.5.1	Comparison: Test totals – Experimental group participants	295
6.5.2	Comparison: Test totals – Control group participants.....	297
6.5.3	Comparison: Sub-tests – Experimental and control group	299
6.6	DATA ANALYSIS AND INTERPRETATION: INTERVIEW DATA	304
6.6.1	Question 1	304
6.6.1.1	Experience versus inexperience playing games.....	305
6.6.1.2	Games are enjoyable, exciting, challenging, and test your mind	306
6.6.2	Question 2	306

6.6.2.1	Cognitive stimulation	307
6.6.2.2	Exploration and navigation	307
6.6.2.3	Goal driven activities	308
6.6.3	Question 3	308
6.6.3.1	Positive, enjoyable experience	309
6.6.3.2	Developmental, exploratory, and thoughtful experience	309
6.6.4	Question 4	311
6.6.4.1	Enjoyment in general	311
6.6.4.2	Focus and attention enhanced	311
6.6.4.3	Cognitive improvement.....	312
6.6.4.4	Difficulty and lack of time pose challenges	312
6.6.5	Question 5	314
6.6.5.1	Cognitive benefits of Portal.....	314
6.6.5.2	Goal planning benefits.....	314
6.6.5.3	Independent thinking benefits.....	315
6.6.6	Question 6	316
6.6.6.1	Solving puzzles lead to excitement, happiness and accomplishment ...	316
6.6.7	Question 7	317
6.6.7.1	Attention and focus enhanced	319
6.6.7.2	Task involvement.....	318
6.6.7.3	Improved understanding of game expectations	318
6.6.7.4	Puzzle games enhance thinking skills	319
6.6.8	Question 8	320
6.6.8.1	Games motivate learning through fun.....	320
6.6.8.2	Engaging and experiential nature of games leads to better learning	320
6.6.8.3	Formal classes are tedious and repetitive, leading to a loss of concentration	321
6.6.9	Visual representation of the interview data.....	322
6.7	INTEGRATION AND INTERPRETATION OF DATA.....	324
6.7.1	Participant 1	325
6.7.2	Participant 2	326
6.7.3	Participant 3	327
6.7.4	Participant 4	329
6.7.5	Integration and interpretation of data: Experimental and control group .	330
6.8	FORMULATING TENTATIVE HYPOTHESES.....	333
6.9	CHAPTER SUMMARY.....	333
	CHAPTER 7 SUMMARY, FINDINGS, AND RECOMMENDATIONS.....	338

7.1	INTRODUCTION	338
7.2	AN OVERVIEW OF THE STUDY	339
7.2.1	Chapter 1.....	339
7.2.2	Chapter 2.....	342
7.2.3	Chapter 3.....	345
7.2.4	Chapter 4.....	349
7.2.5	Chapter 5.....	350
7.2.6	Chapter 6.....	354
7.3	FINDINGS FROM THE LITERATURE REVIEW	359
7.4	FINDINGS FROM THE EMPIRICAL RESEARCH	364
7.5	FINDINGS IN RELATION TO THE AIM AND OBJECTIVES OF THE STUDY	376
7.6	RECOMMENDATIONS	389
7.6.1	Recommendations for developing critical thinking skills	389
7.6.2	Recommendations for developing dispositions	391
7.6.3	Recommendations for developing universal standards for reasoning ...	394
7.6.4	Recommendations for using puzzle video games to develop critical thinking	396
7.6.5	General recommendations	397
7.7	NOVEL GUIDELINES TO DEVELOP CRITICAL THINKING WITH PUZZLE VIDEO GAMES	399
7.7.1	Relevance	399
7.7.2	Effectiveness	401
7.7.3	Efficiency	403
7.7.4	Impact.....	406
7.7.5	Sustainability	408
7.8	LIMITATIONS OF THE STUDY	408
7.9	SUGGESTIONS FOR FURTHER RESEARCH	411
7.10	CONTRIBUTION OF THE STUDY	412
7.10.1	Contribution to theory	412
7.10.2	Contribution to practice.....	413
7.11	CONCLUSIONS	414
	REFERENCES	415

APPENDIX A PROOF OF LANGUAGE EDITING	471
APPENDIX B ETHICS CLEARANCE	473
APPENDIX C CONSENT: RESEARCH DATA GATEKEEPER COMMITTEE	476
APPENDIX D CONSENT: SCHOOL OF LANGUAGES	478
APPENDIX E INFORMED CONSENT LETTER: STUDENTS	480
APPENDIX F W-GCTA TEST (UK).....	492
APPENDIX G ANECDOTAL RECORDS	505
APPENDIX H OBSERVATION CRITERIA.....	543
APPENDIX I INTERVIEW PROTOCOL	550
APPENDIX J INTERVIEW: VERBATIM TRANSCRIPTS AND CODING	552
APPENDIX K THIRTEEN WEEK PVG-CEP INTERVENTION	577
APPENDIX L INTEGRATED OBSERVATIONS AND ANECDOTAL RECORDS	589

LIST OF TABLES

Table 1.1:	The GROW problem solving model (Gorell, 2013, p. 34-37).....	13
Table 3.1:	Strategies to nurture the development of critical thinking dispositions	120
Table 3.2:	Questioning to develop standards for reasoning	121
Table 3.3:	History of video games.....	126
Table 4.1:	PVG-CEP procedural programme.....	160
Table 5.1:	Biographical characteristics of the participants	191
Table 6.1:	Summary of initial findings: Participant 1.....	229
Table 6.2:	Summary of initial findings: Participant 2.....	243
Table 6.3:	Summary of initial findings: Participant 3.....	257
Table 6.4:	Summary of initial findings: Participant 4.....	270
Table 6.5:	Growth in critical thinking skills: Experimental group.....	281
Table 6.6:	Improvement in dispositions and standards for reasoning: Experimental group	282
Table 6.7:	Improvement in critical thinking: Control group	292
Table 6.8:	Comparison of differences between pre- and post-test totals: Experimental group	296
Table 6.9:	Comparison of differences between pre- and post-test totals: Control group	298
Table 6.10:	Comparison: Pre-test results - experimental and control group	301
Table 6.11:	Comparison: Post-test results - experimental and control group.....	303
Table 7.1:	Example of a checklist to promote accuracy and persistence	392
Table 7.2:	Example of written feedback in Portal	395
Table 7.3:	Questions to prompt the development of standards for reasoning	396

LIST OF FIGURES

Figure 2.1:	Paul-Elder Critical Thinking Model	48
Figure 2.2:	The researcher's conceptualisation of critical thinking	50
Figure 2.3:	Stages of critical thinking development (Paul and Elder, 2005b, p. 19)	55
Figure 2.4:	A framework for 21 st century learning.....	69
Figure 3.1:	Teaching methods and strategies	119
Figure 3.2:	Chell and GLaDOS.....	143
Figure 3.3:	Flinging in Portal	145
Figure 4.1:	Handheld portal device.....	169
Figure 4.2:	Test chambers	170
Figure 4.3:	Portal 1.....	169
Figure 4.4:	Portal 2.....	172
Figure 5.1:	Embedded mixed method experimental research (Creswell, 2014) ..	186
Figure 5.2:	The quasi-experimental research design	187
Figure 5.3:	Observation criteria for working systematically	203
Figure 6.1:	Visual representation of interview data.....	323
Figure 7.1:	The Elements of a Plan strategy	394

LIST OF GRAPHS

Graph 6.1:	Participant 1: W-GCTA sub-test scores.....	227
Graph 6.2:	Observations: Drawing inferences – Participant 1.....	228
Graph 6.3:	Observations: Recognition of assumptions – Participant 1	231
Graph 6.4:	Observations: Making deductions – Participant 1	232
Graph 6.5:	Observations: Doing interpretations – Participant 1	232
Graph 6.6:	Observations: Evaluating arguments – Participant 1.....	233
Graph 6.7:	Observations: Systematic working ways – Participant 1	236
Graph 6.8:	Observations: Persistence – Participant 1.....	237
Graph 6.9:	Observations: Accuracy – Participant 1.....	238
Graph 6.10:	Observations: Logic – Participant 1.....	239
Graph 6.11:	Observations: Clarity – Participant 1	240
Graph 6.12:	Observations: Relevancy – Participant 1.....	241
Graph 6.13:	Participant 2: W-GCTA sub-test scores.....	243
Graph 6.14:	Observations: Drawing inferences – Participant 2.....	245
Graph 6.15:	Observations: Recognition of assumptions – Participant 2	246
Graph 6.16:	Observations: Making deductions – Participant 2	247
Graph 6.17:	Observations: Doing interpretations – Participant 2	248
Graph 6.18:	Observations: Evaluating arguments – Participant 2.....	249
Graph 6.19:	Observations: Systematic working ways: - Participant 2	250
Graph 6.20:	Observations: Persistence – Participant 2.....	251
Graph 6.21:	Observations: Accuracy – Participant 2.....	252
Graph 6.22:	Observations: Logic – Participant 2.....	253
Graph 6.23:	Observations: Clarity – Participant 2	254
Graph 6.24:	Observations: Relevancy – Participant 2.....	255
Graph 6.25:	Participant 3: W-GCTA sub-test scores.....	256
Graph 6.26:	Observations: Drawing inferences: Participant 3.....	258
Graph 6.27:	Observations: Recognition of assumptions – Participant 3	259
Graph 6.28:	Observations: Making deductions – Participant 3	260
Graph 6.29:	Observations: Doing interpretations – Participant 3	261
Graph 6.30:	Observations: Evaluating arguments – Participant 3.....	262
Graph 6.31:	Observations: Systematic working ways – Participant 3	263
Graph 6.32:	Observations: Persistence – Participant 3.....	264

Graph 6.33:	Observations: Accuracy – Participant 3.....	265
Graph 6.34:	Observations: Logic – Participant 3.....	266
Graph 6.35:	Observations: Clarity – Participant 3	267
Graph 6.36:	Observations: Relevancy – Participant 3.....	268
Graph 6.37:	Participant 4: W-GCTA sub-test scores.....	269
Graph 6.38:	Observations: Drawing inferences – Participant 4.....	271
Graph 6.39:	Observations: Recognition of assumptions – Participant 4	272
Graph 6.40:	Observations: Making deductions – Participant 4	273
Graph 6.41:	Observations: Doing interpretations – Participant 4	274
Graph 6.42:	Observations: Evaluating arguments – Participants 4.....	275
Graph 6.43:	Observations: Systematic working ways – Participant 4	276
Graph 6.44:	Observations: Persistence – Participant 4.....	277
Graph 6.45:	Observations: Accuracy – Participant 4.....	278
Graph 6.46:	Observations: Logic – Participant 4.....	278
Graph 6.47:	Observations: Clarity – Participant 4	279
Graph 6.48:	Observations: Relevancy – Participant 4.....	280
Graph 6.49:	Pre- and post-test raw score test totals: Experimental group	282
Graph 6.50:	Participant 5: Sub-test results	288
Graph 6.51:	Participant 6: Sub-test results	289
Graph 6.52:	Participant 7: Sub-test results	290
Graph 6.53:	Participant 8: Sub-test results	291
Graph 6.54:	Pre- and post-test raw score totals: Control group B.....	293
Graph 6.55:	Comparison of the average sub-test data between experimental group and control group – pre-test and post-test.....	300

CHAPTER 1

INTRODUCTION AND STATEMENT OF THE PROBLEM

1.1 INTRODUCTION

The development of critical thinking has been considered as a crucial outcome and ideal of education ever since the early days of Socrates, Plato and Aristotle. This ideal was pursued through the Middle Ages and the Renaissance with the emphasis that was placed on the use of reasoning and critiquing thought processes as central activities to the improvement of critical thinking (Daniel, 1992; Goyak, 2009). Sumner (1906) supports this ideal by highlighting the fact that schools should not aim to create the same type of thinking in students, but rather focus on teaching students how to think. John Dewey (1933:2) extends the aforementioned argument by stating that “*the aim of education is to learn and reason.*” Beyer (1983) continues, by indicating that thinking should be critical in nature, and assess the authenticity, accuracy and worth of knowledge. In this regard, Norris (1985, p. 40) concludes that critical thinking denotes to “*the application of what is known and felt and the assessment of one’s own thinking.*” Ennis (1985) conveys the definition that characterises critical thinking most extensively as reasonable, reflective thinking, focused on choosing what to believe. Additionally, the definition of Paul (1988) links critical thinking to the capacity to attain comprehensive conclusions grounded on observations and information. It is evident, that since the 1980s the aforementioned pioneers in the field have provided definitions of critical thinking, which in essence highlight the strong element of thinking that is evaluative in nature (Barnes, 2005; Cheung, Rudowicz, Kwan, & Due, 2002; Facione, 2009; Halx & Reybold, 2005; Halpern, 2007; Pithers & Soden, 2000; Vandermensbrughe, 2004).

Critical thinking has also been linked to values such as freedom and autonomy (Winch, 2006), and is regarded as a cornerstone for democratic citizenship and economic productivity (Arum & Roksa, 2011), as well as a crucial skill for coping with challenges in the twenty-first century (Halpern, 2014) (*cf.* 2.6.2). Critical thinking should therefore be regarded as a goal to be achieved across higher education curricula (Dunne, 2015).

At higher education level, the demands for students to solve problems through critical reasoning and arguing about topics in an academic context are crucial (Barnett, 2015; Howell, 2017; Erikson & Erikson, 2018; Fahim & Shakouri, 2012; Grosser & Nel, 2013; Pienaar, 2001). According to Barnett (2015), Howell (2017) and Erikson and Erikson (2018) the purpose of higher education involves among others, the following:

- To prepare students for employment.
- To provide opportunities for personal development.
- To prepare students to become active participants in a democratic society.

All of the aforementioned purposes encapsulate traces of intellectual development and student empowerment that could be expressed as critical thinking (Erikson & Erikson, 2018).

Pienaar (2001) concludes that the following higher-order critical thinking processes are essential for critical reading and understanding, and Grosser and Nel (2013), assert that these processes augur well with the set of critical, generic exit-level outcomes of the teacher-training programme at the university that took part in the study, and are valued at Higher Education level, namely:

- To solve problems.
- To elaborate on an argument and develop its implications.
- To understand, analyse and evaluate arguments and opinions.
- To support general assertions with details.
- To recognise the central thesis in a work.

Although critical thinking plays an important role in learning and coping with 21st century challenges and uncertainties (Halpern, 2014), escalating evidence points to the reality that higher education students do not improve their critical thinking skills, which among others involve reasoning, argumentation and problem solving (Arum & Roksa, 2011, Bok, 2006; Pascarella, Blaich, Martin, & Hanson, 2011)

Bearing the importance of critical thinking at higher education in mind, it goes without saying that teachers are the key role players in ensuring that students at school become good critical thinkers (Warburton, 2006; Williams, 2005). The improvement of critical

thinking skills has therefore been on the agenda of South African education since 1997 (Department of Education, 1997; Department of Education, 2002). The new National Curriculum and Assessment Policy Statement (CAPS) Grades R-12 supports not only teaching and learning that nurtures the development of thinking skills, but also intellectual dispositions and universal standards for reasoning that are important for critical thinking. According to the Department of Basic Education (2011, p. 11), students should be capable of:

- identifying and solving problems and making decisions using critical and creative thinking;
- working effectively as individuals and with others as members of a group;
- organising and managing themselves and their activities responsibly and efficiently;
- collecting, analysing, organising and critically evaluating information;
- communicating efficiently using visual, symbolic and/or language skills in various modes;
- using science and technology efficiently by critically showing responsibility towards the environment and the health of others; and
- demonstrating an understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation.

Although not explicitly stated, the researcher argues that in order to execute the aforementioned thinking processes that underpin the curriculum objectives effectively, dispositions such as accuracy, persistence, perseverance, open-mindedness, self-confidence in reasoning are also required (*cf.* 2.3.3). In addition, the execution of all thinking should adhere to universal standards for reasoning, namely logic, clarity, breadth, depth, significance and clarity (*cf.* 2.3.6).

It is reasonable to assume that teachers first have to be effective at applying critical thinking themselves, before they can teach and develop critical thinking among students. Internationally in the field of higher education, empirical research on critical thinking has focused on the development of critical thinking skills (Arum & Roksa, 2011; Heijltjes, Van Gog, Leppink, & Paas, 2014; King & Kitchener, 2002, 2004). In addition, researchers have also foregrounded the importance of understanding critical thinking as a social

activity (Kuhn, 2005; Moore, 2004, 2013). Numerous studies conducted internationally report on the fragile and deficient nature of critical thinking skills and dispositions among pre-service teachers (Akyüz & Samsa, 2009; Allamnakrah, 2013; As'ari, Mahmudi, & Nuerlaelah, 2017; Bakir, 2015; Hashim, 2010; Innabi & ElSheikh, 2007; Osana & Seymour, 2004; Qing, Jing & Yan, 2010; Umar & Ahmad, 2010; Turan, 2016; Zascavage, 2010). In contrast to the international studies, the only national studies, to the best knowledge of the researcher, that could be located that point to the fragile development of critical thinking skills among pre-service teachers, were the research studies conducted by Lombard and Grosser (2004), Grosser and Lombard (2008) and Lombard and Grosser (2008).

Various international studies document the effects of specific teaching methods on the development of critical thinking skills of pre-service teachers. The implementation of enquiry-based learning (Qing *et al.*, 2010), philosophy of enquiry (Daniel, 2001), active learning (Burbach, Matkin, & Fritz, 2010), blended learning (Akyüz & Samsa, 2009), cognitive apprenticeship (Osana & Seymour, 2004), discussion-forums (Umar & Ahmad, 2010), enquiry-based learning (Duran & Dökme, 2016; Hadi, Susantini, & Augustini, 2018; Prayogi, Yuanita, & Wasis, 2018), and cooperative learning (Goyak, 2009) have all seemingly delivered advantages and gains in terms of promoting the development of critical thinking skills among pre-service teachers.

A review on critical thinking practices in Higher Education in nine European countries between 2000-2017, revealed that self-study, dialogue, mentoring, peer assessment, experiments, interview, reflective diaries and reflective essay analysis are frequently used as interventions to enhance critical thinking. Moreover, problem-based learning, enquiry and argumentation, as well as argumentation in e-learning, are teaching methods and strategies that seem to be favoured for the development of critical thinking (Dumitru, Elen, Railiené, & Papathanasiu, 2018). None of the mentioned studies however, documents the merits of puzzle video games (*cf.* 5.1.2) for developing critical thinking.

Ever since the beginning of the digital era, with the invention of computer technology, educationalists have pondered over the question whether puzzle video games could be used to enhance learning in the classroom. Some of them agree that technology does indeed have a place in education (Gee, 2003b), whilst others are vehemently opposed to

this notion (Annetta, 2008). With the advent of technology also came the need to further the entertainment industry to catch up with the relentless march of progress (Miller, 2005). To that end, the start of the video game industry boomed as more and more people gained access to home computing devices and gaming platforms such as Nintendo's Nintendo Entertainment System (NES). As time progressed, games became more advanced, with graphical, as well as audio enhancements making games more realistic. In addition, the need emerged to produce video games for an adult audience, which led to the creation of games that contained graphical violence and overly sexual content. According to Fellick (2001), these developments have led to a spate of complaints from parents who claimed that these new realistic games were influencing their children negatively, conditioning them to become violent. Concerns mounted as numerous school shootings took place in the United States of America, the most infamous being the Columbine massacre. The two shooters were obsessed with playing violent video games, such as Doom. This led the general population to believe that the shooters became desensitised to violence because they played video games. However, numerous studies over the years have scientifically proven that video games do not lead to increased levels of violence, and that in almost all cases, the social and family life of children were to blame (Anderson & Bushman, 2001; Fling *et al.*, 1992; Konijn, Nije Bijvank, & Bushman, 2007; Sherry, 2001). Interestingly, not much research has been undertaken to look at the positive effects of playing puzzle video games, and ultimately whether or not they can be used effectively to nurture teaching and learning in a classroom (Squire, 2003).

A number of international research studies investigated the merits of video games in general in order to nurture cognitive stimulation with samples of students at school level as well as university level. All of these studies were conducted internationally, and indicated that purposeful efforts to utilise video games in learning contexts were successful in terms of cognitive stimulation (All, Nuñez Casellar, & Van Looy, 2016; Bavelier, Achtman, Mani, & Föcker, 2012; Bavelier *et al.*, 2018; De Araujo *et al.*, 2015; Granic, Lobel, & Engels, 2014; Hwang, Chiu, & Chen, 2015; Hung, Hwang, Lee, & Su, 2012; Lin & Chen, 2016; Kadam, Sahasrabudhe, & Iyer, 2012; Smith & Middleton, 2003; Wouters & Van Oosterndorp, 2017). The researcher however, identified studies that indicated that the use of games mainly advances lower cognitive skills such as perception

and memory, (Baniqued *et al.*, 2013; Martinovic *et al.*, 2014), as higher order thinking skills for example, critical thinking skills, appear to be difficult to measure (Arias, 2014).

According to Bhalla (2013) there is limited research nationally to establish the ways to use technology in the learning process. Nationally, a number of vaguely related studies relate to the use of technology during teaching and learning, were identified (Du Plessis & Webb, 2008, 2012, Kafui & Cronjé, 2018; Sadeck & Cronjé, 2017, Thinyane, 2010). Between mobile phones, computers and the web, first-year students at South African universities appear to be mainly interested in using mobile phones during studies (Thinyane, 2010). In addition, e-learning, using computers and internet technologies appear to be only at emerging stages in South African schools (Sadek & Cronjé, 2017). A study conducted by Kafui and Cronjé (2018) reveals that the preferences of South African students at Universities of Technology regarding the use of technology include the use of smartphones, laptops, tablets, iPads and e-readers.

The researcher could not identify any national studies that explored the use of video games for the development of critical thinking, and therefore concluded that the identified gap could be worthwhile to explore. Exploring the merits of, in particular, puzzle video games for nurturing critical thinking among students, would therefore contribute to theoretical knowledge in the field of critical thinking development.

In relation to research methodology, completed research on critical thinking mainly applies quantitative multiple-choice tests and questionnaires (Heijltjes *et al.*, 2014; Phan, 2008; Tremblay, Lalancette, & Roseveare, 2012) or qualitative interviews (Kaddoura, 2010; Kember, 2001). More recently, a need has arisen to replace the use of questionnaires with the direct assessment of student performance (Andiliou & Murphy, 2014; Klein, Benjamin, Shavelson, & Bolus, 2007; Shavelson, 2010; Stes, Min-Leliveld, Gijbels, & Van Petegem, 2010), as the researcher envisaged with the present study.

The researcher noticed that many of the cited international and national studies in the sections above, approached the development of critical thinking from either a quantitative or qualitative perspective which only involved the perspectives of teachers, and mainly focused on the development of critical thinking skills, without paying attention to the development of the critical thinking dispositions and the universal standards for

reasoning, that also comprise effective critical thinking (*cf.* 2.3.3, 2.3.6). This study wished to extend present research studies by combining a quantitative and qualitative research design that focused on the development of critical thinking, and involved the development of skills, dispositions and standards for reasoning. Moreover, students' perspectives on the merits of the use of the puzzle video games for developing critical thinking, were gauged. The researcher is of the opinion that the methodological approach taken by the study, also addressed a methodological gap within the field, by exploring students' critical thinking in a problem solving situation in which a multi-method approach for gathering data was applied, in which the qualitative dimension carried the most weight.

Furthermore, many cited studies focused on the benefits that video game play has among others, for sensory motor hand-eye coordination (Griffith, Voloschin, Gibb, & Bailey, 1983; Rosenberg, Landsittel, & Averch, 2005), perception, spatial cognition, attention, visual processing and multi-tasking (All *et al.*, 2016; Bavelier *et al.*, 2018; Green & Bavelier, 2012; Uttal *et al.*, 2013). None of the studies focused on the development of critical thinking whilst playing puzzle video games. It will be the focus of this study to establish whether playing puzzle video games, in particular the puzzle video game Portal (*cf.* 3.5.4.3), hold potential for nurturing the development of critical thinking among first-year BEd students, thus contributing to the development of theory in relation to the development of critical thinking skills by using puzzle video games.

The ideal to develop critical thinking seemingly has not yet been achieved nationally and internationally. This study could therefore be of significance for all educationists involved in teaching and learning at school, and Higher Education levels, who are grappling with ways to develop critical thinking. Through this study an awareness could be created of the potential and merits that puzzle video games hold to develop critical thinking.

Based on the aforementioned discussion, the researcher wishes to formulate the purpose of this study as follows:

The purpose of this embedded mixed method experimental research design was to illuminate the potential benefits of a Puzzle Video Game - Cognitive Enrichment Programme (PVG-CEP) for the development of critical thinking among first-year BEd

students, thus offering a practical perspective to a field of study where practical guidance is often limited.

The next section briefly elaborates on the conceptual and theoretical frameworks of the study.

1.2 THEORETICAL AND CONCEPTUAL FRAMEWORKS

The theoretical framework encompasses the broader relationships between the variables that play a role in the field of study as indicated by the literature, and includes the assumptions within which the researcher will be working (Kachchhap & Mishika, 2015; Regoniel, 2010). The conceptual framework comprises the variables that were explored in the study, and their relationships, thus being the mold in which the data were packaged (Regoniel, 2010), namely critical thinking (skills, dispositions and standards for reasoning) and the influence of puzzle video games on the development of critical thinking.

1.2.1 Theoretical framework

A theoretical framework aims to provide clarification for a certain event or elucidates the research phenomenon or research problem (Imenda, 2014).

In the context of the study, the following theories that encompass the broader relationships between critical thinking and ways to develop critical thinking, guided the execution of the study, namely cognitivism (*cf.* 3.2.3.2), constructivism (*cf.* 3.2.3.3), transformative learning theory (*cf.* 3.2.3.4), experiential learning theory (*cf.* 3.2.3.5), structural cognitive modifiability theory (*cf.* 3.2.3.6), mediated learning theory (*cf.* 3.2.3.7), tangential learning theory (*cf.* 3.2.3.8), and transfer of learning theory (*cf.* 3.2.3.9). In chapter 4, the researcher clarifies how the theoretical framework guided the execution of the study (*cf.* 4.3.1).

1.2.2 Conceptual framework

The conceptual framework represents the integrated manner in which the researcher investigated the research problem. The concepts drawn from the theoretical framework on which the study focussed, are critical thinking, the GROW problem solving model, and puzzle video games. In the context of the study, the relationship between the concepts

implied that the development of critical thinking was nurtured by using a puzzle video game that incorporated the use of the GROW problem solving model.

Critical thinking

Critical thinking is multi-dimensional in nature (Kong & Seng, 2006). Paul and Elder (2006, p. 6) define the multi-dimensional nature of critical thinking as *“purposeful, self-regulatory judgement, which results in interpretation, analysis and evaluation of information”* and includes *“exploration”* to justify reasoning. The common elements of the multi-dimensional nature of the construct critical thinking, as well as the numerous definitions in the literature can be best summarised as follows:

Critical thinking, also called critical analysis, is clear, rational thinking involving critique of information (Barnes, 2005, Elder & Paul, 2008a, Facione, 2009). According to Paul and Elder (2006) and Halpern (2007), critical thinking means making clear, reasoned judgments. Halpern (2007, p. 1) continues to define critical thinking as the *“intellectually disciplined process of actively and skilfully conceptualising, applying, analysing, synthesising, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.”* Paul and Elder (2006, p. 16-17) summarise the definitions by highlighting the three elements that critical thinking comprises of, namely cognitive and meta-cognitive skills and strategies, dispositions, and universal standards for reasoning that always have to be applied when one is engaged in reasoning.

In order to become an effective critical thinker, it could be argued that a student needs to possess and apply **cognitive** and **meta-cognitive skills** when engaged in reasoning and thinking. During the thinking and reasoning process, dispositions are required to ensure the effectiveness of the thinking process. Moreover, the thinking and reasoning process should adhere to the universal standards for reasoning (*cf.* 2.3.2 – 2.3.6).

Facione (2009) mentions that interpretation (attachment of meaning to experiences), analysis (identifying relationships among statements, experiences opinions or information), evaluation (assessment of the credibility of statements, experiences, opinions and beliefs), inference (drawing conclusions that reasonably flow from information), explanation (presenting results of one's thinking in a coherent way) and self-

regulation (skills involving reflection and self-reflexivity) lie at the core of critical thinking. Self-regulation and explanation are regarded as meta-cognitive strategies, because they involve reflective processes to clarify and justify one's own thoughts (*cf.* 2.3.2). In the context of the study, the researcher focused on the following critical thinking skills: Making inferences and deduction, recognising assumptions, doing interpretations and evaluating arguments (*cf.* 2.3.2).

The development of critical thinking also involves the development of **dispositions** for effortful thinking (*cf.* 2.3.3, 2.3.4). Dispositions can be defined as attitudes or habits of mind, such as intellectual curiosity/inquisitiveness, scepticism/seeking the truth, being open minded, analytical, systematic and judicious, and having self-confidence in reasoning (Facione, 2009; Paul & Elder, 2008a). In addition, the habit of being accurate, persistent, analytic, anticipating both the good and the bad potential consequences of a situation, and striving to approach problems in a systematic way, are essential dispositions for critical thinking (Facione, 2009). Intellectual habits that need to be well developed for the effective execution of critical thinking also include intellectual integrity, to remain true to one's own thinking and to admit inconsistencies in one's own thoughts and actions. Intellectual courage is important in order to be conscious of the need to face, address, and investigate ideas or beliefs towards which one might have strong emotions fairly (Facione, 2009; Paul & Elder, 2008a). In this study, the researcher focused on the following dispositions: Systematic working ways, persistence and accuracy (*cf.* 2.3.2).

Paul and Elder (2008a) elucidate that **intellectual standards for reasoning** are standards which ought to be applied to thinking to guarantee its quality (*cf.* 2.3.6). These standards ought to be learned and trained openly to students. The aim is for these standards to become instilled in the thinking of students, forming part of their internal voice, and guiding them to reason better (Paul & Elder, 2008a). Standards for reasoning also involve clarity (expressing in another way), precision (accurate detail), relevance (determining whether information is connected), significance (importance of information), breadth (obtaining insight and depth) and logic (ordering thoughts) (Paul & Elder, 2008a). The following standards for reasoning were regarded as important in the study: Logic, clarity and relevance (*cf.* 2.3.6).

Whenever we think, our thinking is focused on a number of **elements of thought**, namely directed by a purpose, guided by a point of view that is based on assumptions that lead to implications and consequences (Elder & Paul, 2008) (*cf.* 2.3.5). We make use of concepts, ideas and theories to interpret data, facts, and experiences so that we can answer questions, solve problems and resolve issues (Elder & Paul, 2008).

In the context of this study, critical thinking was conceptualised as purposeful thinking for which the application of cognitive and meta-cognitive skills, as well as thinking dispositions and universal standards for reasoning are required to be effective at solving problems. In support of structural cognitive modifiability theory (*cf.* 3.2.3.6), the researcher argued that the cognitive and meta-cognitive skills, dispositions and universal standards for reasoning that comprise critical thinking, could be developed with the puzzle video game intervention programme, and their application transferred to generic test scenarios.

Critical thinking plays an important role in problem solving. According to Fantin (2014), problem solving consists of using generic or ad hoc methods, in an orderly manner, for finding solutions to problems. Problems can also be categorised as ill-defined and well-defined (Buchner, 1995). Ill-defined problems are those that do not have clear goals, solution paths, or expected solutions. Well-defined problems have specific goals, clearly defined solution paths, and clear expected solutions (Schacter, Gilbert, & Wegner, 2009).

Critical thinking is a prerequisite for solving all problems, as problem solving encompasses dealing with pragmatics (logic) and semantics (interpretation of the problem) (Wang & Chiew, 2010). The ability to comprehend what the objective of the problem is and what procedures could be applied represent the key to solving the problem. Sometimes the problem necessitates some abstract thinking and coming up with a creative solution (Wang & Chiew, 2010).

Well-developed critical thinking dispositions are required when solving problems (Anderson, 2010; Costa, 2009). When solving problems, it is for example important to work according to a systematic strategy that requires the critical thinking skill of reflection. Reflection during problem solving refers to managing the problem solving process by planning, monitoring and evaluating it while it is taking place, and constantly adjusting and changing it (Ertmer & Newby, 1996). Moreover, reasoning during problem solving

has to comply with standards of reasoning in order to guarantee the quality of the problem solving.

The problem solving scenarios presented within the puzzle video game Portal that was used in the context of the study, can be defined as a combination of ill-defined and well-defined problems. Some of the scenarios are very simple and the goals can be found easily. Others are more complex, requiring one to seek out the goal while at the same time trying out novel methods to solve the problem. An example of this within the game would involve the player navigating a puzzle room, gathering information about what objects are present, where the exit is located and what obstacles are in the way to obstruct exit. The player will utilise various critical thinking skills when trying to solve each puzzle room. Players must deduce and interpret what solution paths need to be taken, as well as evaluate their arguments and assumptions if their methods do not solve the puzzle.

In order to be effective at problem solving, one needs to consider a few points (Paul & Elder, 2006), the first of which is to re-articulate your goals, purposes and needs regularly. Problems should be taken up one by one and should be stated as clearly as possible. One should be able to distinguish whether a problem is controllable or uncontrollable. One needs to analyse and interpret information carefully, drawing from it the most reasonable inferences. Actions need to be organised into short-term and long-term actions. Sometimes a strategic approach works the best. Once action is taken, one should be sure to monitor the implications of the action (Paul & Elder, 2006). In the context of the study, the GROW problem solving model was employed to promote a strategic approach to the solving of the puzzle video game problems.

The GROW problem solving model

The **GROW** model (Table 1.1), is a simple strategy for goal setting and problem solving (Gorell, 2013), that supports cognitive (*cf.* 3.2.3.2, constructivist (*cf.* 3.2.3.3) and transformative learning theory (*cf.* 3.2.3.4). The model was utilised within the intervention programme as a means to assist students to structure or plan problem solving situations, and for the researcher to mediate (*cf.* 3.2.3.7) and promote the development of the critical thinking skills, dispositions and standards for reasoning on which the study focused.

Table 1.1 provides an overview of the GROW model.

Table 1.1: The GROW problem solving model (Gorell, 2013, p. 34-37)

G	Goal	The Goal is the end point, where the students want to be. The goal has to be defined in such a way that it is very clear to the students when they have achieved it.
R	Reality	The current reality is where the student is at present. What are the issues, the challenges, how far away are they from the goal?
O	Obstacles	There will be obstacles preventing the student getting from where they are now to where the goal is. If there were no obstacles the student would already have achieved their goal.
	Options	Once obstacles have been recognised, the student needs to find methods of coping with them if they are to make progress. These are the options they must discover.
W	Way Forward	The options then need to be adapted into action steps, which will take the student to their goal. These action steps create the way forward (Passmore, 2015)

Puzzle video games

In support of tangential (*cf.* 3.2.3.8) and experiential learning theory (*cf.* 3.2.3.5), one way of making learning more engaging and effective is the use of video games, which offer great potential to facilitate formal and beyond the classroom learning, and encourage problem solving (Arnab *et al.*, 2012). Although entertainment stands central to the use of video games, researchers also emphasise its role in supporting learning (Stone, 2008). Video games support student-centred experiences, where critical thinking and a variety of 21st century skills and dispositions can be nurtured, namely active construction rather than passive reception of knowledge, opportunities to solve problems, making decisions, inquiring, collaborating and being creative (Arnab *et al.*, 2012). Students will have the opportunity to communicate and reason and, in the process, develop confidence in their reasoning, as well as seek the truth by engaging in probing and searching for the best possible information or solutions to problems.

A video game is an electronic game that includes human interaction with a user interface to produce visual feedback on a video device such as a TV screen or computer monitor (Williams & Smith, 2007). The word “video” in video game usually denoted to a

raster display device, but it nowadays suggests any kind of display device that can generate two- or three-dimensional images. Although video games are occasionally assumed to be a form of art, this description is controversial (Rabin, 2005).

Several contemporary studies have exposed that video games, whether violent or not, can aid children in the development of intellectual skills (All *et al.*, 2016; Granic *et al.*, 2014; Hwang *et al.*, 2015; Wouters & Van Oostendorp, 2017), emotional skills (Granic *et al.*, 2014; Ventura, Shute, & Zhao, 2013), pro-social behaviour (Ewoldsen *et al.*, 2012; Granic *et al.*, 2014), and problem solving skills (Granic *et al.*, 2014; Prensky, 2012) that support their academic achievement. These findings have alerted teachers all over the world to recognise the numerous benefits of gaming and to include educational video game learning in their curricula.

Puzzle video games is a genre of video games that emphasises puzzle solving (*cf.* 3.5.4). The kinds of puzzles can test numerous problem solving skills, which could comprise logic, pattern recognition, sequence solving, and word completion (Herman, Horwitz, Kent, & Miller, 2002). Puzzle games concentrate on logical and conceptual challenges, while infrequently the games add time-pressure or other action-elements. While many action games and adventure games involve puzzles such as obtaining inaccessible objects, a true puzzle game focuses on puzzle solving as the primary game play activity. Games usually involve shapes, colours, or symbols, and the player must manipulate them, directly or indirectly into a specific pattern (Adams & Rollings, 2006). The puzzle video game is not necessarily designed to educational use (educational games), but Adams and Rollings (2006) argue, that it could have educational value, even if it is primarily used for entertainment and not structured towards school curricula.

Rather than offering an arbitrary assortment of puzzles to solve, puzzle games usually present a sequence of related puzzles that are a variant on a single theme. This theme could comprise pattern recognition, logic, or understanding a process (Thompson, 2007). These games usually have a simple set of rules, where players manipulate game pieces on a grid, network or other interaction space. Players must unravel clues, in order to achieve some victory condition, which will then allow them to advance to the next level. Completing each puzzle will usually lead to a more difficult challenge, although some

games avoid exhausting the player by offering easier levels between more difficult ones (DeMaria & Wilson, 2003).

According to Adams and Rollings (2006), an action puzzle or arcade puzzle necessitates of the player to operate game pieces in a real-time environment, frequently on a single screen and within a time limit, to resolve the puzzle or clear the level. Puzzle games comprise different sub-sets of games. Firstly, the term contains falling-block puzzles such as *Tetris* and *KLAX*. The term also includes games with characters moving through an environment, controlled either directly (*Lode Runner*) or indirectly (*Lemmings*). These can cross over with other action genres, for example a "puzzle platformer" which entails a unique mechanic to complete levels, such as controlling time in *Braid*. Lastly, an action puzzle or arcade puzzle contains action games that require timing and accuracy with pattern-matching or logic skills, such as the first-person *Portal*, which will be used in the context of the study (Adams & Rollings, 2006).

In the following section, brief definitions of the concepts central to the study are provided.

1.3 CONCEPT DEFINITIONS

In this study, the following concepts that stand central to the study, namely critical thinking and puzzle video games, are briefly defined as follows.

1.3.1 Critical thinking

In the term critical thinking, the word critical is derived from the word critic and implies the application of skills critique or judge, as well as the ability to discern (Barnes, 2005, Elder & Paul, 2008; Facione, 2009). In addition, the execution of critical thinking also encompasses the application of thinking dispositions and universal standards for reasoning that enhance the quality of thinking (Paul & Elder, 2006).

1.3.2 Puzzle video games

Puzzle video games is a genre of video games that emphasises puzzle solving, is primarily used for entertainment and not structured towards school curricula (Adams & Rollings, 2006).

Based on the introduction and statement of the problem, this research wishes to formulate the following research questions as presented in section 1.4 that follows.

1.4 PRIMARY AND SECONDARY RESEARCH QUESTIONS

In line with a mixed-methods study, the primary research question that guided the execution of this research is two-fold.

How sophisticated are first-year BEd students in the application of critical thinking¹, and based on the findings, how can a PVG-CEP, support the development of critical thinking among first-year BEd students?

Within these two primary questions, the following secondary questions arise:

- What are the elements of critical thinking?
- Why is critical thinking important for first-year BEd students?
- How could critical thinking be developed effectively?
- What role does puzzle video games play in developing critical thinking?
- Which puzzle video games would be best suited to develop critical thinking?
- How effective are BEd students at applying critical thinking skills before and after taking part in the PVG-CEP intervention? (Quantitative data)
- How effective are BEd students at applying critical thinking dispositions and standards for reasoning at the onset, and end of the PVG-CEP intervention? (Qualitative data)
- What are the student participants' perceptions and experiences regarding the development of critical thinking through a puzzle video game? (Qualitative data)
- What novel guidelines can be proposed for including the use of puzzle video games during teaching to develop critical thinking among first-year BEd students?

¹ In the context of the study, the development of critical thinking will refer to the interrelated development of skills, dispositions and standards for reasoning.

Questions 1-5 were answered by means of a literature review, and questions 6-8 by means of the empirical study. Question 6 was answered with the quantitative empirical study (test data), and questions 7 and 8 were answered with the qualitative empirical study (observations and interview data). Question 9 was answered using summative evaluation, which was objectives-oriented, and determined the extent to which the objectives with the intervention were successfully attained. The literature review and the empirical study contributed to answering Question 9.

Flowing from the research questions, a main aim and related objectives were formulated.

1.5 AIM AND OBJECTIVES

The main aim of the study was two-fold. Firstly, to determine how sophisticated first-year BEd students are in the application of critical thinking, and based on the findings, to establish and explore how a PVG-CEP supports the development of critical thinking among first-year BEd students.

The main aim was operationalised in the following objectives:

- To understand the elements of critical thinking.
- To determine why critical thinking is important for first-year BEd students.
- To establish how critical thinking could be effectively developed.
- To establish what role puzzle video games play in developing critical thinking.
- To identify which puzzle video games would be best suited to develop critical thinking.
- To determine how effective BEd students are at applying critical thinking before and after taking part in the PVG-CEP intervention.
- To explore how effective BEd students are at applying critical thinking dispositions and standards for reasoning at the onset and end of the PVG-CEP intervention.
- To explore the student participants' perceptions and experiences regarding the development of critical thinking through a puzzle video game.
- To develop novel guidelines for including the use of puzzle video games during teaching to develop critical thinking among first-year BEd students.

1.5.1 Variables

As the sample used in the study was small ($n = 4$), it was not possible to establish the impact of variables on the development of critical thinking among the participants. Initial observations were therefore reported for the impact of the independent variable on the dependent variable. The dependent variable in this study was identified as critical thinking, while the independent variable was the PVG-CEP (Pietersen & Maree, 2007c). Hypotheses were formulated at the end of the study that could guide follow-up studies with more participants.

A brief explanation of the empirical research design employed, follows in the next section.

1.6 EMPIRICAL RESEARCH

1.6.1 The literature study

A literature study was done before the research was carried out. Chapter 5 of this study has a further explanation of which databases were used and which keywords were used to carry out the literature search (*cf.* 5.7).

1.6.2 Research framework

The research paradigm or worldview adopted by this particular research was Pragmatism (Creswell, 2009). The choice of this particular framework and other frameworks that were considered, are further explained in Chapter 5 (*cf.* 5.2).

1.6.3 Research design

Quasi experimental research within an embedded mixed method experimental research design (Creswell, 2014) was utilised within this study. The mixed method design is further explored in detail in Chapter 5 (*cf.* 5.4).

1.6.4 Research strategy

The research made use of the following research strategies for the quantitative and qualitative components of the research respectively:

- For the quantitative research, quasi-experimental research was utilised (Leedy & Ormrod, 2005).
- For the qualitative research, multiple case study research was utilised (McMillan & Schumacher, 2006; Merriam, 2009).

Both of these research strategies are further explained in detail in Chapter 5 (*cf.* 5.5).

1.6.5 Research participants

In the context of the study, the quantitative sampling entailed a non-probability, convenient, purposive sample (Leedy & Ormrod, 2013) of four first-year BEd students from the North-West University on the Vaal Triangle Campus that formed part of an experimental group, and four students that formed part of a control group. The students were allocated randomly to the experimental and control group. The qualitative sampling involved purposive criterion sampling that included the four students who were part of the experimental group. The researcher elaborates on the sampling procedure in Chapter 5 (*cf.* 5.6).

1.7 METHODS OF DATA COLLECTION AND QUALITY CRITERIA

Due to the quantitative and qualitative nature of this study, different data collection instruments were used. The researcher elucidates on the quantitative data collection instrument, followed by the qualitative data collection instrument below.

1.7.1 Quantitative data collection instruments

This next section briefly elucidates upon the Watson-Glaser Critical Thinking Appraisal (UK version) (W-GCTA) that was used for the collection of quantitative test data.

To the best knowledge of the researcher, there are no comprehensive standardised tests that measure the interrelated application of critical thinking skills, dispositions and standards for reasoning available in South Africa, and internationally. The choice therefore fell on using the W-GCTA (Watson & Glaser, 2002a) that comprehensively measures the application of critical thinking skills. Previous research studies in the South African context confirmed the reliability and validity of the W-GCTA for South African pre-service teachers (*cf.* 5.10.1.1, 6.2).

The test, however, does not measure the application of critical thinking dispositions or how well thinking complies with the intellectual standards for reasoning. The W-GCTA consists of five tests that each focus on a critical thinking skill, namely making inferences, making deductions, recognising assumptions, evaluation of arguments and doing interpretations (*cf.* 5.7.1.1). Both experimental and control groups used in the study completed the five tests.

1.7.1.1 Reliability and validity of the quantitative research design

The reliability findings of previous pilot studies with the W-GCTA (*cf.* 5.10.1.1) in the South African context, were considered before employing the W-GCTA in the present study. Validity of the quantitative research design was ensured by adhering to criteria for internal, external, construct and statistical conclusion validity (McMillan & Schumacher, 2006). How the researcher complied with each of these aspects is clarified in Chapter 5 (*cf.* 5.10.1.2). The researcher also ensured the validity of the quasi-experimental research, which is clarified in 5.10.1.3).

1.7.2 Qualitative data collection instruments

The proceeding section will provide detail on collecting qualitative data with observations and interviews.

1.7.2.1 Observations

In order for the researcher to acquire a profound insight into and understanding of critical thinking and its application among first-year university students, the researcher observed and recorded the application and development of the specific critical thinking skills, dispositions, and standards for reasoning on which the research focused in relation to each of the individual participants during the implementation of the intervention programme (Nieuwenhuis, 2007b). Video recordings were made by the independent co-observer to support the reliability of the observations, and to verify the correctness of the observations. Video recordings were used during data collection, but merely for verifying the observation data gathered by the researcher and co-observer.

A four-point rating scale (Cohen, Manion, & Morrison, 2007) with qualitative descriptors was used to make judgements about the skills, dispositions and standards for reasoning

that were observed. The quantitative, pre-determined scale was used to systematically guide the observations across the 13-week intervention for each of the four participants in the experimental group. The observations were concerned with incidences that would reveal the nature and quality of the participants' critical thinking development, and focused on growth, decay and retention of the critical thinking skills, dispositions and standards for reasoning on which the research focused. Observations were visually displayed on line graphs to capture trends in the development of critical thinking (Riley-Tillman & Burns, 2009). The nature of the observed incidences was described qualitatively. In addition, the researcher compiled anecdotal records to provide supportive and complementary evidence for the observations. How the observations were employed in the context of the research, is clarified in Chapter 5 (*cf.* 5.10.2.2).

1.7.2.2 Interviews

Semi-structured, face-to-face interviews (Merriam, 2009) were conducted with the four selected student participants in the experimental group at the end of the intervention, in order to understand their perspectives and thoughts on the use of video games for the development of critical thinking. This set of data was combined with the quantitative and qualitative data collected through the W-GCTA and the observations. The implementation of interviews in the context of the research is clarified in Chapter 5 (*cf.* 5.7.2.3).

1.7.2.3 Rigour of the observations and interviews

According to Babbie and Mouton (2001), the rigour of qualitative research can be ensured by enhancing trustworthiness, which implies adhering to criteria for credibility, transferability, dependability and conformability. How the researcher adhered to criteria for trustworthiness is elucidated upon in Chapter 5 (*cf.* 5.10.2.1, 5.10.2.2).

The role of the researcher as an instrument in the collection of qualitative data can also influence the rigour of the data collection process (Creswell, 2009; Merriam, 2009). The researcher explains the considerations in relation to his role during data collection in Chapter 5 (*cf.* 5.8).

The following section pays attention to the procedures used for analysing data.

1.8 DATA ANALYSIS

The data gathered were analysed in two separate ways, as the research comprised a qualitative and quantitative component. Statistical procedures were used for the analysis of the W-GCTA test responses. A qualitative descriptive analysis linked to a four-point scale was utilised for the analysis and interpretation of the observation data, and content analyses were undertaken for the interpretation of the interview data.

1.8.1 W-GCTA test data

Although the results of each of the individual participants were more important than the results of the group of participants, the independent statistician suggested that the researcher employs statistical procedures to analyse the test data as well. The data analysis of the W-GCTA test made use of both descriptive and non-parametric inferential statistics (Leedy & Ormrod, 2005). Various calculations were done, including frequencies, means, medians and percentages. This was done in order to determine the application level of the critical thinking skills of the first-year BEd student participants at the outset and conclusion of the PVC - CEP intervention. The Mann-Whitney U test was used to compare the W-GCTA pre-test and post-test results of the experimental and control group with one another (Pietersen & Maree, 2007b), and the Wilcoxon Signed-Rank test was utilised to compare the differences between the pre-test and post-test total results within the experimental and control groups respectively, as well as between the five sub-tests (*cf.* 5.9.1).

1.8.2 Interviews and observations

The data analysis procedure for the interviews entailed both an inductive and a deductive content analysis (McMillan & Schumacher, 2006). The explanations for these two qualitative data analysis procedures are discussed in further detail in Chapter 5 of this study (*cf.* 5.9.3).

The quantitative and qualitative data were integrated/combined to come to a clearer and deeper understanding of the nurturing of critical thinking among the first-year BEd students who were part of the research (*cf.* 6.7).

1.9 THE PVG-CEP INTERVENTION

As part of the quasi experimental research a 13-week intervention was implemented for two hours per week on an individual basis with each of the four participants in the experimental group. The intervention comprised taking part in playing the puzzle video game Portal (*cf.* Chapter 4).

As the research entailed working with human beings, consideration had to be given to ethical aspects.

1.10 ETHICAL CONSIDERATIONS

All of the various ethical considerations pertaining to the research are discussed in detail in Chapter 5 (*cf.* 5.11). The various ethical considerations that the researcher adhered to were:

- Ethical issues in the research problem
- Ethical issues in the purpose and questions
- Ethical issues in data collection
- Ethical issues in data analysis and interpretation
- Ethical issues in writing and disseminating the research (Creswell, 2009)

1.11 DEMARCATION OF THIS STUDY

This study aligns well with two of the four knowledge generation categories identified internationally for research in Higher Education, namely knowledge and subject-related aspects dealing with among others, the development of skills and competencies, and person and process related aspects, such as teaching and learning in the field of undergraduate teacher education (Teichler, 2005). Furthermore, the study links with two themes that form part of the extended version of the themes identified by Tight (2003) for research in the South African Higher Education context, namely teaching and learning and course design (Bitzer & Wilkinson, 2008).

The chronological execution of the research is highlighted below.

1.12 RESEARCH PROCEDURE

The research procedure comprised the following steps:

- Step 1: Identification and motivation of the research problem.
- Step 2: Formulation of the problem statement and research questions.
- Step 3: Review of relevant literature pertaining to the study.
- Step 4: Deciding on the empirical research design.
- Step 5: Obtaining ethical clearance.
- Step 6: Sampling of research participants.
- Step 7: Obtaining informed consent: Authorities and participants.
- Step 8: Construction of data collection instruments based on the literature review.
- Step 9: Administering the W-GCTA pre-tests.
- Step 10: Data analysis and interpretation of W-GCTA pre-tests.
- Step 11: Conducting the intervention programme while collecting observation data.
- Step 12: Administering the W-GCTA post-tests.
- Step 13: Data analysis and interpretation of W-GCTA post-tests.
- Step 14: Conducting interviews after the intervention and compiling verbatim transcripts.
- Step 15: Data analysis and interpretation of the interviews.
- Step 16: Combining quantitative and qualitative data.
- Step 17: Discussion of findings, conclusions and recommendations.

1.13 CHAPTER DIVISION

The study unfolded according to the following structure:

- 1. Introduction and motivation of the problem
- 2. Critical thinking conceptualised
- 3. Teaching for critical thinking: The place of formal, informal and non-formal learning contexts
- 4. The Puzzle Video Game - Cognitive Enrichment Programme (PVG-CEP)

5. Empirical research design
6. Data analysis and interpretation
7. Summary, findings and recommendations

1.14 CHAPTER SUMMARY

From a national perspective, it was noted that the critical cross-field outcomes that guide the implementation of teaching and learning in classrooms at school, required of students to think both critically and creatively (*cf.* 1.1). The latter implies that teachers need to be able to develop the skills to think creatively and critically among their students, assuming that teachers need to possess well-developed skills themselves. The focus of the research therefore deals with the development of critical thinking among prospective teachers.

A number of research studies were consulted to verify the importance of and research conducted in the field of critical thinking in Higher Education institutions, with specific reference to teacher education. It was found that this topic has received attention on a national level and that internationally the topic was being researched extensively (*cf.* 1.1). Both national and international perspectives report on the fragile and deficient nature of critical thinking skills among pre-service teachers. A gap in terms of specific research linked to the development of critical thinking through the use of puzzle video games was identified.

The study conceptualised critical thinking as the interrelated application of skills, dispositions and standards for reasoning when engaged in thinking and problem solving (*cf.* 1.2.1, 1.3.1, 1.3.2). Puzzle video games is a genre of video games that emphasises puzzle solving that tests the application of problem solving and critical thinking skills, which would include logic, pattern recognition, sequence solving, and word completion (*cf.* 1.2.2, 1.3.3).

The main aim of the study, entailed determining how sophisticated first-year BEd students are in the application of critical thinking, and based on the findings, to establish how a PVG-CEP could support the development of critical thinking skills among first-year BEd students (*cf.* 1.4).

In order to achieve the aim of the study, quasi-experimental research embedded within an embedded mixed method experimental design, and framed within a pragmatic research paradigm, was utilised (*cf.* 1.6.2, 1.6.3). By means of quantitative descriptive survey research, quantitative test data in relation to the research participants' application of critical thinking skills were collected with the W-GCTA prior to, and after the implementation of the PVG-CEP intervention (*cf.* 1.6.4, 1.7.1). By means of case study research (*cf.* 1.6.4) that involved four first-year BEd students, qualitative observation data supported by anecdotal records, were collected during the implementation of the PVG-CEP to explore growth, decay or retention in relation to the critical thinking skills, dispositions and standards for reasoning on which the research focused (*cf.* 1.7.2). Qualitative data were also collected by means of semi-structured interviews to explore the participants' experiences with the puzzle video game for developing critical thinking (*cf.* 1.7.2). The research participants were sampled by using non-probability, purposeful and convenient sampling (*cf.* 1.6.5), and comprised eight first-year BEd students, of which four students were randomly assigned to an experimental and a control group, respectively.

The data analysis of the W-GCTA test involved the use of both descriptive and non-parametric inferential statistics (*cf.* 1.8.1), and the data analysis of the interviews and observations entailed an inductive and deductive content analysis (*cf.* 1.8.2). Once both sets of data were analysed, they were combined to come to a clearer and deeper understanding regarding the development of critical thinking through the use of puzzle video games.

The following chapter, Chapter 2, pertains to the literature review regarding critical thinking.

CHAPTER 2

CRITICAL THINKING CONCEPTUALISED

2.1 INTRODUCTION

Critical thinking is a complex concept to define and understand, difficult to develop and to assess (Moore, 2013). As this study accentuated the conceptualisation, development and assessment of critical thinking, it was important to clarify what constitutes critical thinking, how it manifests in action, the milestones that have to be reached during its development, what contributes to, or obstructs its development, and how its development might best be assessed. This chapter therefore unfolds according to the following structure:

2.2 The origins of critical thinking

2.2.1 Introduction

2.2.2 The origins of critical thinking

2.3 Critical thinking: A concept clarification

2.3.1 The nature of critical thinking

2.3.2 Core cognitive and meta-cognitive skills

2.3.3 Critical thinking dispositions

2.3.4 Critical thinking intellectual traits

2.3.5 The elements of critical thinking

2.3.6 Universal standards for reasoning

2.3.7 The researcher's conceptualisation of critical thinking in the context of the study

2.4 Critical thinking in action

2.4.1 Applying the logical thinking mode

2.4.2 Applying the critical questioning mode

2.4.3 Applying the creative thinking mode

2.4.4 Applying the big picture thinking mode

2.5 The ideal critical thinker

2.5.1 Stage one: The unreflective thinker

2.5.2 Stage two: The challenged thinker

2.5.3 Stage three: The beginning thinker

2.5.4 Stage four: The practicing thinker

- 2.5.5 Stage five: The advanced thinker
- 2.5.6 Stage six: The master thinker
- 2.5.7 Developing dispositions and standards for reasoning

2.6 The importance of critical thinking for teacher education

- 2.6.1 Critical thinking and the Curriculum and Assessment Policy
- 2.6.2 Critical thinking and teaching and learning in the 21st century
- 2.6.3 Critical thinking as a life skill

2.7 Gathering information on students' critical thinking skills

- 2.7.1 The purpose of critical thinking assessment
- 2.7.2 Measuring instruments
 - Multiple choice tests
 - Direct classroom observation
 - Individual interviews
 - Student-teacher journals
 - Constructed response tests
- 2.7.3 Information gathering techniques on critical thinking
 - Aspect specific techniques
 - Comprehensive techniques
 - General knowledge techniques
 - Subject specific techniques
 - Techniques with a variety of tasks
- 2.7.4 Commercially available tests to determine critical thinking

2.8 Factors influencing the development of critical thinking skills

- 2.8.1 Education factors
- 2.8.2 Student factors
- 2.8.3 Personal factors

2.9 Chapter summary

Before embarking on an analysis of critical thinking itself, a comprehensive literature review of the origins of critical thinking was carried out. This was done to highlight the fact that throughout the ages, critical thinking has been and still is an ideal of education, thus providing a rationale for the present study.

2.2 THE ORIGINS OF CRITICAL THINKING

2.2.1 Introduction

The proceeding section pertains to the origins of critical thinking, which is crucial in order to ground the study.

2.2.2 The origins of critical thinking

Critical thinking has its origins as early as 2500 years ago, due to the three Greek philosophers Socrates, Plato and Aristotle. The philosopher Socrates is considered the initial forerunner of critical thinking, as he used the method of questioning and dialogue to encourage in-depth thinking among his students (Gutek, 2009). Plato, like Socrates, did not explicitly refer to the nurturing of critical thinking skills, but stimulated his students to acquire the aptitude to think for themselves and weigh up different facts to derive at a better solution or clarification (Leigh, 2007). According to Daly (1998), Plato's view on education was that it is an action that teaches students to ask questions, examine and reflect on ideas and values, in addition to providing information, which endorses the application of critical thinking skills. In addition to Socrates' view of teaching, Plato furthered the view by adding that students should have the aptitude to discriminate whether certain claims are true or false, and that this ability needed to be taught, directly or indirectly (Leigh, 2007). Aristotle who was also a follower of Socrates' teachings, extended Socrates' view by setting out rules for correct reasoning, even though he did not refer to it as critical thinking (Bailin, Case, Coombs, & Daniels, 1999).

It can be concluded that even though critical thinking had not been named as such in the early years, it can be said that effective learning was characterised by critical thinking that involved the ability to think systematically (Socrates), made use of reasoning (Aristotle) and involved determining whether a claim is true or false (Plato).

The philosophers Socrates, Plato and Aristotle are said to have introduced critical thinking as a way of thinking without claiming the term explicitly. The term 'critical thinking' was born in the twentieth century through the first work of John Dewey in the field of reflective thinking (in Buffington, 2007; in Fisher, 2001), which was then extended during a number of developmental phases, highlighted below.

Prior to Dewey, Sumner (1906) supported the ideal of developing critical thinking by emphasising the fact that schools should not aim to create the same type of thinking in students, but rather focus on teaching students how to think. In the next section, John Dewey's theory of reflective thinking and its influence on the critical thinking scholarship is discussed as part of the first phase of critical thinking development.

2.2.2.1 First phase of the critical thinking movement: The work of John Dewey (1910)

According to Sumner (1979), critical thinking is the inspection and testing of suggestions of any kind which are offered for approval, in order to find out if they relate to reality or not. The critical ability is a product of teaching and preparation, and is a mental habit and power. It is a prime condition of human welfare that men and women should be trained in becoming good critical thinkers. It is our only guarantee against delusion, deception, superstition, and misapprehension of our earthly circumstances and ourselves (Sumner, 1979).

Education is worthwhile just as far as it promotes well-developed critical faculties. A teacher of any subject, who maintains accuracy and a rational control of all thinking, and who holds everything open to unrestricted confirmation and revision, is nurturing critical thinking as a habit in students (Sumner, 1979). Developing critical thinking among students is a process that cannot be rushed. Students are slow to believe, and can hold notions and ideas as possible or probable in all degrees, without certainty. Students can wait for evidence and weigh or judge evidence. Students can resist appeals to their deepest prejudices. According to Sumner (1979), education aimed at the development of critical thinking is the only education of which it can be truly said that it makes good citizens.

In his ground breaking work, *"How we think"*, John Dewey coined the phrase *"reflective thinking"* as an attempt to define critical thinking in a more deliberate way (Dewey, 1910, p. 16). Reflective thinking, according to Dewey (1910, p.16), is *"an active consideration of any belief founded on the grounds that back the belief and the conclusions to which it leads"*.

Bearing Plato, Aristotle and Socrates in mind (*cf.* 2.2.1), a strong link is evident between their views of effective learning (thinking) and Dewey's view of reflective thinking. Dewey (1910) remarks that reflective thinking can be done through the systematic process of the science method, which Socrates mentioned as the ability to process thinking systematically. Aristotle focused on the use of reasoning, which is evidently stipulated by Dewey in his explanation of the mental aspects of the thought cycle, being inference and reasoning (Dewey, 1910). The connection between Plato and Dewey's ideas could be identified as establishing whether a claim is true/false, which was directly underpinned by Dewey (1910) as the outcome of reflective thinking.

Dewey (1933) defined the process of reflective thinking as a five-step process, which is elucidated below.

Step 1: Experiencing a challenge

When an individual is confronted with a problem within a learning or everyday life situation it is described as a challenge. An individual must therefore be faced with a difficulty in order for reflective thinking to take place. If there is no challenge, reflective thinking will not arise as it will not be necessary.

Step 2: Definition of the challenge/problem

The challenge/problem as defined in the first step needs to be clear in terms of its characteristics to know what the individual has to address in the problem, in order to pass through the reflective process.

Step 3 Suggestions for possible solutions

As soon as the characteristics of the challenge have been defined, proposals for possible solutions need to be recognised in order to achieve a final solution.

Step 4: Development of solutions through reasoning

By means of reasoning skills, numerous possible solutions to solve a problem can be suggested. Solutions can be compared with one another according to their merits and

suitability for solving the problem. The best conceivable solution can then be selected through reflective thinking.

Step 5: Further observations and experiments leading to the acceptance or rejection of suggested solutions

Once proposed, a conceivable solution is chosen, and the individual makes use of additional observations and experiments to test the answer. Centred on the consequence of these observations and experiments, the solution is either accepted or excluded. Dewey (1922) states that the terms '*critical thinking*' and '*reflective thinking*' can be used interchangeably. Therefore, the five steps stated above are relevant to both critical thinking and reflective thinking, making Dewey the first to coin this method of thinking '*critical thinking*'. Buffington (2007) also assigned the first conceptualisation of critical thinking to the works of John Dewey; though, he notes that it was solely in the second phase of the critical thinking movement that the term '*critical thinking*' was born.

2.2.2.2 The second phase of the critical thinking movement: The work of Robert Glaser (1941) and Bertrand Russell (1943)

Buffington (2007) notes that it was the work of among others Robert Glaser (1941), and Bertrand Russell (1943) that led to the second phase of the critical thinking movement, clarifying the relationship **reflective thinking** versus **critical thinking**.

Glaser (1941) defines critical thinking as the solving of problems in a thoughtful way. This involves having knowledge of logic and reasoning methods to take on the problem as well the skills to use these methods to address the problem (Glaser, 1941). Glaser (1941) mentions a list of skills that are related to critical thinking:

- recognising a problem;
- finding feasible means for solving problems;
- collecting applicable information in order to analyse a problem;
- using suitable language skills in the critical thinking process;
- interpreting data;
- analysing evidence and statements;

- recognising correlations between propositions;
- inferring conclusions;
- evaluating conclusions;
- changing one's beliefs after evaluation; and
- making judgements accordingly.

Though the above mentioned list of skills is more comprehensive than Dewey's five steps of reflective thinking, it needs to be noted that the five steps and Glaser's eleven skills, link to one another in the following ways:

- they indicate the consciousness or awareness (Glaser) or difficulty (Dewey) of a problem;
- both highlight the process of logic and reasoning to work through the problem;
- both mention that the individual needs to investigate the grounds of inferences; and
- both explain that the thinking process needs a concluding judgement.

Russell (1943), considered as one of the main researchers in the second phase of the development of critical thinking, mentions four features that constitute critical thinking:

- knowledge of the field in which thinking is done;
- an attitude to enquire/question and make judgements;
- application of the scientific method; and
- taking action in accordance with the thinking being done.

Glaser (1941) brought forth his own definition of critical thinking, as the ability that involves three things, namely (1) an attitude of being willing to reflect in a thoughtful way the problems and subjects that come within the series of one's experiences, (2) knowledge of the approaches of logical investigation and reasoning, and (3) some skill in practically using those methods.

All three theorists (Russell, Dewey and Glaser) focused on knowledge, questioning, the scientific method (logic or reasoning) and drawing conclusions that influence critical thinking development. Glaser (1941) and Russell (1943) extended Dewey's process of reflective thinking by giving a more comprehensive definition of critical thinking. Glaser

(1941) placed focus on problem solving during critical thinking while Russell (1943) concentrates on the aspect of thinking in general. Both Glaser (1941) and Russell (1943) add the importance of attitude and willingness to engage in critical thinking as an important element of critical thinking.

The following section outlines the third phase of the critical thinking movement that builds upon Dewey's conception of critical thought. The work of Dewey was primarily extended by Ennis (1964, 1987), McPeck (1981), Beyer, (1983), Norris and Ennis (1989) and Paul (1990).

2.2.2.3 The third phase of the critical thinking movement: The work of Robert Ennis (1964, 1987), McPeck (1981), Beyer, (1983), Norris and Ennis (1989), and Paul (1990)

Buffington (2007) and Fisher (2001) assert that the work of Robert Ennis (1964), is the most cited work on scholarship of critical thinking.

Ennis (1964, p. 599) defined critical thinking as the "*correct assessment of statements*", which indicates that he emphasises drawing the right conclusions instead of merely just drawing conclusions (Buffington, 2007). Beyer (1983) refers in this regard to critical thinking as making clear and reasoned judgements. The focus that Ennis (1964) placed on the procedure of assessing statements as a tenet of critical thinking, is clear in his account of an operational critical thinker, whom he described as an individual who can:

- judge whether a statement is in accordance with a premise;
- identify assumptions;
- judge whether an observation is reliable;
- judge whether generalisation is possible;
- test hypotheses;
- test a theory;
- judge whether an argument is based on ambiguity;
- determine whether a statement is unclear or overly detailed; and
- judge whether an authority is reliable (Ennis, 1964).

The above-mentioned nine characteristics place emphasis on the result of thinking. Thinking consequently becomes the process behind critical thinking. Each of the characteristics entails a set of thoughts to be applied before the characteristic can be developed. The definition of Ennis (1964) on critical thinking is slightly different from that of his predecessors as they (Dewey, Glaser and Russell) were all more focused on the process of thinking, whereas Ennis (1964) was concerned with the assessment or judgement of the outcome of thinking, which he classified according to different levels of development. The outcome levels of thinking range from the unreflective (inattentive) thinker, the challenged (tested) thinker, the beginning (novice) thinker, the practicing (rehearsing) thinker, the advanced (refined) thinker to the accomplished (expert, sophisticated) thinker (Ennis, 1964) (*cf.* 2.5).

As Buffington (2007) notes, and as mentioned in the previous section (*cf.* 2.2.2), the critical thinking movement reached a pivotal moment when its definition became increasingly complex during the third phase of development, and additional components such as cognitive and meta-cognitive competencies, were added. According to Kuhn (1999) the competencies described as most applicable to critical thinking remain meta-cognitive rather than cognitive in nature. In distinction to first-order cognitive skills that aid one to have knowledge about the world, meta-cognitive skills are second-order meta-knowing skills that involve knowing about one's own (and others') knowing (Kuhn, 1999).

It should be noted; that metacognition appears in the descriptions of critical thinking suggested by most educational philosophers, who have addressed the topic, and whose respective definitions contain some element of what Paul (1990, p. 32) refers to as *"the art of thinking about your thinking"*. Ennis (1987, p. 35), and Norris and Ennis (1989, p. 14) view critical thinking as *"reasonable and reflective thinking concerned with what to do or believe"*, and Siegel (1988, p. 165) defines critical thinking as thinking that is *"appropriately moved by reasons"*. Lipman's (1991, p. 116) definition of critical thinking that refers to thinking that *"can be assessed by appeal to criteria"*, and the *"evaluation of thinking by appeal to criteria"* implies metacognition. In addition, Lipman (1991, p. 116) adds that in order to qualify as critical thinking, thinking must be *"self-correcting"*.

Educational philosophers have also concerned themselves with the question as to whether critical thinking skills are domain specific or domain general. Critical thinking

skills appear to be domain-specific (McPeck, 1981) as well as domain-general (Paul, 1990), although their debates of this issue tend not to have been influenced by empirical evidence.

In the context of this study, the researcher focused on the development of critical thinking skills in a general context. The intervention programme used in this study did not make reference to subject specific domains of knowledge, and rather paid attention to the developmental nature of critical thinking which, according to Kuhn (1999), has received relatively little attention from educational philosophers.

2.2.2.4 The recent critical thinking movement: The work of Facione (1990, 2009), Paul and Elder (2006), Halpern (2007) and Sternberg (2007)

The conceptualisation of critical thinking has changed through the ages; nevertheless, its conceptualisation has not yet come to a halt and is constantly varying and evolving. According to McAllister, Billett, Moyle, & Zimmer-Gembeck (2009), Facione's definition of critical thinking is the most comprehensive and quoted definition of critical thinking. Facione (1990, p. 2) defines critical thinking as *"purposeful, self-regulatory judgement that results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual consideration upon which that judgement is based"*.

According to the researcher, Facione's (1990) definition incorporates characteristics from the philosophers' era of Socrates, Plato and Aristotle as it highlights the systematic approach (critical thinking is decisive action), applies the use of reasoning (critical thinking involves **interpretation, analysis, evaluation** and making **inferences**) and intends to **regulate** if a claim is true or false (that is, determines whether a judgement is correct). Additionally, the work of Dewey (1910) in relation to reflective thinking is also evident in the definition as it aims to establish if a judgement is true by testing the judgement.

Halpern (2007, p. 1-12) developed five classes of critical thinking skills, namely **verbal reasoning** (e.g. distinguishing the use of universal or misleading language), **argument analysis** (e.g. identifying reasons, assumptions, and conclusions in arguments), thinking as **hypothesis testing** (e.g. generalisations), using **likelihood and uncertainty** (e.g. applying appropriate principles of probability), as well as **decision making** and **problem**

solving (e.g. recognising the problem goal, producing and choosing solutions among alternatives). Aligned to the view of Halpern (2007), Sternberg (2007) argue that critical thinking includes the mental processes, methods, and representations that society make use of to solve problems, make decisions, and learn new concepts.

For Paul and Elder (2006), critical thinking is that mode of thinking about any subject, content, or problem in which the thinker develops the quality of his or her thinking by proficiently taking command of the structures integral in thinking and imposing intellectual standards upon them. The views of Facione (1990, 2009) and Paul-Elder (2006) present a comprehensive conceptualisation of critical thinking and the elements it comprises of, namely:

- Core cognitive and meta-cognitive skills (*cf.* 2.3.2)
- Critical thinking dispositions or attitudes/habits of mind (*cf.* 2.3.3).
- Universal standards that should be applied to all thinking and reasoning (*cf.* 2.3.6)
- The intellectual traits associated with a cultivated critical thinker that result from the consistent and disciplined application of dispositions and the standards for reasoning to the elements of thought (*cf.* 2.3.4)

Based on the preceding section, the following section outlines the conceptualisation of critical thinking that guided the execution of the study.

2.3 CRITICAL THINKING: A CONCEPT CLARIFICATION

The subsequent sections (2.3 - 2.5) foreground the viewpoints of Facione (1990, 2009) and Paul and Elder (2006) and provide a concept clarification for critical thinking as applied in the study. Focus is placed on the nature of critical thinking, the elements of critical thinking, which comprise core thinking skills involved in the execution of critical thinking, the critical thinking dispositions, intellectual traits, and universal standards for reasoning.

2.3.1 The nature of critical thinking

Recent definitions of critical thinking describe it as goal-oriented and rational thinking (Butler, Pentoney, & Bong, 2017), and thinking that involves creative dimensions (Sola,

Hoekstra, Fiore, & MCCauley, 2017; Wechsler *et al.*, 2018). When combining recent and earlier definitions of critical thinking, its multi-faceted and multi-dimensional nature (Kong & Seng, 2006) is revealed. The elements that comprise critical thinking include interrelated core cognitive and meta-cognitive skills, critical thinking dispositions, intellectual traits, and universal standards for reasoning (Adler & Perkins, 2016; Cottrell, 2011; Grosser & Olivier, 2017; McPeck, 2015). Intellectual traits result from the consistent and disciplined application of skills, dispositions and the standards for reasoning to the elements of thought (*cf.* 2.3.4).

According to Bok (2006) and Ennis (1993), critical thinking demands the use of different types of knowledge. Students need to have knowledge about a specific topic, before they can think critically about the topic (Halpern, 2014; Reddy & Lantz, 2010). Critical thinking could therefore be regarded as domain specific in nature (Hyytinen, 2015, McPeck, 1981), and therefore reasoning and critical thinking could vary across different subject domains. Over and above, critical thinking can also be general in nature, thus being applied to everyday problem solving scenarios and decision making (Hyytinen, 2015; Paul, 1990).

When analysing the nature of critical thinking, it is important to dissect the term and identify the core elements that are imbedded in critical thinking. The following section elaborates on the multi-dimensional nature of critical thinking, by eluding to the core elements of critical thinking, namely cognitive and meta-cognitive skills, dispositions, and universal standards for reasoning that are applied to elements of reasoning to develop specific intellectual traits.

2.3.2 Core cognitive and meta-cognitive critical thinking skills

In support of Facione (1990, 2000), Reynolds (2011), and Stupinsky, Renaud, Daniels, Haynes and Perry (2008) also concluded that the core critical thinking skills comprise **observation, interpretation, analysis, inference, evaluation, explanation, and metacognition**. As stated by Reynolds (2011), an individual or group engaged in robust critical thinking gives due deliberation to establish for instance:

- Evidence through reality.
- Background skills to separate a problem from a situation.
- Applicable criteria for making sound judgments.

- Appropriate methods or strategies for making a judgment.
- Valid theoretical constructs for understanding a problem and the question at hand.

In his Delphi study intended at reaching agreement concerning critical thinking, Facione (1990; 2009) discovered that experts in the field of critical thinking regard the subsequent cognitive and meta-cognitive skills as relating to critical thinking:

Cognitive skills

- **Inference:** The ability to draw reasonable conclusions flowing from given information that can include opinions and judgements (Chartrand & Rose, 2008; Facione, 2009). In order to draw inferences one needs to possess the ability to question information.
- **Evaluation:** Judging the authenticity and credibility of information, and to establish if information that is provided is supportive of conclusions being made. Evaluation also means to be able to assess the logical strength of an inferred relationship between different sets of information (Chartrand & Rose, 2008; Facione, 2009; Woolfolk, 2010).
- **Analysis:** Identifying relationships between different sets of information, by focusing on similarities and differences (Chartrand & Rose, 2008; Facione, 2009).
- **Interpretation:** Understanding and communicating the meaning of information, which involves the application of skills such as categorisation and decoding information. Interpretation, implies comprehension and expression of meaning in relation to experiences, situations, and information (Chartrand & Rose, 2008; Facione, 2009).

Meta-cognitive skills

- **Self-regulation:** Questioning, correcting and validating one's own thinking, opinions and assumptions (reflection) (Bandura, 2015; Dignath & Büttner, 2008). In essence, the practice of self-regulation, means checking up on one's ideas and thoughts in order to establish if one's ideas and thoughts are logical, justified, and in accordance with the task that one is involved in.
- **Explanation:** Expressing the results of one's thinking and providing reasons for the way of thinking coherently (Facione, 2009).

It appears that pivotal skills applied during critical thinking are logical reasoning skills (Halpern, 2003a), that according to Bjorklund (2005) and Hughes and Lavery (2015), are

involved in almost every human activity such as problem solving, decision making, interpreting, and making inferences (Kompf & Bond, 2001).

The following section discusses the various critical thinking dispositions that exist and that can be fostered among students.

2.3.3 Critical thinking dispositions

In addition to cognitive and meta-cognitive skills, critical thinkers should also attain a level of maturity in their development of critical thinking, by acquiring certain critical thinking attitudes or dispositions in addition to the aforementioned set of skills (Davies, 2013; Dewey, 1933; Fahim & Shakouri, 2012; Norris & Ennis, 1989). It is not enough to teach students to perform thinking operations and tasks. They should also be disposed to carrying them out on their own, unasked (Ennis, 1987), thus requiring habitual dispositions, or behavioural traits displayed automatically without any prompting on the teacher's part. According to Ennis (1987, p. 25) these dispositions include:

- Seeking a clear statement of the thesis or question.
- Seeking reasons.
- Trying to be well informed.
- Using and mentioning trustworthy sources.
- Taking into account the entire situation.
- Trying to remain relevant to the main point.
- Keeping in mind the primary or basic concern.
- Looking for alternatives.
- Being open-minded.
- Taking a position (and changing a position) when the evidence and reasons are adequate to do so.
- Seeking as much accuracy as the subject allows.
- Dealing in an orderly manner with the parts of a complex whole.
- Using one's critical thinking abilities.

- Being sensitive to the feelings, level of knowledge, and degree of sophistication of others.

The dispositions mentioned by Ennis (1987) align well with the view of Facione (2000, p. 64), who defined human dispositions as *"...a person's consistent internal motivation to act toward, or to respond to, persons, events, or circumstances in habitual, and yet potentially malleable, ways"*.

The seven critical thinking dispositions identified by Facione (2000, p. 64; 2009, p. 8) include:

- **Truth-seeking:** A daring aspiration for the best knowledge, even if such knowledge fails to support or challenges one's preconceptions, beliefs or self-interests.
- **Open-mindedness:** Acceptance of different views, and self-monitoring for likely subjectivity.
- **Inquisitiveness:** Being inquisitive and enthusiastic to obtain knowledge and learn explanations even when the applications of the knowledge are not directly obvious.
- **Analyticity:** Demanding the application of reason and evidence, attentive to challenging situations, disposed to expect consequences.
- **Systematicity:** Appreciating administration, attention and thoroughness to approach problems of all levels of complexity.
- **Critical thinking self-confidence:** Trusting of one's own reasoning skills and seeing oneself as a good thinker.
- **Cognitive maturity:** Being discrete in making, suspending, or reviewing judgment, displaying an awareness that multiple solutions can be acceptable, and appreciating the need to reach closure even in the absence of complete knowledge.

Dispositions are also referred to as habits of mind that define a person's predisposition toward critical thinking, and comprise a willingness to follow reason, a logical approach to problem solving, curiosity, impartiality, and confidence in reasoning (Costa, 2009).

Costa and Kallick (2005, p. 4), indicate that habits of mind are *"an identified set of 16 problem solving, life-related skills, necessary to effectively operate in society and promote strategic reasoning, insightfulness, perseverance, creativity and craftsmanship"*. The

understanding and application of these 16 habits of mind function to afford the individual with skills to work through actual life situations that prepare that person to react using awareness (cues), thought, and intentional strategy in order to gain a positive outcome (Costa & Kallick, 2005). The following section provides an overview of the 16 habits of mind in more depth.

- **Persisting:** Remaining focused on the task and following through in order to complete a task.
- **Managing impulsivity:** Taking the time to decide upon options; thinking prior to speaking or acting; staying composed when stressed or challenged; being sympathetic and considerate of others; and advancing carefully.
- **Listening with understanding and empathy:** Paying attention to and not ignoring another person's opinions, emotion and thoughts; striving to put oneself in another person's shoes; expressing verbally to others when one can relate to what they are conveying; and holding thoughts at a distance in order to respect another person's point of view and feelings.
- **Thinking flexibly:** Being capable of changing a viewpoint; considering the contributions of others; creating alternatives; and considering options.
- **Thinking about thinking (Metacognition):** Being mindful of individual thoughts, emotions, goals and actions; knowing what one does and says has an emotional impact on others; and being eager to reflect on the effect of choices on oneself and others.
- **Striving for accuracy:** Determining if there are errors; measuring at least twice; and cultivating a need for precision, commitment and expertise.
- **Questioning and posing problems:** Asking oneself, "How do I know this?"; cultivating a questioning outlook; contemplating on what information is required; selecting strategies to obtain that information; and contemplating on the impediments that are necessary to resolve.
- **Applying past knowledge to new situations:** Practicing what is learned; contemplating on prior knowledge and experience; and applying knowledge outside of the context in which it was acquired.

- **Thinking and communicating with clarity and precision:** Endeavouring to be clear when communicating and writing; attempting to be precise when communicating; evading generalisations, misrepresentations, simplifications and omissions when communicating, and writing.
- **Gathering data through all senses:** Taking the time to observe what one sees; listening to what one hears; taking note of what one smells; tasting what one eats; and feeling what one is touching.
- **Creating, imagining, innovating:** Thinking about how something might be done differently from the norm; suggesting novel ideas; endeavouring for innovation; and considering novel suggestions others might make.
- **Responding with wonderment and awe:** Being intrigued by the world's beauty, nature's power and vastness of the universe; having regard for what is awe-inspiring and can touch one's heart; and opening up to the little and big surprises in life.
- **Taking responsible risks:** Preparing to try something different; contemplating doing things that are safe and rational even though it may be new; and facing the fear of making errors.
- **Finding humour:** Being eager to laugh appropriately; searching for the whimsical, silly, sarcastic and unexpected in life; and laughing at oneself when one can.
- **Thinking interdependently:** Being eager to engage with others and openly seek their input and viewpoint; accepting the decisions that others make even though one might differ slightly; and being disposed to learn from others in mutual circumstances.
- **Remaining open to continuous learning:** Being receptive to novel experiences in order to learn; being grateful and modest enough to acknowledge when not knowing something; and gladly accepting new information on all subjects.

The critical thinking dispositions as espoused by Facione (2000) link well with Costa and Kallick's (2005) extensive list of 16 habits of mind, as both describe an individual's tendency or inclination to reason or think in a critical manner. Both refer to actions or thoughts that occur on a regular basis. Dispositions enhance the quality of thinking, and are therefore necessary, in order for one to recognise when critical thinking skills are needed. Moreover, a willing and mental effort is required to apply critical thinking skills (Facione 2011; Profetto-McGrath (2003).

2.3.4 Critical thinking intellectual traits

Intellectual traits comprise patterns of thinking, behaviour and feeling that are unique to each person (Paul & Elder, 2006).

Paul and Elder (2006) view the following intellectual traits that result from the meticulous application of critical thinking skills and dispositions over time as important:

- **Intellectual humility versus intellectual arrogance:** It is important to possess an awareness of the boundaries of one's own knowledge. Intellectual humility depends on distinguishing that one should not claim more than one truly knows.
- **Intellectual courage versus intellectual cowardice:** One needs to possess an awareness of the desire to face and honestly address ideas, beliefs or viewpoints toward which we have strong undesirable emotions and to which we have not given a serious hearing.
- **Intellectual empathy versus intellectual close-mindedness:** Being aware of the need to put oneself in the place of others in order to understand them sincerely. This attribute associates with the ability to reconstruct correctly the viewpoints and reasoning of others and to reason from premises, assumptions, and ideas other than one's own.
- **Intellectual autonomy versus intellectual conformity:** Intellectual autonomy implies possessing coherent control of one's beliefs, values, and inferences. The ideal of critical thinking is to learn to think for oneself, and to acquire expertise over one's thought processes.
- **Intellectual integrity versus intellectual hypocrisy:** It is important to acknowledge the desire to be true to one's own thinking; to be reliable in the intellectual standards a person applies; to hold one's self to the same rigorous standards of evidence and proof to which one holds one's rivals; to apply what one promotes for others; and to fairly confess inconsistencies and irregularities in one's own thought and action.
- **Intellectual perseverance versus intellectual laziness:** It is important to possess an awareness of the desire to use intellectual perceptions and truths in spite of problems, obstacles, and frustrations.

All critical thinking and reasoning are directed to different elements of reasoning (Elder & Paul, 2007), which are outlined below.

2.3.5 The elements of reasoning

The elements of critical reasoning include the following:

- All reasoning has a **purpose**, namely to achieve something. One needs to state one's purpose of thinking and reasoning clearly. Elder and Paul (2007) also indicate that purposes ought to be clear and justified. One must continuously ask oneself what the purpose is for doing or thinking about a particular matter.
- All reasoning is an attempt to **figure something out, to settle some question, to solve some problem**. In order to solve a problem, one needs to determine questions and sub-questions clearly. Moreover, one needs to establish whether the question requires one correct answer or involves opinions. Questions outline problems or concerns and direct peoples' thinking; consequently, questions ought to be clear, because if they are ambiguous, thinking with clarity and distinctness will be absent (Elder & Paul, 2007). Put in another way, the questions we ask should be simple and accurate enough to guide our thinking efficiently (Elder & Paul, 2007).
- All reasoning is based on **assumptions**. It is important that one identifies what one takes for granted during reasoning, and how the assumptions shape one's viewpoint. Elder and Paul (2007) state that assumptions are formulated in the subconscious or unconscious level of cognition, and recommend that people must ensure that their assumptions are clear and that they are defensible by sound evidence.
- All reasoning is done from some **point of view**. A person's point of view comprises what evidence or learning content they are dealing with, and the manner in which they understand the aspects or content thereof (Elder & Paul, 2007). Thus, people ought to wholly reflect on other applicable viewpoints, and understand the restrictions of their own viewpoints (Elder & Paul, 2007).
- All reasoning is based on **data, information and evidence**. Information, comprises facts, data, evidence or experiences that one uses in order to understand (Elder & Paul, 2007). Even though one utilises this information, it does not automatically suggest accuracy or correctness. Therefore, Elder and Paul (2007) recommend that

users of information ensure that the information they utilise is accurate and applicable to the question or issue they are addressing.

- All reasoning is expressed through, and shaped by, **concepts** and **ideas**. The multitude of ideas, theories, laws, principles, and/or hypotheses that people utilise in thinking in order to understand the world are termed concepts (Elder & Paul, 2007). Consequently, people ought to be clear regarding the concepts they use, and ensure that they use them reasonably.
- All reasoning contains **inferences** or **interpretations** by which we draw **conclusions** and give meaning to information. Interpretations and/or conclusions are generated or formed when people are making inferences (Elder & Paul, 2007). Inferences ought to logically flow from evidence. Consequently, one would also infer no more or less, than what is implied in a particular circumstance or problem (Elder & Paul, 2007).
- All reasoning leads somewhere or has **implications** and **consequences** (Elder, & Paul, 2007). Implications are an integral part of peoples' thoughts, despite the fact that they cannot perceive them physically (Elder & Paul, 2007). Implications, as stated by Elder and Paul (2007), are also assertions or truths that rationally flow from other assertions or truths.

2.3.6 Universal standards for reasoning

According to Paul and Elder (2006) the execution of critical thinking encompasses the application of a number of universal intellectual standards for reasoning that enhance the quality of thinking or reasoning. These standards include **clarity, accuracy/precision, relevance, significance, breadth, and logic**. Students, therefore, need to have a good command of these standards when they engage in critical thinking.

- Clarity is important to express something in another way, or to elaborate further on an issue.
- In order to check whether something is true, accuracy is required. Without precision, specific and accurate detail regarding an issue would be lacking.
- Relevancy, as well as the significance of ideas, facts or problems, are important intellectual standards for determining whether information is connected.

- Significance enables one to determine whether information has any bearing on an issue.
- Breadth is important to obtain insight and depth into an issue.
- Logic allows one to put a variety of thoughts together into some order.

Paul and Elder (2006) state, that if we do not apply these intellectual standards to our thinking, then our thinking becomes innately egocentric, socio-centric, wish fulfilment, self-validating or selfish, which they explain as follows:

- **Innate egocentrism:** Assuming that ones' beliefs are true, although one has not questioned the basis of one's beliefs.
- **Innate socio-centrism:** Assuming that the beliefs in a group to which one belongs are true, although the beliefs have never been questioned.
- **Innate wish fulfilment:** The tendency to believe in that what feels good and supports one's beliefs.
- **Innate self-validation:** Keeping to one's beliefs, although one has never questioned or justified one's beliefs.
- **Innate selfishness:** Holding onto beliefs because they are beneficial, even though these beliefs are not rooted in comprehensive reasoning.

In summary, Elder and Paul (2007) agree that critical thinking is thinking that is self-directed, self-disciplined, self-monitored, and self-corrective. Paul and Elder (2007, 2008 a, b) also highlight that effective communication, problem solving skills and genuine commitment to exercising critical thinking skills are all fundamentally important for effective critical thinking. The conceptualisation of critical thinking according to the view of Paul and Elder (2007), which guided the researcher's study, is captured in Figure 2.1 below.

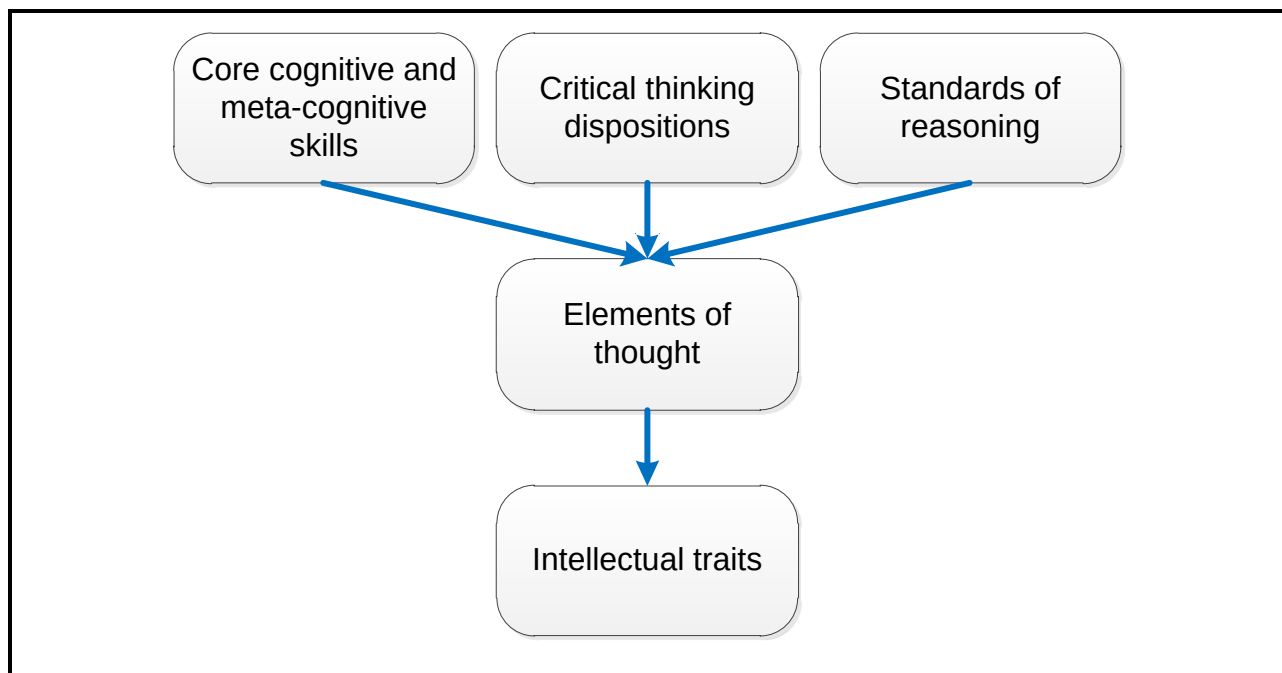


Figure 2.1: Paul-Elder Critical Thinking Model

Figure 2.1 highlights that critical thinking implies the integrated application of the core cognitive and meta-cognitive skills (*cf.* 2.3.2), dispositions (*cf.* 2.3.3) and intellectual standards for reasoning such as clarity, relevance and logic (*cf.* 2.3.6) to the elements of reasoning, which comprise among others, the making of inferences, clarifying concepts, and recognising assumptions (*cf.* 2.3.5) in order to develop various intellectual traits, such as humility, autonomous thinking, empathy and integrity (*cf.* 2.3.6).

In a nutshell, the researcher identified the following trends in the aforementioned sections (*cf.* 2.2, 2.3) that aimed to provide a conceptualisation of critical thinking:

- A limited conceptualisation of critical thinking as the ability to think scientifically in a disciplinary context (Halpern, 2014; Reddy & Lantz, 2010).
- A broader conceptualisation of critical thinking as the ability to critically reflect on personal experiences and about the world at large (Hyytinen, 2015; Paul, 1990).
- A general conceptualisation of critical thinking as the application of cognitive and meta-cognitive skills (Beyer, 1983; Dewey, 1910; Ennis, 1964; Facione, 1990, 2000; Glaser, 1941; Halpern, 2007; McPeck, 1981; Norris & Ennis, 1989; Reynolds, 2011; Russell, 1943; Sternberg, 2007; Stupinsky *et al.*, 2008).

- The application of dispositions that support the effective use of the cognitive and meta-cognitive skills involved in critical thinking (Davies, 2013; Costa, 2009; Ennis, 1987; Facione, 2000).
- The integrated application of cognitive and meta-cognitive skills, dispositions and intellectual standards for reasoning to develop intellectual traits (Paul & Elder, 2006).

The following section wishes to elucidate upon the researcher's own conceptualisation of critical thinking in the context of the study given the aforementioned literature review.

2.3.7 The researcher's conceptualisation of critical thinking in the context of the study

In the context of the study, the researcher conceptualised critical thinking (Figure 2.2) by combining the viewpoints of Paul and Elder (2006, 2007) and Facione (1990, 2000, 2009), as their viewpoints presented a comprehensive view of what critical thinking entails, and aligned with the components on which the W-GCTA that was used in the context of the study to collect data, focused. The viewpoints of Facione (1990, 2000, 2009) and Paul and Elder (2006) include over and above the core cognitive and meta-cognitive skills, also standards for reasoning and thinking dispositions as important elements of critical thinking, which, according to the researcher, cannot be ignored in the conceptualisation and development of critical thinking. The conceptualisation of Watson and Glaser (2002a) (*cf.* 5.7.1.1) is included, with particular reference to the critical thinking skills, as their conceptualisation underpinned the W-GCTA that was used for data collection in the context of the research. In addition, the researcher supported a broader conceptualisation of critical thinking that does not only imply thinking critically in a disciplinary context.

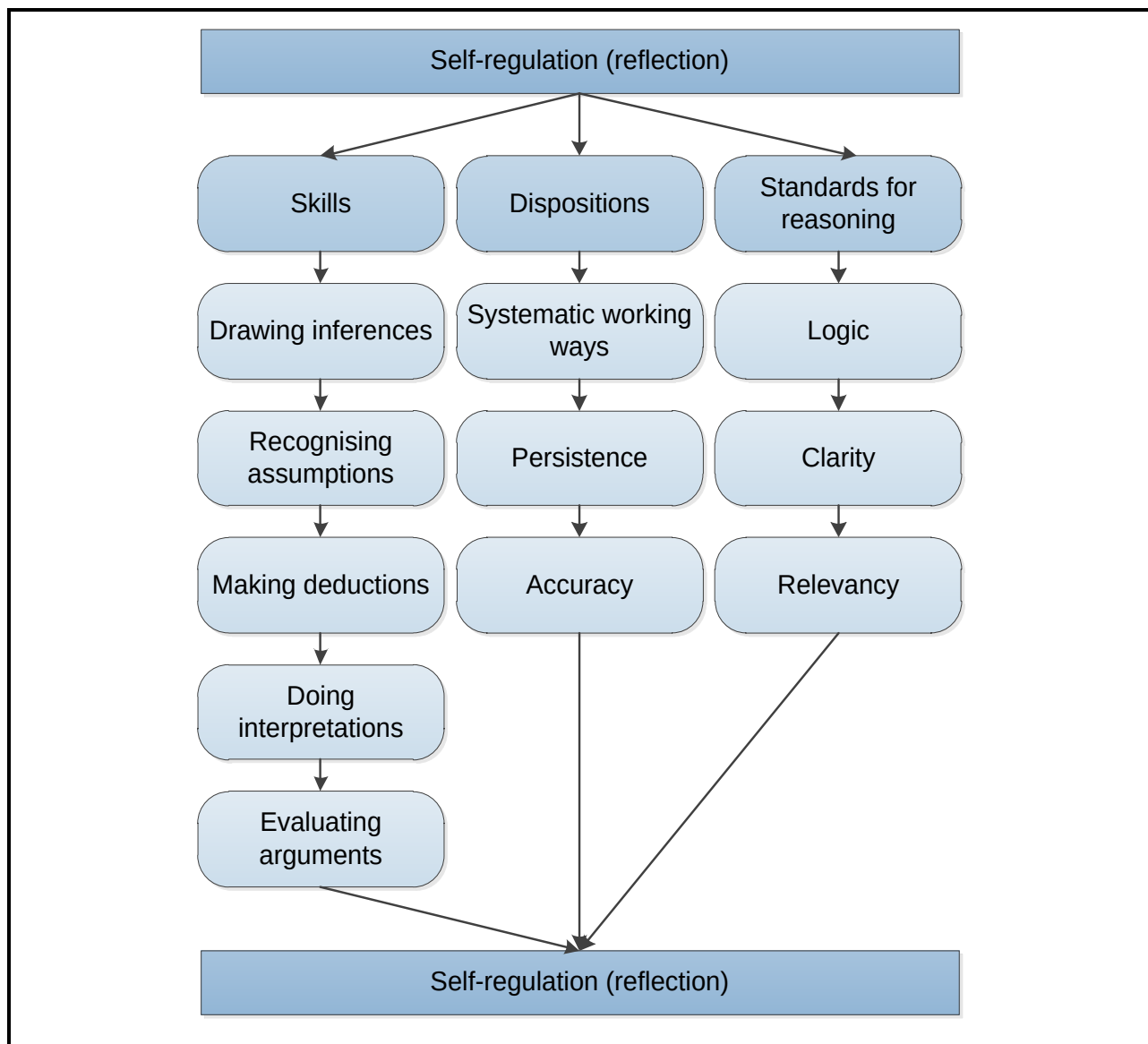


Figure 2.2: The researcher's conceptualisation of critical thinking

The above figure displays that in the context of the study, critical thinking comprised the integrated application of three different elements to be effective at solving problems during the PVG-CEP. Developing critical thinking therefore does not only involve a process of cognitive actions. Dispositions and emotions as well as standards for reasoning are intrinsic to being critical (Burbules, 2016; Sibbett, 2016). Firstly, various critical thinking skills, namely cognitive skills such as making inferences, recognising assumptions, making deductions and evaluating arguments, and doing interpretations, as well as the meta-cognitive skill (Facione, 2009) that involves reflective and self-regulated thinking, need to be applied throughout the critical thinking process. The second element involves the application of critical thinking dispositions, such as working

systematically with persistence and accuracy (Facione, 2000), and the third element entails adhering to standards for reasoning, which include logic, clarity and relevancy (Paul & Elder, 2006). During problem solving as part of the PVG-CEP intervention, the students had to deal with a number of elements of reasoning (*cf.* 2.3.5), such as identifying the purpose of their actions, posing questions to solve the problems, recognising assumptions that could obstruct the successful solving of problems, search for evidence to solve problems, and make inferences about their proposed ways to solve problems. Guiding the application of all the skills, dispositions and standards for reasoning, is the meta-cognitive skill of self-regulation, that involves continuous reflection about and improving the quality and correctness of the application of the cognitive skills, dispositions and standards for reasoning.

The number of dispositions and standards for reasoning that were addressed in the study, were limited, to include those that were regarded as most relevant to the implementation of the PVG-CEP, and to enable more reliable observations during the implementation of the intervention. The conceptualisation was applied throughout the study, and the application of all elements were nurtured as part of the intervention.

According to the researcher, the development of good critical thinking skills implies that the three mentioned elements (skills, dispositions, standards for reasoning) have to be developed in unison. For example, reasonable conclusions will not flow from given information, if inferences that are made are not accurate and logic.

The concept critical thinking has been clarified, and the researcher shifts the attention to how the ideal critical thinker behaves when faced with problems to solve. Information about how students behave when involved in activities that require the application of critical thinking is important for the researcher as he had to make evaluations about the nature of the research participants' application of critical thinking when involved in solving problems. The following section therefore addresses the characteristics of critical thinking in action.

2.4 CRITICAL THINKING IN ACTION

Good critical thinking in action comprises elements of logical, critical, creative, and big picture thinking modes (Beyer, 1987; Olivier, 2012). A thinking mode is a state of mind

which involves thinking attitudes and dispositions (Grosser & Olivier, 2017). Thinking modes are used to analyse information, determine consistencies and inconsistencies, identify patterns in information, determine cause and effect, to predict, identify alternatives and formulate conclusions (Grosser & Olivier, 2017). According to Grosser and Olivier (2017), if students possess well-developed thinking modes, they will be able to construct their own understanding of information.

Each of the thinking modes involved in the application of critical thinking is discussed below.

2.4.1 Applying the logical thinking mode

The logical thinking mode is a cause-and-effect thinking mode that provides a variety of logical results or outcomes that assist or enable the mind to achieve solutions (Grosser & Olivier, 2017). It selects, sorts, combines and deselects information and ideas until the information and ideas make sense. When the logical mode stumbles across a problem, it could temporarily switch to the creative mode for a solution.

According to Grosser and Olivier (2017) teachers should be equipped with skills to embrace the logical thinking mode. They need to intentionally direct students' logical thinking mode by asking the following drill-down and chaining questions:

- What is the logic of this?
- What is the pattern?
- How can we work this out?
- What is the sequence?
- What comes first and what comes last?"

Teachers could also prescribe certain actions to prompt the use of the logical thinking mode, such as:

- Determine the process or procedure.
- Make a list.
- Draw a flow chart.

Teachers can even go further by asking the following two questions:

- What is the next question I should ask?
- What is the answer to my next question?

The latter two questions already point to the application of the critical questioning thinking mode.

2.4.2 Applying the critical questioning mode

When working in the critical thinking mode, the mind asks questions to obtain different and alternative perspectives to solve problems. This mode is important in all subjects where cause and effect and alignment or misalignment of concepts is important. The critical questioning thinking mode challenges the mind, and teachers could encourage the use of the critical thinking mode by using effective questioning, as indicated in the examples below:

- Do you agree with this statement/argument? Why? Why not?
- What is the solution? Is this the only solution to the problem? What other possible solutions are there?
- What are the advantages/disadvantages of...?
- What would happen if ...?
- How can the question be phrased to achieve the solution easier?
- How can the question be phrased to make it more difficult? (Grosser & Olivier, 2017).

2.4.3 Applying the creative thinking mode

According to Beyer (1987), when one contrasts creative and critical thinking, it can be said that creative thinking is divergent whereas critical thinking is convergent, meaning that when thinking creatively, ideas and concepts are broader and more spread out, while critical thinking involves ideas and concepts that are logical and to the point. Creative thinking attempts to create something original, and critical thinking pursues to evaluate value or validity in anything that exists. Although creative and critical thinking can be seen as opposite sides of the same coin, they are not identical (Beyer, 1987; Wechsler *et al.*, 2018). Creative thinking encompasses examining significant new connections by

generating numerous unusual, original, and diverse possibilities, in addition to specifics that magnify or enrich possibilities. Critical thinking, in contrast, includes exploring possibilities cautiously, fairly, and constructively, concentrating one's thoughts and actions by organising and analysing opportunities, refining and developing the most favourable opportunities, ranking or prioritising decisions, and choosing specific options.

The creative thinking mode enables us to move away from foreseeable thinking and emphasises the creation of new meaning or structure, or seeing things from a different perspective that involves the skills of analysis, synthesis and evaluation.

In general, teachers can enhance creative thinking by using the following phrases:

- What is new?
- Come up with a smarter answer.
- How can you adapt your answer?
- How can one make this work? (Grosser & Olivier, 2017).

2.4.4 Applying the big picture thinking mode

The big picture thinking mode involves the ability to fit newly acquired ideas and information into previously gained ideas and information. A key characteristic of big picture thinking is the ability to see how learning connects to the wider world (Eyre, 2016). Bigger picture thinking provides us with a wider perspective on a topic (Grosser & Olivier, 2017). Normally, curricula and teaching do not position learning in a wider context, and teaching introduces information as chunked pieces (Eyre, 2016). Teachers need to ensure that students develop insight into the holistic interrelatedness of the topics covered by the curriculum, and should refrain from providing students with ready-made summaries of the content that was dealt with in class. Students should rather be motivated to find links and relationships between different sets of information on their own.

According to Grosser and Olivier (2017), if students cannot apply the various critical thinking modes, thinking can become an irritating activity, which is regarded as difficult. Without well-developed critical thinking skills, it remains a challenge to find solutions to problems, and students resort to finding ready-made answers.

It is important that teachers understand that developing good critical thinking skills is a journey, and involves a developmental process. In this regard, the next section clarifies the stages in the development of an ideal critical thinker.

2.5 THE IDEAL CRITICAL THINKER

Although most teachers desire to make critical thinking a primary outcome of their teaching, many also do not comprehend that, to develop as thinkers, students must progress through stages of development in critical thinking. Elder and Paul (2010) believe that substantial advances in the intellectual quality of student work will not be realised if teachers do not know that skilled critical thinking develops only when correctly nurtured, and only through predictable stages.

Previous work in the field by Ennis (1964) (*cf.* 2.2.2.3) as well as the work of Elder and Paul (2010), Papp *et al.* (2014), and Paul and Elder (2005b) provide an indication of how critical thinking might develop and manifest across different stages. The stages of critical thinking development are summarised in Figure 2.3 below.

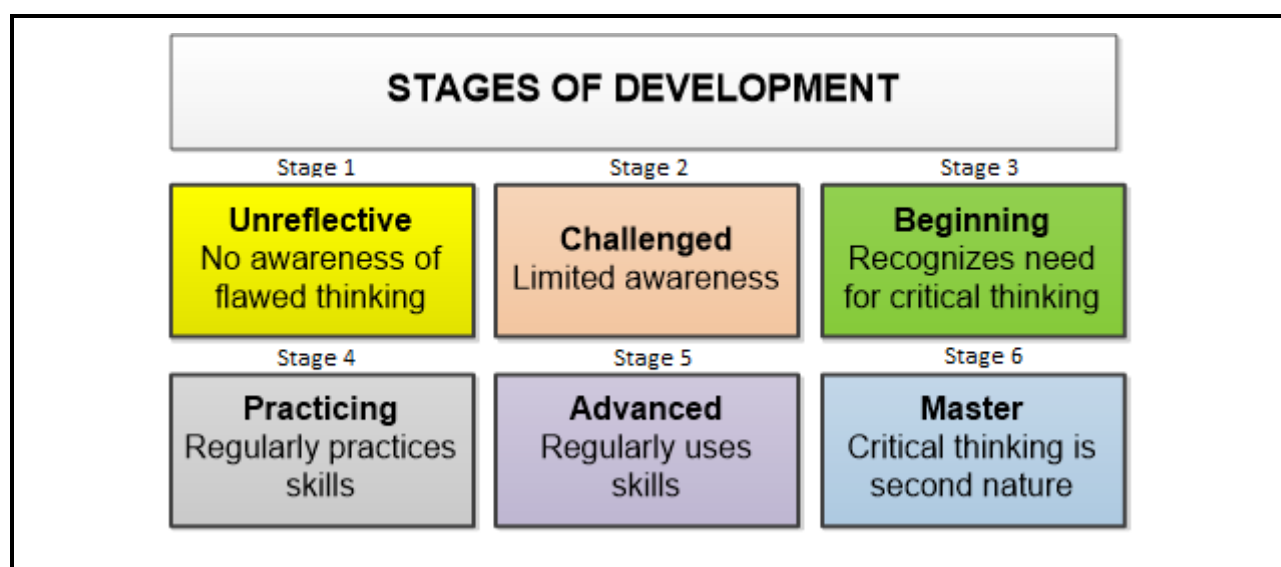


Figure 2.3: Stages of critical thinking development (Paul & Elder, 2005b, p. 19)

2.5.1 Stage one: The unreflective thinker

Defining feature: According to Paul and Elder (2005b, 2006), unreflective thinkers are principally ignorant and inattentive of the decisive role that thinking plays in their lives and

of the numerous ways that poor thinking create problems in their lives (Ennis, 1964; Paul & Elder, 2006). Unreflective thinkers lack the ability to explicitly assess their thinking and improve it (Elder & Paul, 2010). Moreover, they cannot examine the thinking processes of others (Papp *et al.*, 2014).

Knowledge of thinking: Unreflective thinkers are mostly ignorant of thinking as such, and therefore fail to identify thinking as an activity involving concepts, assumptions, inferences, implications, and points of view. Unreflective thinkers are largely unaware of the appropriate standards for the assessment of thinking, namely clarity, accuracy, precision, relevance and logicalness (Elder & Paul, 2010).

Skill in thinking: Unreflective thinkers lack skills to self-monitor their thoughts. Prejudices and misconceptions frequently destabilise the quality of thought of the unreflective thinker (Elder & Paul, 2010). According to Papp *et al.* (2014), unreflective thinkers lack flexibility and cannot adapt to new knowledge. They have a single approach to gathering and processing information based on rote learning and memorisation (Papp *et al.*, 2014).

Relevant intellectual trait: Since unreflective thinkers do not apply intellectual standards to their thinking, their thinking is innately egocentric, socio-centric, based on wish fulfilment, self-validating or selfish (Paul & Elder, 2006) (*cf.* 2.3.6).

Some implications for instruction: Paul and Elder (2006) assert that though all students think, the majority of students are essentially ignorant of how their thinking is structured or how to assess or develop it. Consequently, when they experience problems in thinking, they lack the skills to recognise and remedy these problems. Most teachers do not seem to be aware of how unaware most students are of their thinking, and therefore not much is being done to help students to discover the ways they are thinking (Elder & Paul, 2010; Papp *et al.*, 2014).

2.5.2 Stage two: The challenged thinker

Defining features: Elder and Paul (2010), Ennis (1964) and Paul and Elder (2005a, b) claim that challenged thinkers are tested thinkers, who become primarily aware of the determining role that thinking plays in their lives, and that problematic, ineffective thinking causes them substantial problems (Papp *et al.*, 2014).

Principal challenge: Challenged thinkers become primarily conscious of the determining role of thinking in one's life and of basic problems that come from one's own poor thinking and the thinking of others (Elder & Paul, 2010; Papp *et al.*, 2014).

Knowledge of thinking: Papp *et al.* (2014) state that challenged thinkers, in contrast to unreflective thinkers, become conscious of the fact that high quality thinking necessitates thoughtful reflective thinking about thinking in order to improve thinking. They know that their thinking is frequently weak, although they are not capable of identifying many of the flaws in their thinking (Papp *et al.*, 2014). Challenged thinkers possibly will develop a preliminary consciousness of thinking as involving concepts, assumptions, inferences, implications and points of view, as well as involving standards for the assessment of thinking, namely clarity, accuracy, precision, relevance, and logic. Challenged thinkers only have a superficial understanding of these standards and what it would take to adopt them. Challenged thinkers also cultivate limited understanding of the role of self-deception in thinking, however their understanding is very limited. The challenged thinker develops some reflective awareness of how thinking operates for good or ill (Elder & Paul, 2010).

Skill in thinking: Elder and Paul (2010) maintain that most of the challenged thinkers have very incomplete thinking skills. Nonetheless, like unreflective thinkers, they may have developed a variety of thinking skills without being conscious of them, and these skills may function ironically as obstacles to development (Papp *et al.*, 2014). At this stage, thinkers with some inherent critical thinking abilities may more effortlessly mislead themselves into believing that their thinking is better than it actually is, making it more challenging to distinguish the problems inherent to poor thinking. To accept the challenge at this level necessitates that thinkers gain awareness of the fact that whatever intellectual skills they have, are inconsistently applied across the domains of their lives (Elder & Paul, 2010). Challenged thinkers make use of limited approaches to find information in a focused manner (Papp *et al.*, 2014:716).

Relevant intellectual trait: The central intellectual trait to be developed at this stage is intellectual humility (*cf.* 2.3.4); in order to understand the problems intrinsic to thinking (Elder & Paul, 2010).

Some implications for instruction: It is the view of Papp *et al.* (2014) that one must be aware of the significance of challenging students in a sympathetic way to identify both that they are thinkers, and that their thinking frequently goes awry. One must promote class discussions about thinking, openly apply thinking (e.g., thinking aloud through a problem), design classroom activities that clearly oblige students to think about their thinking, have students scrutinise both poor and sound thinking by talking about the dissimilarities, and introduce students to the parts of thinking and the intellectual standards necessary to assess thinking. We must introduce the idea of intellectual humility to students; that is, the idea of becoming aware of our own ignorance (Elder & Paul, 2010; Papp, *et al.*, 2014).

2.5.3 Stage three: The beginning thinker

Defining feature: Papp *et al.* (2014) reveal that beginning thinkers, or novice thinkers (Ennis, 1964), actively take up the challenge to take clear command of their thinking across many domains of their lives. Thinkers at this stage identify that they have rudimentary problems in their thinking and make early efforts to understand how they can take charge of and develop the problems better. Based on this initial understanding, beginning thinkers begin to change some of their thinking, but have limited understanding of deeper levels of the problems built into their thinking. Most importantly, they do not have a well-thought-out plan to practice for improving their thinking (Elder & Paul, 2010; Papp *et al.*, 2014; Paul & Elder, 2005a, b).

Principal challenge: Beginning thinkers need to see the importance of developing as a thinker, start looking for ways to develop as a thinker and make a thinking-related promise to become a better thinker (Elder & Paul, 2010). Although they are open to feedback from others about their thinking, they seldom reflect on their own thinking (Papp *et al.*, 2014).

Knowledge of thinking: Beginning thinkers, unlike challenged thinkers, become aware not only of thinking as such, but also of the role of thinking of understanding ideas, recognising assumptions, making suggestions and sharing points of view (Papp *et al.*, 2014:716). Beginning thinkers are also at some beginning stage of recognising not only that there are standards for the evaluation of thinking, namely clarity, precision, quality, relevance, and logic, but also that one needs to internalise the standards and start to

apply them in a carefully-planned way when involved in thinking. Beginning thinkers have a foundational understanding of the role of self-centred thinking in human life (Elder & Paul, 2010).

Skill in thinking: Beginning thinkers can appreciate an opinion of their powers of thought, and have enough skill in thinking to begin to watch for changes in their own thoughts. However, as beginners, they are rarely in control. They are beginning to recognise self-centred thinking in themselves and others (Elder & Paul, 2010).

Relevant intellectual traits: The key thinking-related feature needed at this stage is some degree of intellectual humility to recognise the problems built into thinking (Papp *et al.*, 2014). Beginning thinkers must have some degree of intellectual confidence in reasoning, a feature which provides the driving force to take up the challenge and begin the process of active development as critical thinkers, even though there is the existence of limited understanding of what it means to do high quality thinking. In addition, Elder and Paul (2010) assert that beginning thinkers have enough intellectual perseverance to struggle with serious problems in thinking while yet missing a clear solution to those problems. In other words, at this stage, thinkers are recognising more and more problems in their thinking, but have not yet discovered how to organise and assign procedures to their efforts to solve them.

Some suggestions for instruction: Papp *et al.* (2014) state that once teachers have convinced most of their students that much of their thinking is flawed and that they are capable of improving as thinkers, teachers must teach in such a way as to help them to see that everyone needs to practice good thinking regularly to become good thinkers. Teachers must not only look for opportunities to encourage them to think well, they must help them to begin to understand what it is to develop good habits of thinking. Moreover, teachers must draw attention to the importance of taking charge of applying thinking-related standards. Elder and Paul (2010) argue that students need to begin to recognise when their thinking is self-centred in nature.

2.5.4 **Stage Four: The practicing thinker**

Defining feature: Thinkers at this stage have a sense of the dispositions they require to develop and to take charge of their thinking (Papp *et al.*, 2014). They not only know that

problems exist in their thinking, but they also identify the necessity to tackle these problems globally and in an organised way (Paul & Elder, 2005a, b). Based on their sense of the need to practice and rehearse regularly (Ennis, 1964), they actively and carefully study their thinking in some domains. However, according to Elder and Paul (2010), since practicing thinkers are only beginning to approach the improvement of their thinking in a well-thought-out way, they still have limited understanding of deeper levels of thought, and so into deeper levels of the problems embedded in thinking.

Principal challenge: The main challenge for practicing thinkers is to begin to develop knowledge of the need for well-thought-out practice in thinking (Elder & Paul, 2010).

Knowledge of thinking: Practicing thinkers, unlike beginning thinkers, are becoming knowledgeable of what it would take to monitor their role in thinking about ideas, integrity, assumptions, suggestions and points of view in an organised way (Papp *et al.*, 2014). Elder and Paul (2010) indicate that practicing thinkers also become knowledgeable of what it would take to test/evaluate their thinking regularly for clarity, accuracy, relevance and logic. Practicing thinkers recognise the need for systematic critical thinking and deep internalisation of thinking habits. They clearly recognise the natural habit/desire of the human mind to work at self-centred thinking and self-deception (Elder & Paul, 2010).

Skill in thinking: Elder and Paul (2010) argue that practicing thinkers have enough skill in thinking to find the faults of their own thinking, and to construct a realistic opinion of their powers of thought. Practicing thinkers also have enough skill to begin to regularly monitor their own thoughts, and state the strengths and weaknesses in their thinking. Practicing thinkers can often recognise their own self-centred thinking as well as self-centred thinking on the part of others. Furthermore, practicing thinkers actively monitor their thinking to eliminate self-centred thinking, although they are often unsuccessful (Elder & Paul, 2010; Papp *et al.*, 2014).

Relevant intellectual traits: The key thinking-related feature needed to move to becoming a practicing thinker, is persistence. This trait delivers the driving force for designing a realistic plan for well-thought-out practice with an opinion to taking better command of one's thinking. In addition, thinkers at this stage have the intellectual humility needed to understand that thinking in all the domains of their lives must be subject to

close attention, as they begin to approach the improvement of their thinking in a well-thought-out way (Elder & Paul, 2010; Papp *et al.*, 2014).

Some suggestions for instruction: Elder and Paul (2010) advise that teachers ought to teach in such a manner that students come to comprehend the power in knowing that whenever humans reason, they have no alternative but to utilise certain expected structures of thought (*cf.* 2.3.5), namely that:

- thinking is unavoidably driven by questions;
- we look for answers to questions for some purpose;
- to answer questions, we need information;
- to use information, we must understand/explain it (i.e. by making guesses (based on what one has been told);
- our guesses (based on what one has been told), in turn, are based on ideas one thinks are true; and
- we have suggestions, all of which involve ideas or ideas within some point of view.

2.5.5 Stage Five: The advanced thinker

Elder and Paul (2007) determined that the greatest thinkers think through rational implications in any given situation before deciding to act upon it. Paul and Elder (2005) conclude that an advanced critical thinker is a person who can:

- pose important questions while expressing them clearly and precisely;
- collect, evaluate and understand information effectively;
- generate well-reasoned deductions and solutions by testing them alongside appropriate criteria;
- think unbiased by identifying and evaluating assumptions, implications and practical consequences; and
- communicate efficiently with others when solving complex problems.

Defining feature: Elder and Paul (2010) argue that thinkers at this stage have now established good habits of thought. Based on these habits, advanced thinkers not only actively study their thinking in all the significant domains of their lives, but also have a

significant understanding of problems at deeper levels of thought. Although advanced thinkers can think well across the important dimensions of their lives, they are not yet able to think regularly at a high level across all of these dimensions. Advanced thinkers have good general command over their self-centred nature, and constantly try to be fair-minded (Elder & Paul, 2010). In addition, they take charge of their thinking and monitor and revise their approaches to thinking, and acknowledge biases and assumptions in their thinking (Papp *et al.*, 2014).

Principal challenge: Advanced critical thinkers are challenged to refine their thinking (Ennis, 1964), and begin to develop depth of understanding not only of the need for well-thought-out practice in thinking, but also understanding of deep levels of problems in thought (Papp *et al.*, 2014). Some of these problems refer to consistent recognition, for example, of self-centred and socio-centric thought in one's thinking, the ability to identify areas of significant ignorance and prejudice, and the ability to develop new basic habits of thought based on deep values to which one has committed oneself (Elder & Paul, 2010).

Knowledge of thinking: Advanced thinkers work actively and successfully in an organised way supervising the role in their thinking of ideas, inferences, assumptions, suggestions, and points of view (Elder & Paul, 2010). Advanced thinkers are also cognisant of what it takes to test/evaluate their thinking for clarity, accuracy, precision, relevance and logic, regularly. Advanced thinkers value the deep and well-thought-out internalisation of critical thinking into their daily habits, and have a deep understanding of the role of self-centred thinking and socio-centrism in thinking, as well as the relationship between thoughts, feelings and desires (Elder & Paul, 2010). They have a deep understanding of the powerful role that thinking plays in the quality of their lives. Moreover, they understand that although self-centred thinking will always play a role in their thinking, they can reduce the power that self-centred thinking has over their thinking and their lives (Elder & Paul, 2010; Papp *et al.*, 2014).

Skill in thinking: Advanced thinkers regularly give opinions about their own plan for well-thought-out practice, and improve it in that way (Papp *et al.*, 2014). They can state the strengths and weaknesses in their thinking are able to identify when self-centred thinking

drives their thinking; and effectively use some strategy to reduce the power of their self-centred thoughts (Elder & Paul, 2010).

Relevant intellectual traits: The key thinking-related feature needed at this stage is a high degree of intellectual humility in recognising self-centred and socio-centric thought in one's life as well as areas of significant ignorance and prejudice. In addition, the thinker at this level needs:

- insight and persistence to actually develop new basic habits of thought based on deep values to which one has committed oneself;
- the integrity to recognise areas of inconsistency and disagreement between two issues in one's life;
- thinking-related understanding that is necessary to put oneself in the place of others in order to really/honestly understand them;
- thinking-related courage to face and fairly address ideas, beliefs, or viewpoints toward which one has strong negative feelings of love, hate, and fear; and
- the fair-mindedness that is necessary to approach all viewpoints without prejudice, and without reference to one's own feelings or interests.

In the advanced thinker these qualities are newly appearing, but may not be visible at the highest level or in the deepest dimensions of thought (Elder & Paul, 2010; Papp *et al.*, 2014).

Some suggestions for instruction: Most students might not become advanced thinkers. Nevertheless, it is important that they learn what is required to become an advanced thinker. It is important that they see it as an important goal. Teachers can help students move in this direction by helping the development of their knowledge of self-centred thinking and socio-centrism in their thinking, by leading discussions on perseverance, integrity, intellectual empathy, intellectual courage, and fair-mindedness (Elder & Paul, 2010; Papp *et al.*, 2014).

2.5.6 Stage Six: The master thinker

Elder and Paul (2010) and Ennis (1964) regard the sixth stage as the stage where one becomes a master, accomplished, expert, and sophisticated critical thinker.

Defining feature: Accomplished thinkers not only have in an organised way take charge of their thinking, but also constantly watch/supervise, revise, and re-think plans or ways of reaching goals for constant improvement of their thinking. They have internalised the basic skills of thought, so that critical thinking is conscious and obvious. They self-evaluate their thinking in all the domains of their lives and constantly develop new understanding of problems at deeper levels of thought. Accomplished thinkers are committed to fair-minded thinking, and have a high level of, although not perfect, control over self-centred thinking (Elder & Paul, 2010).

Principal challenge: Accomplished critical thinkers make critical thinking obvious in every domain of life (Elder & Paul, 2010).

Knowledge of thinking: Accomplished thinkers actively supervise the role of thinking in formulating ideas, recognising assumptions, making guesses based on what one has been told, identifying effects/results/suggestions and expressing points of view (Papp *et al.*, 2014). Accomplished thinkers have not only a high degree of knowledge of thinking, but a high degree of practical understanding of complex concepts too, and they instinctively test/evaluate their thinking for clarity, quality, relevance and logic, and understand the role that self-centred and socio-centric thinking plays in the lives of human beings (Elder & Paul, 2010).

Skill in thinking: According to Elder and Paul (2010), accomplished thinkers regularly give opinions about and improve their own use of thinking. They regularly monitor their own thoughts, and identify the strengths and weaknesses built into their thinking, and know the qualities of their own thinking.

Relevant intellectual traits: Accomplished thinkers possess all the important thinking-related qualities, namely thinking-related courage, thinking-related deep caring, thinking-related understanding of feelings, thinking-related independence, thinking-related responsibility and fair-mindedness. Self-centred and socio-centric thought is quite unusual for the accomplished thinker (Elder & Paul, 2010).

Some suggestions for instruction: Papp *et al.* (2014) state that many students might not become accomplished thinkers. Nevertheless, it is important that they learn what it would be to become a very skilful thinker. It is important that they see that it is possible to

develop good critical thinking skills, and that applying thinking skills is part of day-to-day living (Elder & Paul, 2010).

The researcher finds the above classification of thinking stages noteworthy, because they clearly reflect the interrelated application of critical thinking skills, dispositions and standards for reasoning, in order for somebody to become effective in the application of critical thinking. The interrelated application of critical thinking skills, dispositions and standards for reasoning, was supported in the researcher's study.

The various stages of development as presented above, guided the researcher in interpreting the test results of the research participants.

2.5.7 Developing dispositions and standards for reasoning

Limited information is available regarding growth levels of achievement in relation to the development of critical thinking dispositions (attitude of mind) and standards for reasoning. The work of Anderson (2010) and Costa and Kallick (2009a) provide some guidance in establishing descriptive levels to qualify the nature of the application of critical thinking dispositions. When working towards improving dispositions it is important to focus on ongoing improvement rather than specific standards (Anderson, 2010). The focus should rather be on continual growth. In order to provide some guidance to direct the assessment of ongoing improvement of the dispositions, Anderson (2012) argues that it is important to depart from the premise that no student will completely lack dispositions. Some students might just have less well-developed dispositions than others.

If students are not successful in applying dispositions, Anderson (2010) indicates that the problem might be related to one of the following dimensions that play an important role in becoming more mature in the application of dispositions, namely: meaning, value, capacity, alertness, and commitment. It is important to understand what a disposition means and why it is significant. Students should have the capacity, thus possess strategies to enact the various dispositions, and be alert to recognise when and where dispositions should be applied. Moreover, they need to place importance on the various dispositions by connecting the success they experience, to the application of a particular disposition. Finally, students should become committed to self-assess the growth and development of their dispositions and set goals for improvement.

Anderson (2012) asserts that there are no fixed paths of development for the various dimensions in relation to each of the dispositions. The researcher therefore developed his own descriptive statements to evaluate the research participants' maturity levels in applying the dispositions that the study focused on, by using the four-point scale (**novice, able, skilled, sophisticated**) suggested by Anderson (2012). The same scale was used to observe the development of the standards for reasoning, as no information regarding the development of standards for reasoning could be located in the literature (*cf.* Appendix H).

The following section synthesises the researcher's view about the importance of critical thinking for teacher education. This section bears relevance to the study, as it provides a rationale for the present study.

2.6 THE IMPORTANCE OF CRITICAL THINKING FOR TEACHER EDUCATION

Placing emphasis on the development of critical thinking during initial teacher education is not an option. Developing critical thinking skills stands central to the objectives of the CAPS (Department of Education, 2011) that drives teaching and learning in South African classrooms. Teachers therefore need to instil good critical thinking skills among the students whom they will teach. It is sensible to accept that teachers themselves then need to be proficient critical thinkers before they will be able to instil the skills among students.

2.6.1 Critical thinking and the Curriculum and Assessment Policy

The CAPS Grades R-12 continues to endorse the facilitation of teaching and learning that ought to cultivate the cognitive and meta-cognitive skills (*cf.* 2.3.2) as well as intellectual dispositions that are important for critical thinking (*cf.* 2.3.3). The curriculum requires that students should be able to identify and solve problems and make decisions using critical and creative thinking (Department of Basic Education, 2011). It is therefore of the utmost importance that critical thinking be developed in classrooms in South Africa.

The following section pays attention to the importance of critical thinking as one of the 21st century skills that are required in the modern world.

2.6.2 Critical thinking and teaching and learning in the 21st century

According to Barell (2010) and Eyre (2016), critical thinking skills are considered to be a sequence of higher-order skills, abilities, and learning outlooks that have been indicated to be of a necessity for achievement and success in a 21st century society and workplaces by teachers, business leaders, academics, and governmental organisations. Critical thinking skills are prerequisites for preparing students for achievement in a rapidly changing, digital society (Dede, 2010; Goldrick-Rab, 2010).

A student that exits the South African school system after 12 years needs to be an advanced performer, and an enterprising and a global student, capable of coping with academic, workplace and life challenges of the 21st century (Eyre, 2016; Toner & Moran, 2016). A changing and challenging world of the 21st century therefore demands not only the teaching of knowledge, but also the cultivation of critical thinking skills, and in particular, well developed critical thinking dispositions (Eyre, 2016; Pink, 2006).

Advanced performers, enterprising students and global students are academic achievers, who are also sophisticated in the application of good critical thinking skills and dispositions (Eyre, 2016). They are students who are effective at problem solving; are academically successful, of whom many are ready for higher education and could gain access to excellent universities. They are also students who make leading contributions as citizens; are prepared for the work-place and life, and keen to improve the world. The world faces interconnected, global challenges, such as global warming, health problems, and poverty, which require global solutions. It is therefore essential that education should move beyond producing individuals who can read, write and count. It must be transformative and bring shared values to life, and cultivate an active care for the world and for those with whom we share it (Barell, 2010; Dede, 2010; Eyre, 2016; Gardner, 2010); thus going beyond the ability to pass exams by placing the focus on developing a wider range of critical thinking skills and dispositions, often not tested in examinations.

Preparing pre-service teachers with good critical thinking skills and dispositions could enable them to instil critical thinking skills and dispositions in the students whom they will teach at school. According to Barell (2010), the various critical thinking skills are related to deeper learning, which is rooted in attaining and grasping skills such as analytic

reasoning, complex problem solving, and teamwork. These particular skills alter from old-fashioned academic skills, as they are not mainly content knowledge-based.

Dede (2010) asserts that towards the end of the 20th century and into the 21st century, society experienced an accelerating tempo of change in economy and technology. This change influenced the workplace, and consequently the demands on the educational system in preparing students to develop core skills required for the workplace (Dede, 2010). In this regard, Trilling and Fadel (2009) opine that there is a significant possibility that the contemporary workforce will often change career fields or jobs. People from the Baby Boom generation, who are people born between 1946 and 1964, joined the workforce with a goal of stability. Successive generations are more focused on finding happiness, gratification, and contentment in their work lives (Trilling & Fadel, 2009). On average young workers in North America are prone to change jobs at a much higher rate than previously, as much as once every 4.4 years. This employment mobility comes with a demand for different skills, among others, critical thinking, that would allow people to be flexible and adaptable in various roles or in numerous career fields.

According to Trilling and Fadel (2009), trades and vocations have lesser functions, due to western economies that have transformed from industrial-based to service-based. Yet, certain hard skills and attainment of specific skill sets, with an emphasis on digital literacy (the use of digital and communications technology), are increasingly required. Social skills that require interaction, collaboration, and managing others are gradually becoming vital. There is a larger demand for skills that allow people to be flexible and adaptable in various roles or in diverse fields, those that entail processing information and supervising people more than manipulating equipment. The above mentioned skills include personal, interpersonal, or learning-based skills, such as life skills (problem solving behaviours), people skills, and social skills. The 21st century skills have been grouped into the following main areas, as indicated in Figure 2.4 below (Dede, 2010; Trilling & Fadel, 2009).

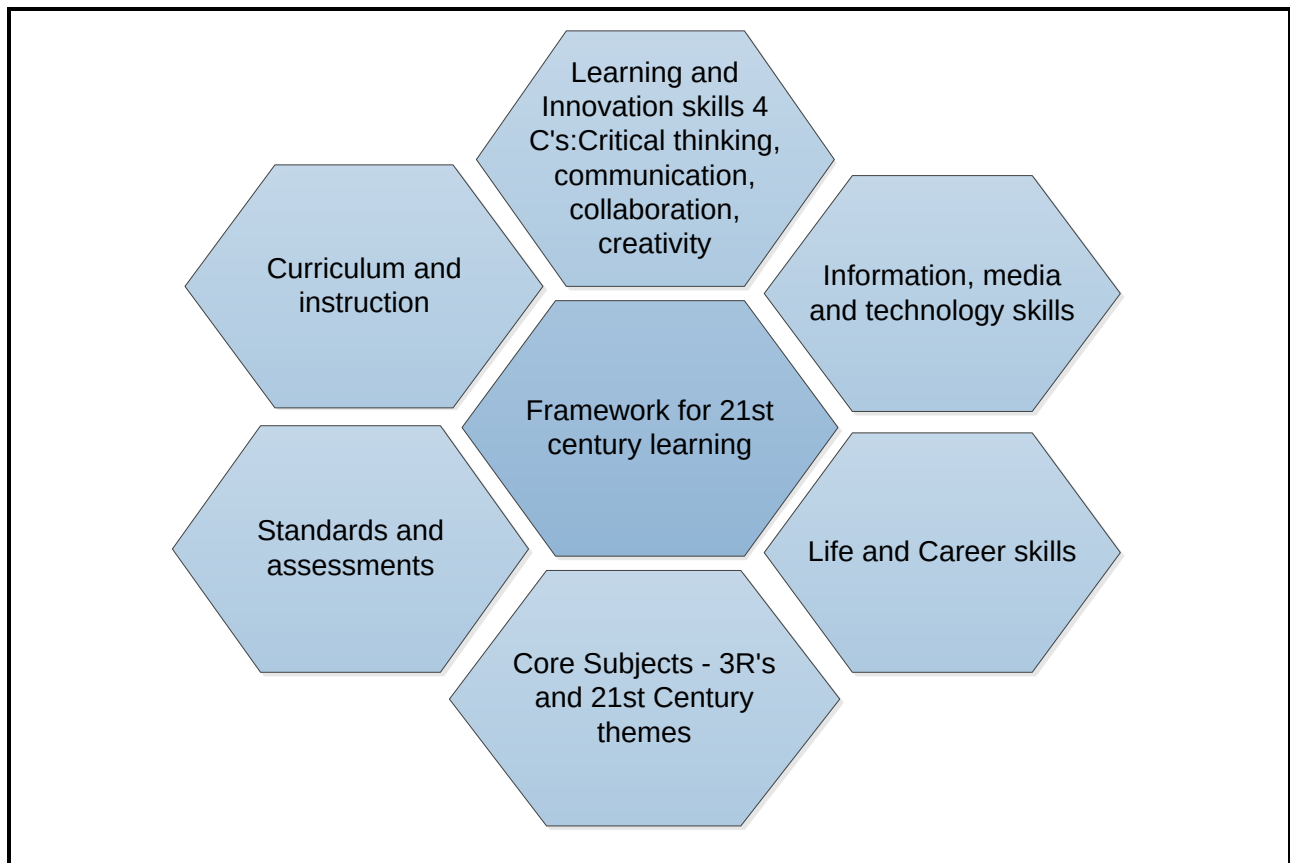


Figure 2.4: A framework for 21st century learning

Figure 2.4 indicates that in addition to core subject content knowledge, a student requires the acquisition of a number of additional skills, such as:

- **Learning and innovation skills:** Critical thinking and problem solving, communications and partnership, creativity and innovation.
- **Information, media and technology skills:** These skills comprise information literacy, media literacy, information and communication technologies literacy.
- **Life and career skills:** Career and life skills refer to flexibility and adaptability, initiative and self-direction, social and cross-cultural interaction, productivity and accountability.

The proceeding section discusses the importance of developing critical thinking as a 21st century life skill.

2.6.3 Critical thinking as a life skill

Critical thinking has an impact on the overall education of an individual as well as an individual's ability to contribute to a society. According to Brettenny (2017) all individuals are on the road of life as a citizen, parent, professional, employee, employer, spouse, customer etc.), and although thinking appears to be something that we do naturally, good thinking is not easy. Paul and Elder (2014) argue that irrespective of one's circumstances or goals, one is better off, when one is skilled at thinking, however, it appears as if short-term, quick fix thinking is the option that many people choose. In support of Paul and Elder (2014), Brookfield (2012) reasons that one's survival is in danger if one cannot think critically. We have to make decisions and choices daily in relation to numerous personal issues, such as health, diet, and exercise. According to Brettenny (2017), good critical thinking enhances the rationality of all our decisions.

In a globalised age where access to data is readily available to anyone, emphasis on critical thinking skills to nurture critical involvement in the modern society is essential (Ten Dam & Volman, 2004). McAllister *et al.* (2009) back this notion and contend that students are in need of critical thinking skills in order to become prosperous citizens in a democratic society. One aspect of being part of a global society is access to information through the internet. Browne and Freeman (2000) notice that the importance given to critical thinking in an age where individuals rely on the internet to gain knowledge is needed. The internet offers various truths and fake knowledge and therefore, and as Yang, Newby, and Bill (2005) and Lorenzo and Dziuban (2006) conclude that critical thinking is the desired skill to apply when individuals work with the internet in order to find relevant and trustworthy information (Lorenzo & Dziuban, 2006).

The following section discusses the purpose of and the numerous options that exist to assess the development of students' critical thinking. It was important for the researcher to take cognisance of the purpose and availability of various assessment strategies, in order to select an appropriate measuring instrument in the context of the study.

2.7 GATHERING INFORMATION ON STUDENTS' CRITICAL THINKING SKILLS

According to Ennis (2001) and Norris and Ennis (1989) it is important to have a defensible and elaborated definition of critical thinking, and identify the purpose of critical thinking assessment, before deciding on the type of measuring instrument and information gathering techniques. This section relies heavily on the work of Norris and Ennis (1989) as, according to the view of the researcher, it provides the most comprehensive and in-depth view on how to assess critical thinking.

2.7.1 The purpose of critical thinking assessment

Some of the major purposes of critical thinking assessment according to Ennis (2001), include the following:

- **Diagnosing the levels of the students' critical thinking.** Tests can be helpful to identify areas of strengths and weaknesses.
- **Giving students feedback about critical thinking, to motivate them to become better at critical thinking.** If students are made aware of their strengths and weaknesses, focused attempts can be made to enhance the weaknesses.
- **Informing teachers about the success of their efforts to teach students to think critically.** Teachers will benefit from feedback about the development of students' critical thinking skills, in order to plan for further intervention.
- **Providing help in deciding whether a student should enter an educational programme.** Establishing the critical thinking power of a student is often regarded as a prerequisite to enrol for specific educational programmes.
- **Providing information for holding schools accountable for the critical development of their students.** Schools need to ensure that students develop critical thinking skills. To assess students regularly indicates how well schools are living up to this ideal.

In addition to the aforementioned, Norris and Ennis (1989, p. 102-104) add the following purposes that need to be considered before assessing for the development of critical thinking.

- **Testing for transfer.** One cannot assume that skills transfer automatically take place from school subjects to other areas in life. An important purpose is therefore to test if transfer of skills has taken place.
- **Testing for critical thinking in specific subjects.** If one needs to assess the application of critical thinking in a particular subject, then content from the specific subject needs to be used during the assessment.
- **Judging students versus judging programmes.** A decision has to be taken if individual students are going to be appraised for their application of critical thinking or whether an average result of students' efforts to apply critical thinking in a specific programme will be established. When calculating averages, a student's individual performance gets lost.
- **Summative versus formative evaluation.** Summative evaluation aims to establish whether a programme that focuses on the development of critical thinking has worked or achieved its goals on completion of the programme. Formative evaluation takes place during the implementation of a programme aimed at improving critical thinking with the purpose of making amendments to the programme as its implementation progresses.
- **Aspect specific versus comprehensive testing.** If one aims to identify strengths and weaknesses in the application of specific elements of critical thinking, one needs to obtain assessments for each of the aspects in separate sections in a test. Comprehensive assessment provides a more holistic view on the application of critical thinking.
- **Norm-referenced testing versus criterion referenced testing.** Norm-referenced testing compares the test scores of students with one another. In criterion-referenced testing students are not compared with one another, but each individual student is compared to a standard of performance that was set in advance.

The following section discusses the various types of measuring instruments that exist in the evaluation of critical thinking.

2.7.2 Measuring instruments

A wide variety of measuring instruments to assess the development of critical thinking, is available. These instruments are presented below.

2.7.2.1 Multiple choice tests

According to Norris and Ennis (1989) and Ennis (2001, 2009) the use of multiple-choice tests is a common practice when gathering information on critical thinking from students. Usually these tests start with lead in phrases that have multiple ways to complete each phrase, or more commonly, a set of questions with a choice of multiple answers. Students normally are graded on the number of correctly answered items (Norris & Ennis, 1989).

An advantage of using these types of tests is that it can quickly be graded and can speedily acquire reproducible results. Some tests can even be graded electronically. These types of tests also provide reasonably consistent results, therefore improving the reliability of the results (Norris & Ennis, 1989).

A few criticisms have been directed at these types of tests, as issues that require critical thinking often do not have a single correct or best answer. In addition, these tests usually do not provide any indication of the thinking processes, which students use to arrive at their answers (Ku, 2009). This being said, multiple choice tests can still be used when one needs to gauge a large sample's critical thinking skills. However, it cannot be the only technique used when gathering information on students' critical thinking (Norris & Ennis, 1989). Multiple-choice assessment also appears incompatible with the conceptualisation of critical thinking and mainly focuses on the cognitive component of critical thinking and ignores the dispositional component (Ku, 2009). According to Ennis (2003) and Halpern (2003b) multiple-choice tests do not reflect the ability to engage in critical thinking and the ability to think critically in unprompted contexts.

2.7.2.2 Direct classroom observation

Norris and Ennis (1989) explain that direct classroom observation attempts to record some aspects of an ongoing classroom situation while disturbing the normal course of events in that classroom to the smallest degree possible. A usual criterion of successful direct observation is ecological validity. An observation is ecologically valid if it represents

what happens in normal situations, in the ecology of ordinary life situations. Ecological validity is achieved through the observer's trying to control to the least extent possible what occurs in the classroom and being satisfied to accept what happened (Norris & Ennis, 1989).

According to Norris and Ennis (1989), an important advantage of using observation is that it gives an indication of normal critical thinking performance. The observations can be more or less open-ended in that the observer simply observes the students' application of critical thinking, without looking for anything in particular. On the other hand, the observation can focus on particular aspects of critical thinking. For example, the observer may watch for the occurrence of different practices such as, how students seek for reasons, withhold judgment, apply criteria to evaluate the credibility of information, and make distinctions between dictionary meanings and stipulated meanings of words (Norris & Ennis, 1989). In order to be confident that the observations of any particular student are indicative of how that student generally behaves, Norris and Ennis (1989) argue that it is necessary to observe that student on several occasions for making important decisions about that person, which can be time consuming.

2.7.2.3 Individual interviews

As stated by Norris and Ennis (1989), interviewing is an additional method for collecting information on students' critical thinking that makes substantial demands on resources but that can provide very beneficial purposes. This method, when utilised correctly, is usually better than any other is for obtaining information on the thinking processes that students follow when working on problems, and responding to probing questions such as "*what are you thinking now?*" or "*can you tell me what you are thinking?*" (Norris & Ennis, 1989, p. 34).

2.7.2.4 Student-teacher journals

According to Norris and Ennis (1989) student-teacher journals can be useful sources of information in evaluating students' critical thinking. Journals need to direct students' thinking for example, teachers need to ask students to reflect or report on particular things, such as the major news items of each day, or the activities they were involved in and how they could have done the activities in a better way (Norris & Ennis, 1989).

Teachers can read the journals and assess the students in relation to criteria such as, their open-mindedness, systematicity in reporting on events, and the clarity of communication.

2.7.2.5 Constructed response tests

Constructed response tests require several short written pieces in response to specific questions, as well as more extended essays in response to more general questions (Norris & Ennis, 1989). Unfortunately, these tests are time consuming to score as opposed to the multiple-choice tests, and require in depth reading and comprehensive knowledge about what critical thinking entails. In addition, constructed response tests are generally less reliable than multiple-choice tests, as it is difficult to specify exactly how these tests should be graded (Norris & Ennis, 1989). Constructed response tests however provide students with more opportunity to approach problem solving in different ways, and to apply a number of critical thinking skills and dispositions (Larsson, 2017).

In addition to reviewing the possibilities available for identifying a measuring instrument for critical thinking, it is also important to understand the way tasks should be carried out to gather information on the application of critical thinking.

The following section addresses the information gathering techniques (and not measuring instruments) for assessing the development of critical thinking.

2.7.3 Information gathering techniques on critical thinking

The proceeding section outlines the various techniques used to gather information on critical thinking.

2.7.3.1 Aspect specific techniques

The aspect-specific information-gathering technique for evaluating students' critical thinking focuses on a single aspect of critical thinking, such as ability to identify assumptions, ability to judge the credibility of sources, inductive reasoning ability, or ability in defining. Such approaches are useful when we need detailed information on specific aspects of critical thinking. For example, even the ability to judge the credibility

of sources is quite complex, since it involves the use of several criteria (Norris & Ennis, 1989).

2.7.3.2 Comprehensive techniques

Comprehensive techniques include the following in relation to the five broad areas of critical thinking, namely clarity-related abilities, inference-related abilities, basic support-related abilities, strategies and tactics, and dispositions. However, critical thinking tests cannot easily be grouped into either the aspect-specific, or comprehensive category. Some tests may cover only two, three or four of the five broad areas (Norris & Ennis, 1989), and do not allow for justifiable conclusions about the development of critical thinking to be drawn (Norris & Ennis, 1989).

2.7.3.3 General knowledge techniques

A general knowledge information-gathering technique for evaluating critical thinking does not focus on special knowledge of any particular discipline or school subject. Students' critical thinking is assessed in general scenarios, for example by asking the students to compare critically the coverage of a news event by various media, to a plan for obtaining a better turnout at a student function, or to appraise critically a letter to the editor of a newspaper (Norris & Ennis, 1989). The use of general knowledge information-gathering techniques is supported by the argument that critical thinking is applicable to people's everyday lives as well (Norris & Ennis, 1989).

2.7.3.4 Subject specific techniques

Subject specific information-gathering techniques test for critical thinking in specific school subjects. Thus, there can be critical thinking tests in science, history, and art et cetera. Each would reflect the aspects of critical thinking, which have been emphasised in that subject and would use special knowledge from that subject (Norris & Ennis, 1989).

Norris and Ennis (1989) suggest that, until more is known about how people learn and transfer critical thinking, a variety of contexts should be used to assess the application of critical thinking.

2.7.3.5 Techniques with a variety of tasks

Multiple-choice tests, constructed-response tests, individual interviews and other information-gathering techniques all present students with different tasks. The use of different sorts of tasks is usually desirable to avoid errors in establishing how well critical thinking skills are developed (Bensley *et al.*, 2016; Norris & Ennis, 1989; Ku, 2009; Paul, 2011).

The following section outlines the various commercially available tests that can determine the extent to which critical thinking skills are developed.

2.7.4 Commercially available tests to determine critical thinking

Facione (1990) stresses the significance of developing (and implementing) a valid and reliable critical thinking assessment instrument which can be utilised to make reliable inferences concerning students' critical thinking skills.

Dunn, Halonen, and Smith (2008, p. 72–75) provide an overview of the most established measuring instruments that are utilised in the assessment of Critical Thinking. These comprise the:

- Academic Profile test.
- Assessment of Reasoning and Communication Test.
- California Critical Thinking Skills Test (CCTST) – college level.
- California Critical Thinking Disposition Inventory Test (CCTDI).
- Cornell Critical Thinking Test – Level X.
- Cornell Critical Thinking Test – Level Z.
- Cambridge Thinking Skills Assessment Test.
- Ennis–Weir Critical Thinking Essay Test.
- International Centre for the Assessment of Thinking (ICAT) Critical Thinking Essay Test.
- Test of Everyday Reasoning (TER).
- Watson–Glaser Critical Thinking Appraisal (W–GCTA).

All of the above-mentioned measuring instruments are briefly elaborated upon in the following sections.

2.7.4.1 Academic Profile test

Marr (2008) defines the Academic Profile test as a test created by the Education Testing Service of America to measure skills of undergraduate general education programmes. The test evaluates academic skills such as reading, writing and critical thinking skills.

2.7.4.2 Assessment of Reasoning and Communication Test

The Assessment of Reasoning and Communication Test is designed to test social reasoning, scientific reasoning and artistic reasoning (Dunn *et al.*, 2008). According to Goodwin and Sommervold (2012), it is an established critical thinking assessment instrument. This test necessitates that students write three short essays and three short speeches. The main purpose of the test is to score participants' reasoning skills through their writing, which is scored using a rubric (Ennis, 2009).

2.7.4.3 The California Critical Thinking Skills Test (CCTST) – college level

The CCTST was created by Facione (1990) to assess critical thinking skills that are essential to flourish in educational or workplace environments (Insight Assessment, 2013). The test comprises of 35 piloted multiple-choice items concentrating on cognitive skills, namely interpretation, analysis, evaluation and inference (Facione, 1990).

2.7.4.4 The California Critical Thinking Disposition Inventory Test (CCTDIT)

The CCTDIT was designed together with the CCTST to test seven critical thinking dispositions, namely analyticity, open-mindedness, truth seeking, systematicity, self-confidence, inquisitiveness and maturity (Ghadi, Alwi, Bakar, & Talib, 2012). The researcher scrutinised the CCTDIT for its applicability in the context of the research. The CCTDIT relies on students' perceptions about the development of their dispositions in relation to critical thinking. As the test does not assess the application of dispositions, it was not considered for data collection in the context of the research that focused on among others, the application of dispositions.

2.7.4.5 Cornell Critical Thinking Test – Level X

The Cornell Critical Thinking Test – Level X, is the most extensively and commonly utilised critical thinking test and is appropriate for Grades 5 to 12 (Critical Thinking Company, 2013; French, Hand, Therrien, & Vazquez, 2012). The test however, only assesses the application of four critical thinking skills, namely induction, deduction, credibility and identification of assumptions, in general scenarios.

2.7.4.6 Cornell Critical Thinking Test – Level Z

The Cornell Critical Thinking Test – Level Z is well known for extensive use in Grade 11 and above, and in addition to the critical thinking skills assessed in the Level X version, assesses semantics, definition and prediction in planning experiments (Critical Thinking Company, 2013).

2.7.4.7 Cambridge Thinking Skills Assessment Test

The test was designed by the University of Cambridge Local Examination Syndicate in order to measure thinking skills. The test contains 50 questions of which 25 are problem solving questions and 25 are critical thinking questions (Admission Testing Service, 2013). The Cambridge Thinking Skills Assessment Test is a university entry level test utilised as part of the University of Cambridge's admission procedure (Admission Testing Service, 2013) and consequently not utilised as regularly as other critical thinking tests.

2.7.4.8 Ennis–Weir Critical Thinking Essay Test

The Ennis–Weir Critical Thinking Essay Test is an essay-based test that involves university students writing a letter to an editor of a fictional newspaper making a proposal and offering arguments in support of a proposal (Ennis & Weir, 1985). Ennis and Weir (1985) state that the test focuses on a number of several critical thinking abilities like reasoning, arguing and determining relevance. While the test has been utilised at high school and university level, Ennis and Weir (1985) established it as more appropriate for younger students. The test is open-ended and relies on flexible scoring and judgment.

2.7.4.9 International Centre for the Assessment of Thinking Critical Thinking Essay Test (ICAT CT)

The ICAT CT essay test was originally created by Paul and Elder (1997) to measure the basic fundamentals of critical thinking. The test is separated into two parts, namely analysis of a written report and assessment of a written report. In the analysis segment of the test, the student must identify the elements of reasoning within a written piece, and in the assessment segment of the test, the student must construct a critical analysis and evaluation of the reasoning applied in the report.

2.7.4.10 The Test of Everyday Reasoning (TER)

The TER is intended to examine the reasoning skills needed for reflective decision making of college students, high school students as well as adults (Insight Assessment, 2013). It is separated into 35 multiple-choice questions which comprise sections on analysis, interpretation, evaluation, explanation, induction, deduction, as well as numeracy skills (Insight Assessment, 2013). Although the focus of the TER could have been regarded as suitable for data collection in the context of the study, the researcher had no information available about its reliability in the South African context, and therefore decided not to employ the test.

2.7.4.11 Watson–Glaser Critical Thinking Appraisal (W-GCTA) UK edition

The W-GCTA assesses critical thinking ability comprehensively via an 80-item multiple-choice questionnaire. The W-GCTA is frequently utilised by managers to assess future employees; conversely, only trained test administrators may oversee the completion of the W-GCTA (Watson & Glaser, 2002b).

Grosser and Lombard (2008) utilised the W-GCTA within the South African context, and established its reliability for a group of pre-service teachers at the same university where the present research was conducted (*cf.* 6.2). The researcher is aware that a streamlined version of the W-GCTA, namely the Watson-Glaser III, comprising 40 items is available. As the researcher is not aware that the reliability of this version has been established for pre-service South African teachers, the W-GCTA (UK Edition), was chosen.

The aforementioned discussion guided the researcher in the approach he adopted for data collection in the study. In this study, the purpose of assessment was mainly to establish the level of individual participants' critical thinking, and to identify areas of strengths and weaknesses before and after the completion of an intervention programme (*cf.* 2.7.1). In the context of the study, a multiple-choice measuring instrument (*cf.* 2.7.2.1), as well as observations (*cf.* 2.7.2.2) and probing questions during the observations (*cf.* 2.7.2.3) were utilised to gather comprehensive information (*cf.* 2.7.3.2) about the critical thinking skills, dispositions and standards for reasoning of the research participants. Multiple-choice items would enhance the reliability of the researcher's assessment, and the observations and probing questions would provide more detail about the nature of the application of the critical thinking skills. It would have been difficult for the researcher to deduct information in relation to practical application of the critical thinking skills from the completion of multiple-choice test items only. Comprehensive information was gathered about the application of five critical thinking skills during the completion of the multiple-choice test items, namely making inferences, recognising assumptions, making deductions, doing interpretations and evaluating arguments. In addition, the observations and probing questions focused on the practical application of the aforementioned skills, as well as the application of dispositions (systematic working ways, persistence, accuracy) and standards for reasoning (logic, clarity, relevance).

Because the W-GCTA comprehensively assesses the application of critical thinking skills, it was selected to gather data in the context of the study. As the conceptualisation of critical thinking in the W-GCTA mainly focuses on the skills component of critical thinking, and the researcher could not locate a data collection instrument that assessed the application of critical thinking dispositions and standards for reasoning, the researcher made use of observations that included the asking of probing questions on several occasions to provide evidence of the students' application of critical thinking dispositions and standards for reasoning in conjunction to the W-GCTA test scores for the application of the critical thinking skills (Norris & Ennis, 1989). It was therefore not possible to obtain a pre-test assessment of the students' application of dispositions and standards of reasoning. An extended rationale for the use of the W-GCTA and observations to gather information about the students' application of critical thinking is provided in Chapter 5 (*cf.* 5.7.1.1).

Although Paul and Elder (2005a, b) and Willingham, Hughes, and Dobolyi (2015) accentuate the significance of teaching critical thinking in conjunction with specific subject content, some researchers (Facione, 1990; Halpern, 1998; Halpern, 2003b; Marin & Halpern, 2011) highlight the benefits of explicit critical thinking instruction in general contexts as well (*cf.* 2.7.3.3, 2.8.1.2). In the context of the study, the researcher supported the latter approach, in order to establish whether the critical thinking skills that students might acquire through the PVG-CEP, could be successfully transferred to a dissimilar situation, namely solving the general problem scenarios in the W-GCTA.

This W-GCTA was ultimately utilised within the context of the study as it was found to present the most comprehensive measure of the skills component of critical thinking, and its reliability was previously established within the South African context (*cf.* 6.2).

The subsequent section deals with factors that could possibly influence the development of critical thinking skills.

2.8 FACTORS INFLUENCING THE DEVELOPMENT OF CRITICAL THINKING SKILLS

It was necessary to reflect about factors that could obstruct the development of critical thinking, as they could impact on the findings of the study, positively or negatively. Some of the factors, that the researcher clusters as education factors, student factors and personal factors, are elucidated below.

2.8.1 Education factors

Education factors that could influence the development of critical thinking comprise among other things, the type of classroom atmosphere fostered by the teacher, the use of imbedded versus explicit instruction, and finally the role of the facilitator/teacher in developing critical thinking.

2.8.1.1 Classroom atmosphere

According to Cheung and Wan (2017) classroom environment has a strong influence on the development of critical thinking. Watson (2015) argues that in order to make sense of the information explosion in the 21st century, critical thinking is required to question

information, check for clarity, accuracy, precision, relevance, depth, breadth, significance, logic, and fairness, as well as to build knowledge from a range of sources; including ones' own experience. It is however strange that across the world an approach to knowledge that relies on rote learning, and regards questioning as offensive, still seems to prevail.

According to Watson (2015), education systems are faced with a dual challenge. Classroom atmospheres often testify to silence and students lack the confidence to question information. In addition, many teachers lack the skill to think critically. In this regard, Greene and Yu (2015), Mahapoonyanont (2010, 2012) and Stoddar (2010) argue that the critical thinking abilities of teachers first have to improve to enable them to promote critical thinking among students.

According to the researcher, the aforementioned problem is exacerbated, as the CAPS curriculum fails to provide direct guidance in terms of regulatory operations for developing critical thinking in the delivery of the curriculum, as well as how manifestations of critical thinking would look like.

2.8.1.2 Imbedded or explicit instruction

Marin and Halpern (2011) state that the imbedded method to develop critical thinking transpires when the development of critical thinking is intertwined into subject content. Explicit instruction ensues when the development of critical thinking takes place during separate lessons, which concentrate explicitly on the development critical thinking out of subject content (Marin & Halpern, 2011). Willingham (2008), Willingham *et al.* (2015), and Paul and Elder (2005a, b) debate that explicit critical thinking development programmes are unsuccessful and that critical thinking improvement should transpire within the framework of a specific subject. Researchers such as Facione (1990), Halpern (1998), Halpern (2003b), and Marin and Halpern, (2011), however argue that critical thinking instruction cannot be restricted to subject content, and needs to contain general and authentic topics of global value such as normative, moral, ethical or political content.

In class periods of 45–50 minutes, teachers do not have adequate time to pay attention to the development of critical thinking (McAllister *et al.*, 2009), and therefore frequently neglect its explicit development. Marin and Halpern (2011) illustrated this idea with their study, where they directed their focus on establishing whether critical thinking were better

taught explicitly or imbedded in a subject. Twenty-eight participants completed an explicit critical thinking web-based workshop and 18 participants completed an introductory psychology module, which imbedded critical thinking for six sessions over three weeks. Marin and Halpern (2011) discovered that the critical thinking of both groups improved; however, the explicit instruction group scored much higher than the group that received imbedded instruction. This observation suggests interventions targeting specific critical thinking skills is a worthwhile option for developing critical thinking (Niu, Behar-Horenstein, & Garvan, 2013). The present research also focused on the development of critical thinking via a puzzle video game detached from subject content.

The two aspects debated above, generate evidence that the improvement of critical thinking using explicit instruction could be advantageous. However, in circumstances where explicit instruction is unmanageable, imbedded instruction ought to result in as much benefit if critical thinking development is intentionally included in the subject matter.

Though critical thinking either can be promoted through explicit instruction or imbedded instruction, the role of the facilitator/teacher in relation to the development of critical thinking ought to be clearly demarcated, as the facilitator/teacher also plays an important role in the success of critical thinking development.

2.8.1.3 The role of the facilitator/teacher

Brookhart (2010), Duron, Limbach, & Waugh (2006), Paul (1985) and Paul and Elder (2006) view critical thinking as the ability to answer questions of analysis, synthesis and evaluation, solving problems and being creative. It is therefore reasonable to argue that a teacher has to guard against using a passive, teacher-centred, behaviourist approach to teaching. Schunk (2000) supports this argument by stating that it is generally agreed that a behaviourist approach (*cf.* 3.2.3.1) does not purposively focus on the acquisition of higher-level skills for solving problems, generating inferences or other critical thinking skills. According to Kramer (2006) and Kwan and Wong (2015), a direct teaching-centred approach (*cf.* 3.3.1) does not develop higher order thinking skills such as analysis, synthesis, evaluation, problem solving or understanding, but is more suitable for achieving cognitive objectives related to recall and knowledge.

In contrast to a behaviourist approach to teaching, a cognitive (*cf.* 3.2.3.2) and constructivist (*cf.* 3.2.3.3) approach provides a clear shift from a stimulus and response theory to an approach that regards people as information processors (Ertmer & Newby, 2013; Kwan & Wong, 2015; McNeeley, 2007; Pintrich & Schunk, 2002; Schunk, 2000), who can gain and process knowledge by applying higher level critical thinking skills (*cf.* 2.3.2).

Powell and Kalina (2009), also reject the idea that learning is a passive process where a student assimilates transmitted knowledge. Learning is rather a dynamic process where students actively discover new information and solve problems independently by applying higher order thinking skills. Learning involves more than memorising, and students need to understand what they learn and be able to apply knowledge, solve problems and discover information, for which higher order cognitive and meta-cognitive skills are required. Moreover, learning has to be transformative (*cf.* 3.2.3.4) in nature; requiring teachers to create environments that encourage and reward intellectual contributions and open-mindedness, where students are allowed to share their opinions with one another (Cranton & King, 2003; McGonigal, 2005). In support of McGonigal (2005), Brown and Brown (2015) argue for cooperative teaching and learning environments (*cf.* 3.3.4) that promote intellectual openness through the interaction that takes place between teachers and students, thus providing opportunities for students to engage in critical discussions with other students and to compare, evaluate and adjust their perspectives about issues.

In order to promote the development of higher order critical thinking skills, Rützmann and Kipper (2011) and Schmidt, Rotgans, and Yew (2011) suggest the use of indirect and independent teaching strategies that emphasise the facilitation of enquiry-based and problem-based learning (*cf.* 3.3.2, 3.3.3). The above suggestions imply that teachers facilitate learning by supporting, guiding, and observing the learning development of students, enhancing students' self-confidence to tackle problems, while also extending their understanding.

Spence (2001) contends that problem-based learning offers students chances to scrutinise and try out what they previously know; to ascertain what they need to learn; to cultivate skills for improved performance in groups; to increase their communication skills (verbally and written); to declare and defend sound arguments and to become open-

mindful about their own beliefs and attitudes. Hmelo-Silver, Duncan, and Chin (2007) and Spence (2001) also found that problem-based learning environments increase students' critical thinking skills and knowledge acquisition. According to Hmelo-Silver *et al.* (2007) problem-based learning holds the potential to nurture critical thinking because:

- During problem-based activities, students learn to apply critical thinking skills and strategies such as interpretation, analysis, evaluation, making inferences, explanation and self-regulation.
- Students have to distinguish between different solutions to a problem and motivate the selection.
- When selecting solutions to problems, students learn to demonstrate the application of a number of dispositions, such as curiosity, truth-seeking, open-mindedness and systematicity. Moreover, students have to comply with the universal intellectual standards for reasoning, such as clarity, accuracy, precision, relevancy, significance, breadth and depth to ensure successful problem solving.

In the context of the study the researcher acknowledges that the PVG-CEP encouraged an open and non-authoritarian atmosphere with the intention that participants should feel comfortable with asking questions. There was no link with specific subjects or content, and the game itself did not explicitly teach critical thinking. In support of tangential learning theory, it was envisaged that the participants would develop the critical thinking skills during their involvement in the puzzle video game intervention (*cf.* 3.2.3.8).

The intervention utilised an independent teaching strategy, namely the GROW problem solving model (*cf.* 4.3.3), that emphasised enquiry-based and problem-based learning. The researcher facilitated learning by supporting, guiding, and monitoring the learning process of each participant.

The following section highlights the student specific factors that could influence the development of critical thinking.

2.8.2 Student factors

A variety of student factors could influence the development of critical thinking. These, according to the researcher could relate to the students themselves that among others,

involve their reading ability, their internal motivation for success as well as their intention, or willingness, to study.

2.8.2.1 Reading ability

Reading ability is the ability to process text, comprehend its meaning, and to assimilate the contents with the reader's prior knowledge (Grabe, 2009). Essential skills needed in effective reading ability are for example, knowing the meaning of words, comprehending meaning of words from discourse context, following the organisation of a passage and to detect antecedents and references within it, drawing inferences from a passage about its contents, recognising the main thought of a passage, answering questions in a passage, distinguishing the literary devices or propositional structures utilised in a passage and determining its tone, understanding the situational mood (agents, objects, temporal and spatial reference points, casual and intentional inflections, etc.) conveyed for assertions, and lastly, determining the author's purpose, intention and point of view, and drawing inferences about the author (discourse-semantics) (Liu, 2010).

A person's ability to understand text is directly influenced by their skills and their ability to process information critically (Pressley & Allington, 2014). If word recognition is problematic, students use too much of their processing capability to read separate words, which inhibits their ability to understand what is read.

2.8.2.2 Motivation for success

According to Fahim and Hajimaghsoodi (2014) and Halonen (1995) the demonstration of critical thinking is related to motivation. The disposition to think critically has been defined as the "*consistent internal motivation to engage problems and make decisions by using critical thinking*" (Facione, 2000, p. 65).

Motivation seems to be a secondary condition for critical thinking, suggesting that unenthusiastic persons are unlikely to display critical thinking. Conversely, some motivation research has advocated that the underlying link goes the other way, proposing that difficult or challenging tasks, chiefly those emphasising higher-order thinking skills, may be more motivating to students than easy tasks that can be solved through the rote application of a pre-determined algorithm (Fahim & Hajimaghsoodi, 2014; Turner, 1995).

2.8.2.3 Intention to study

Feuerstein and Feuerstein (1991) propose, among others, three criteria that are essential to facilitate the development of thinking processes, namely intentionality and reciprocity, meaning, and transcendence (Shamir, Tzuriel, & Rosen, 2006) (*cf.* 3.2.3.7). These three criteria, which are responsible for a person's cognitive modifiability, are also thought to be universal and can be identified in all races, cultures, ethnic groups, and socioeconomic levels (Isman & Tzuriel, 2008; Tzuriel, 2013).

Intentionality and reciprocity refer to a teacher's or mediator's deliberate determination to alter a student's functioning, thinking, attention, awareness, perception, processing, or reaction (Isman & Tzuriel, 2008). Reciprocity occurs when the student replies vocally, verbally, or nonverbally to a mediator's behaviour and intentions (Tzuriel, 2013). The three criteria are considered as crucial for mediating the development of thinking processes, and later on for the development of feelings of competence and self-determination (Tzuriel, 2013).

2.8.3 Personal factors

Several personal factors could influence the development of critical thinking, namely societal and cultural challenges, as well as language ability.

2.8.3.1 Societal and cultural challenges

Teachers agree that critical thinking is an important skill for the 21st century, and it remains questionable whether critical thinking is harder to teach in some cultures and contexts than in others (Manalo, Kusumi, Koyasu, Michita, & Tanaka, 2013; Watson, 2015).

Members of a culture share certain beliefs, habits and customs, and exclude elements that are inconsistent with those beliefs, habits and customs (DiMaggio, 1997). According to DiMaggio (1997), many cultures demand respect and obedience from children, such as the African culture (Rothstein, 2000), which could promote an uncritical approach to information that relies heavily on culturally available knowledge and ways of processing information (Higgins, 2008; Higgins, Kruglanski, & Pierro, 2003; Higgins, Pierro, & Kruglanski, 2008). Therefore, when children start asking questions they might be regarded as disobedient and disrespectful (Watson, 2015). In the African culture, the

philosophy of “*Ubuntu*” is emphasised (Thorpe, 1996, p. 32). Ubuntu philosophy postulates that all people should be treated with respect, and that the good of the community surpasses the good of the individual (Grosser & Lombard, 2008). Individuals form part of a coherent group of people where prescriptive role relations and collective thought guide conduct (Nisbett, Peng, Choi, & Norenzayan, 2001). In addition, there are cultures that rely on a variety of strategies and less on cultural elements to approach knowledge. Individuals in these cultures may, when unsatisfied with an issue, think critically and reflexively (DiMaggio, 1997). Nisbett *et al.* (2001) argue that individuals who grow up in an environment or society that emphasises personal freedom, choice, criticism, debate, curiosity and diversity, for example, the Western culture, would more regularly apply analytical and critical thought.

Cultures differ in their approaches to the development of thinking due to different ways in which societies developed historically that lead to different activities and tools to process information (Nisbett & Norenzayan, 2002). It is important to acknowledge that thinking processes may be equally available in different cultures, but accessed in different ways in different cultures (Nisbett & Norenzayan, 2002). People may therefore rely on different strategies to solve similar everyday problems. In the context of the research, the participants were representative of the Western and African cultures, which could imply that they approach problem solving in different ways.

The mind-set that all students are expected to develop during their school careers contrast sharply with the beliefs and values of an individual growing up in a context where collective thought is valued. Schools aim to develop 21st century skills required by the global economy (Grosser & Lombard, 2008). In this regard, the idea of “*frame switching*” and a “*dynamic cultural approach*” (DiMaggio, 1997, p. 280; Hong, Morris, Chiu, & Benet-Martínez, 2000, p. 710), becomes of importance. Frame switching involves that a student internalises two cultures, for example the African (home culture) and Western cultures (school culture), without replacing the original, home culture. Hong *et al.* (2000) indicate that an individual can acquire and possess more than one cultural meaning system, even if they contain conflicting beliefs. Both can however not simultaneously guide the application of thinking processes. Therefore, the thinking processes of the school culture will be applied in the execution of certain specific tasks. Given the aforementioned

arguments, it seems possible to promote the development of critical thinking among students, even if critical thinking is not operative in their internalised, home culture (Grosser & Lombard, 2008).

Manalo *et al.* (2013) conducted a study to determine whether culture-related factors have an impact on critical thinking development of undergraduate students from Japan and New Zealand. They established that there were no differences between Western and Asian cultures in terms of the use of critical thinking. In addition, research conducted by Myers and Dyer (2006), and the research conducted by Lombard and Grosser (2004), revealed that critical thinking skills are not predisposed by intellect or learning style (Myers & Dyer, 2006), culture or gender (Lombard & Grosser, 2004; Myers & Dyer, 2006).

2.8.3.2 Language and critical thinking

Research revealed that language ability could influence the production of evaluative thinking (Feuerstein, 2007; Floyd, 2011; Lun, Fischer, & Ward, 2010; Manalo & Sheppard, 2016; Paton, 2005). According to Manalo and Sheppard (2016), the language that one is not so proficient in requires greater cognitive processing resources.

According to Pienaar (2001), critical thinking at Higher Education level requires from students, among others, elaboration on arguments, developing the implications of arguments; and understanding, analysing and evaluating arguments and opinions. It will be more difficult for students to achieve the aforementioned when they receive teaching in their second or additional language (Donald, Lazarus, & Lolwana, 2006; Nel, 2011; Nel & Nel, 2012). Donald *et al.* (2006) argue, that using an additional language for learning, could obstruct active communication about information, and the inability to apply higher order thinking, which results in rote learning, as it is linguistically easier to handle (Donald *et al.*, 2006). This inability indicates a lack of academic language proficiency (Krashen & Brown, 2007), which also refers to receptive competence. Students need to be able to access academic knowledge found in textbooks or instructions, and convey knowledge through writing (Ramani & Joseph, 2008). As the W-GCTA focuses on receptive competence, it was important that the research participants had to understand and interpret texts during the pre- and post-tests, which might have been problematic as all the participants complete their studies in English as an additional language.

Without underscoring the role of each of the factors discussed above, the role of the teacher cannot be underestimated. The researcher argues that students spend a large part of a day at school, which places teachers in a favourable position to drive the development of critical thinking.

The proceeding section summarises the information presented in the chapter.

2.9 CHAPTER SUMMARY

The chapter began by looking at the origin of the term critical thinking and its development (*cf.* 2.2), starting with the three philosophers Socrates, Plato and Aristotle who used questioning to encourage in-depth thinking, moving through to researchers such as John Dewey (*cf.* 2.2.2.1), who viewed critical thinking as reflective in nature, Glaser and Russell, who viewed critical thinking as essential in problem solving (*cf.* 2.2.2.2), the work of Ennis, McPeck, Beyer, Norris and Paul, who viewed critical thinking as the correct assessment of information conveyed in statements (*cf.* 2.2.2.3), and the work of Facione, Paul and Elder, Halpern and Sternberg, according to which critical thinking comprises the application of cognitive and meta-cognitive components as well as dispositions (*cf.* 2.2.2.4).

The concept clarification for the term critical thinking (*cf.* 2.3), revealed that critical thinking comprises the application of interrelated core cognitive and meta-cognitive skills (*cf.* 2.3.2), critical thinking dispositions (*cf.* 2.3.3), and universal standards for reasoning (*cf.* 2.3.6) in order to develop intellectual traits (*cf.* 2.3.4), such as intellectual humility, courage, empathy, autonomy, integrity, perseverance, confidence in reasoning and fairmindedness. Critical thinking always relates to the different elements of reasoning (*cf.* 2.3.5) that include identifying the purpose of thinking, questioning information, recognising assumptions, reflecting on points of view, using data and evidence to interpret information, expressing ideas and points of view, making inferences as well as identifying implications embedded in thinking and reasoning.

The researcher's conceptualisation of critical thinking merged the viewpoints of Facione (2000, 2009), Paul and Elder (2007), as well as Watson and Glaser (2002a) (*cf.* 2.3, 2.3.7, 5.7), thus perceiving critical thinking as the interrelated application of cognitive and meta-cognitive thinking skills, dispositions and standards for reasoning.

Critical thinking in action (*cf.* 2.4), involves the utilisation of various thinking modes, namely the logical thinking mode (*cf.* 2.4.1), the critical questioning mode (*cf.* 2.4.2), the creative thinking mode (*cf.* 2.4.3), and the big picture thinking mode (*cf.* 2.4.4), which all play an important role in constructing understanding of information.

Becoming an ideal critical thinker, involves six different stages or levels of development (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5). The levels of development include the following: The unreflective thinker (*cf.* 2.5.1), the challenged thinker (*cf.* 2.5.2), the beginner thinker (*cf.* 2.5.3), the practicing thinker (*cf.* 2.5.4), the advanced thinker (*cf.* 2.5.5) and lastly the master thinker (*cf.* 2.5.6)

The importance of critical thinking for teacher education (*cf.* 2.6), was related to the CAPS (*cf.* 2.6.1). Well-developed critical thinking skills are foundational to achieving the objectives of the South African curriculum. In addition, critical thinking skills are required in the rapidly changing digital society of the 21st century (*cf.* 2.6.2), and could be regarded as a life skill (*cf.* 2.6.3) that has an impact on the overall education of an individual as well as in relation to effectively contributing to a society.

Assessing the development of critical thinking highlighted a number of areas to consider (*cf.* 2.7), such as the purpose of critical thinking assessment (*cf.* 2.7.1), the various available measurement instruments that could be used to assess critical thinking. In the context of the study, the purpose of assessing the development of critical thinking was to establish the level of development for each individual research participant and to identify areas of strengths and weaknesses before and after the completion of an intervention programme (*cf.* 2.7.1). Considering the various instruments, the researcher opted for the use of a multiple choice test and observations during which probing questions were used. Various information-gathering techniques on critical thinking are available (*cf.* 2.7.3), which included aspect specific techniques (*cf.* 2.7.3.1), comprehensive techniques (*cf.* 2.7.3.2), general knowledge techniques (*cf.* 2.7.3.3), subject specific techniques (*cf.* 2.7.3.4) and techniques with a variety of tasks (*cf.* 2.7.3.5). Based on the information, the researcher decided to gather comprehensive information about critical thinking, implying the application of skills, dispositions and universal standards for reasoning in a general context.

Commercially available tests to determine critical thinking were identified, which included the Academic Profile Test (*cf.* 2.7.4.1), Assessment of Reasoning and Communication Test (*cf.* 2.7.4.2), California Critical Thinking Skills Test (*cf.* 2.7.4.3), California Critical Thinking Disposition Inventory Test (*cf.* 2.7.4.4), Cornell Critical Thinking Test Level X (*cf.* 2.7.4.5), Cornell Critical Thinking Test Level Z (*cf.* 2.7.4.6), Cambridge Thinking Skills Assessment Test (*cf.* 2.7.4.7), Ennis-Weir Critical Thinking Essay Test (*cf.* 2.7.4.8), International Centre for the Assessment of Thinking Critical Thinking Essay Test (*cf.* 2.7.4.9), Test of Everyday Reasoning (*cf.* 2.7.4.10) and lastly the Watson-Glaser Critical Thinking Appraisal (*cf.* 2.7.4.11). The researcher determined that the W-GCTA would be the most suitable test for assessing critical thinking comprehensively. Moreover, it appeared to be the most valid tool in the South African context, having been utilised in local studies that confirmed reliability. In addition, the W-GCTA does not expect pre-knowledge about specific subject content that might have placed students at a disadvantage when completing the test.

The final section in the chapter explored some of the factors that could influence the development of critical thinking (*cf.* 2.8), which included a discussion on educational factors (*cf.* 2.8.1), in relation to classroom atmosphere (*cf.* 2.8.1.1), imbedded or explicit instruction (*cf.* 2.8.1.2) as well as the role of the facilitator/teacher (*cf.* 2.8.1.3). Other factors that could influence the development of critical thinking included student factors (*cf.* 2.8.2), such as the reading ability of students (*cf.* 2.8.2.1), which refers to their ability to process text and comprehend its meaning. Motivation to engage in critical thinking is also regarded as another student factor, which is a necessary precondition for the development of critical thinking (*cf.* 2.8.2.2). The intention to study (*cf.* 2.8.2.3), which emphasises a student's willingness, or reciprocity towards the mediator/teacher's intentions to develop critical thinking, was also foregrounded as an important factor that could influence the development of critical thinking. Lastly, several personal factors were scrutinised (*cf.* 2.8.3), which included societal and cultural challenges that could impact on the development of critical thinking (*cf.* 2.8.3.1). It was found that thinking processes may be equally available in different cultures, but accessed in different ways. Finally, the relationship between language and critical thinking (*cf.* 2.8.3.2) revealed that language ability could influence the production of critical, evaluative thinking.

As the present research has the development of critical thinking in mind, Chapter 3 focuses on options to develop critical thinking in formal, informal and non-formal teaching and learning contexts, with particular emphasis on the use of puzzle video games as part of informal and non-formal learning.

CHAPTER 3

TEACHING FOR CRITICAL THINKING: THE PLACE OF FORMAL, INFORMAL AND NON-FORMAL TEACHING AND LEARNING

3.1 INTRODUCTION

This chapter aims to provide a comprehensive overview of how critical thinking might be taught within formal, informal and non-formal learning contexts, and extends the information in 2.8.1.3 regarding the facilitation of learning. Various international studies record the effects of specific formal teaching methods on the development of critical thinking skills of pre-service teachers, but there is limited evidence that reports on the merits of informal, and non-formal learning for the development of critical thinking (*cf.* 1.1). This research focused on developing critical thinking in a formal classroom context by using an informal and non-formal approach, namely the use of a puzzle video game that does not relate to a formal curriculum (informal), and could be regarded as an extra-curricular activity (non-formal). It was therefore essential to explore the theoretical underpinnings of teaching and learning in all the mentioned contexts to ensure that the intervention used in the study, was framed within a suitable teaching and learning framework.

The chapter unfolds according to the following structure:

3.2 Teaching for critical thinking in formal, informal and non-formal learning contexts

- 3.2.1 Teaching in formal learning contexts
- 3.2.2 Teaching in informal and non-formal learning contexts
- 3.2.3 Teaching and learning theories and their relation to the development of critical thinking
 - 3.2.3.1 Behaviourism
 - 3.2.3.2 Cognitivism
 - 3.2.3.3 Constructivism
 - 3.2.3.4 Transformative learning theory
 - 3.2.3.5 Experiential learning theory
 - 3.2.3.6 Structural cognitive modifiability theory
 - 3.2.3.7 Mediated learning theory

- 3.2.3.8 Tangential learning theory
- 3.2.3.9 Transfer of learning theory

3.3 Teaching methods and strategies to develop critical thinking

- 3.3.1 Direct teaching methods and related strategies
- 3.3.2 Indirect teaching methods and related strategies
- 3.3.3 Independent teaching methods and related strategies
- 3.3.4 Interactive/participative teaching methods and related strategies
- 3.3.5 Strategies to develop critical thinking dispositions and standards for reasoning

3.4 Creating classroom environments conducive to the development of critical thinking

- 3.4.1 Frequent evaluative questions
- 3.4.2 Encouragement of active learning
- 3.4.3 Developmental tension

3.5 The role of game-based learning to develop critical thinking

- 3.5.1 Introduction
- 3.5.2 Serious games and game-based learning
- 3.5.3 Video games: A conceptualisation
- 3.5.4 Puzzle video games and its subgenres
- 3.5.5 Developing critical thinking skills with Portal

3.6 Chapter summary

The following section outlines the variety of teaching and learning theories that exist for teaching critical thinking in formal, classroom contexts.

3.2 TEACHING FOR CRITICAL THINKING IN FORMAL, INFORMAL AND NON-FORMAL LEARNING CONTEXTS

3.2.1 Teaching in formal contexts

Learning in a formal context is organised, chronologically graded learning that is guided by a formal curriculum, and takes place in an educational institution. Teachers implement the curriculum in a linear way (Rogers, 2014). According to the researcher, if teachers want to develop critical thinking skills in a formal classroom context, they have to devote

less time to teaching facts and content and emphasise the development and reinforcement of thinking and reflective abilities purposefully.

Research projects in the field of developing critical thinking through various classroom interventions within a formal context have yielded positive effects (Abrami *et al.*, 2008; Bailin *et al.*, 1999; Bonk & Smith, 1998; Halpern, 1998; Heyman, 2008; Kennedy, 1991; Nelson, 1994; Paul, 1992; Thayer-Bacon, 2000). In a meta-analysis of 117 empirical studies examining the influence of instructional interventions on students' critical thinking skills and dispositions, Abrami *et al.* (2008) discovered that these interventions predominantly had a positive effect, with a mean effect size of 0.34. All the studies seem to be imbedded in Piagetian and Vygotskyian traditions that focus on the importance of collaborative learning and social interactions for promoting the development of critical thinking skills (Goyak, 2009; Heyman, 2008; Thayer-Bacon, 2000).

Numerous researchers have observed that critical thinking skills are unlikely to improve and develop in the absence of explicit instruction (Abrami *et al.*, 2008; Case, 2005; Facione, 1990; Halpern, 1998; Paul, 1992). Along with explicit instruction and collaboration, various other strategies have been recognised as helpful in developing critical thinking (*cf.* 1.1). An example of this can be seen where teachers are encouraged to use constructivist learning methods, which are recognised to be more student-centred than teacher-centred (Bonk & Smith, 1998; Duffy & Jonassen, 2013; Lunenburg, 2011; Paul, 1992) (*cf.* 3.2.3.3, 3.3.2, 3.3.3, 3.3.4).

3.2.2 Teaching in informal and non-formal contexts

Informal learning denotes to learning that does not include a formal curriculum and no credits towards completing a qualification are earned. The teacher can be anybody with more experience such as a parent, grandparent or a friend. Occasionally, informal learning is denoted as experiential learning (*cf.* 3.2.3.5), that emphasises learning from daily life activities and experience, educative stimuli and resources in the environment (family, neighbours, play, the library, mass media, video games), and is considered as a natural supplement to everyday life (Coombs, Prosser, & Ahmed, 1973; Rogers, 2014; UNESCO, 2012). Informal learning can contribute towards obtaining qualifications, and is not engaged by schools or externally authorised, but student controlled (Ferguson,

Faulkner, Whitelock, & Sheehy, 2015; Luckin *et al.*, 2009) and self-directed (Cerasoli *et al.*, 2014; Dabbagh & Kitsantas, 2012; Mardis, 2013). While informal learning can also ensue in formal classroom situations, informal learning chiefly takes place outside the classroom and is frequently disregarded and considered as less valuable than formal, rigid learning (Eaton, 2012).

Rogers (2014) indicates that there is a close connection between formal and **non-formal learning**, as both forms of learning can be demarcated as a situation where one person is “*assisting somebody to learn*” and “*any action [that is] undertaken on the part of one person with the goal of helping another person to learn*” (Swann, 2012, p. 95). Continuing education courses are an example for adults, and extra-curricular activities are examples of non-formal learning for children. Non-formal learning could contain accredited learning programmes delivered by commercial agencies (Rogers, 2014).

Coombs *et al.* (1973) argue that informal and non-formal learning can happen at the initiative of an individual, but can also ensue as a result of prearranged learning activities, regardless of whether the activities are intended at achieving learning objectives or not. This type of education can be directed by a qualified teacher or by someone with more experience. Non-formal learning does not result in a formal qualification, but is extremely inspirational and builds an individual’s skills and capabilities (Coombs *et al.*, 1973). It is frequently considered more appealing, as the student’s interest is a driving force behind their involvement (Eaton, 2012). Non-formal education is an addition, or supplement to formal education. It does not offer an organised pathway style to education where a formal qualification is attained, and rather emphasises short courses, workshops and seminars (Yasunaga, 2014).

There are diverse types of informal learning, specifically self-directed learning, incidental learning or task-conscious learning and unintentional learning (Rogers, 2014). As per self-directed learning, a student plans and manages the implementation of a learning activity autonomously, which can include formal and non-formal learning. Much of what children learn is attained virtually spontaneously and immediately – that is, incidentally – as they perceive other children and adults interact with the environment and emulate their activities. Incidental learning is learning acquired by observing people and events around us, day by day, and one develops awareness of learning taking place while concentrating

on a particular act or task. Unintentional learning is almost always accidental and unconscious (Hager & Halliday, 2009), and often also unplanned, for example, the many advertisements in the media people are exposed to everyday and the abundant campaigns aimed at, for example, health. Daily experiences of life's trials, solving problems, unsuccessful plans or experiencing the consequences of making bad decisions, and making new friends offer opportunities for incidental learning. Dufura, Parcel, and Troutman (2013) contend that several competencies which lead to accomplishment are not learned during schooling or higher education, but instead informally through daily activities, social interaction and the media.

Disputes in the literature divulge some intersection amid learning in (formal) and beyond the classroom contexts and there are intervals when the lines between formal, informal and non-formal learning get blurry. Rogers (2014) consequently contends that one should not view them as disconnected groups, but to see them as a continuum.

The borders between the different types of learning will adjust from context to context. According to Colley, Hodkinson, and Malcolm (2003) there are limited, if any, learning conditions where either informal or formal elements are totally absent. In informal learning there are frequently elements of formal learning evident, with structured mechanisms intended to master certain outcomes. In numerous formal learning situations there are informal elements at play, for example the life situation of the students, their capabilities and learning undertaken by students themselves (Cerasoli *et al.*, 2014; Lave, 1992).

Given the aforementioned background to formal, informal and non-formal learning, the researcher decided to adopt a combined approach in the context of the study. Although the intervention took place in a **formal** classroom learning environment where a formal teaching strategy, the GROW model was applied. Additionally, participants were **informally** involved in self-directed, experiential learning not aligned to achieving objectives in relation to curriculum learning material. In addition, **non-formal** learning that was not aligned to achieving learning objectives in an organised way was promoted, as participants' interest was regarded as a driving force during their involvement in self-directed learning during the intervention.

The following section outlines some teaching and learning theories that could possibly support the development of critical thinking when using a combined formal, informal and non-formal approach. Various teaching and learning theories were explored in order to identify an appropriate theory or theories that could guide the implementation of the PVG-CEP. These theories include behaviourism, cognitivism, constructivism, transformative learning, experiential learning, structural cognitive modifiability, mediated learning, tangential learning and transfer of learning.

3.2.3 Teaching and learning theories and their relation to the development of critical thinking

3.2.3.1 Behaviourism

Behaviourism views a student as fundamentally passive, reacting to environmental stimuli (Skinner, 2011). The student begins as a clean slate (i.e. tabula rasa) and behaviour is moulded through positive reinforcement or negative reinforcement (Watson, 2013). Together, positive reinforcement and negative reinforcement increase the possibility that the precursor behaviour will happen or not happen again. Learning is consequently defined as a change in behaviour in the student (Pavlov & Anrep, 2003).

Within the behaviourist view of learning, the teacher is the central person in the classroom and takes complete control (Arends, 2004; Neisser, 2014). The student has limited occasions for evaluation or reflection within the learning process, and is merely told what is right or wrong, thus supporting a positivist realist approach to knowledge acquisition (South African Institute for Distance Education, 2012). In addition, a critical realist approach could also characterise behaviourism, which implies that knowledge is viewed as non-prescriptive and fallible (South African Institute for Distance Education, 2012). According to Arends (2004) and Neisser (2014) the conceptualisation of learning by means of a positivist realist approach could be regarded as insignificant, as the emphasis is on the product or outcome of learning without giving consideration to the internal thinking processes and emotions involved during the process to produce the learning outcome.

3.2.3.2 **Cognitivism**

The cognitivist revolution substituted behaviourism in the 1960s as the prevailing teaching and learning paradigm. Cognitivism emphasises that the human mind is important and essential for understanding how individuals learn. Mental processes such as thinking, memory, knowing, and problem solving play an important role in learning (Ertmer & Newby, 1993; Knowles, Hilton, & Swanson, 2014).

According to the cognitive learning theory, individuals do not simply react to environmental stimuli (behaviourism); they are rational beings that need active participation in order to learn, and whose actions are a consequence of thinking (Merrill, 2009). Cognitive theory focuses on the student's learning procedure, namely how information is acquired; how information is processed and arranged into current knowledge structures; and how information is retrieved upon recollection (Ertmer & Newby, 1993; Knowles *et al.*, 2014; Reigeluth, 2013). Learning is therefore not about the procedure of what a student does, but rather a process reliant on what the student already knows (prior knowledge) and the technique applied to obtain new knowledge (how they integrate new information into their existing schemas).

3.2.3.3 **Constructivism**

Constructivism postulates that learning is an active, constructive process, where learning takes place by doing and discovery (Ackermann, 2001; Killen, 2015; Kirschner, Sweller, & Clark, 2006; Powell & Kalina, 2009; Tobias & Duffy, 2009). The student is an information builder and constructs knowledge out of experiences (Bächtold, 2013; Duffy & Jonassen, 2013; Piaget, 2013; Tobias & Duffy, 2009; Vygotsky, 1980).

Constructivism distinguishes between cognitive constructivism, social constructivism and radical constructivism.

Cognitive constructivism focuses on a within-the-human perspective, which is commonly credited to Jean Piaget (2013), who recognised methods of accommodation and assimilation that are crucial in the interaction and experiences of an individual with the environment to build new knowledge (Vygotsky, 1980; Piaget, 2013). Once individuals experience novel information (assimilation), they combine it into a previously existing

framework (accommodation) (Lave & Wenger, 1991). As soon as novel experiences contradict existing internal representations, perceptions of the experiences might be changed to fit the internal representations (Berk, 2012; Brown, Collins, & Duguid, 1989; Eddy, 2004; Piaget, 2013; Rogoff, 2009). Learning thus requires a constant restructuring of current cognitive structures, which necessitates a major personal investment on the part of the student (Perry, 1999). Cognitivist teaching methods aim to assist students in assimilating new information to existing knowledge, and enabling them to make the appropriate modifications to their existing intellectual framework to accommodate that information (Perry, 1999), for which thinking skills are required. For instance, asking students to explain new material in their own words can assist them in assimilating it by forcing them to re-express the new ideas in their existing vocabulary (Piaget, 2013).

Social constructivism. Bauersfeld (2012) opines that according to the social constructivist approach, instructors need to adjust to the role of facilitators and not teachers, to enable students to create and discover information in collaboration with others (Snowman, McCown, & Biehler, 2011; Wertsch & Toma 1995). Whereas a teacher gives a didactic lecture that covers the subject matter, a facilitator guides a student to get to his or her own particular understanding of the content. The importance therefore turns away from the instructor and the content, and towards the student (Bauersfeld, 2012; Gamoran, Secada, & Marrett, 2000). This dramatic modification of role suggests that a facilitator must exhibit a totally altered set of skills than that of a teacher (Brownstein, 2001). A teacher tells, a facilitator asks; a teacher lectures from the front, a facilitator supports from the back; a teacher gives answers according to a set curriculum, a facilitator provides guidelines and builds the environment for the student to arrive at his or her own conclusions; a teacher frequently gives a monologue, and a facilitator is in constant dialogue with the students, and allows students to engage in dialogue with their peers (Bauersfeld, 2012; Rhodes & Bellamy, 1999). Facilitation produces a vibrant interaction between task, instructor and student, and students among one another, necessitating that students and instructors ought to cultivate an awareness of each other's perspectives and then inspect their personal beliefs, standards and values, thus being both subjective and objective at the same time (Bauersfeld, 2012; Savery, 1994).

Radical constructivism adds a second principle to trivial constructivism (von Glasersfeld, 1984, p. 17), namely *“Coming to know is a process of dynamic adaptation towards viable interpretations of experience. The knower does not necessarily construct knowledge of a “real” world. Knowledge is therefore is result of a self-organized cognitive process”*. From a radical constructivist perspective, communication need not involve identically shared meanings between participants. It is sufficient for their meanings to be compatible (Hardy, 1997). The emphasis in radical constructivism focuses on the individual learner as a constructor.

In the context of the study, the focus was mainly on promoting cognitive constructivist approach to developing critical thinking.

3.2.3.4 Transformative learning theory

Transformative learning cultivates independent thinking (Mezirow, 1997). An important part of transformative learning is for persons to modify their frames of reference by critically reflecting on their assumptions and beliefs and deliberately creating and applying plans that bring about new ways of defining their worlds. This process is fundamentally critical, rational and analytical (Dirkx, Mezirow, & Cranton, 2006; Grabove, 1997).

In order to nurture transformative learning, the educator's role is to support students in becoming conscious and critical of assumptions. This contains their own assumptions that lead to their interpretations, beliefs, habits of mind, or points of view, as well as the assumptions of others (Loughlin, 1993). Teachers must offer students practice in identifying frames of reference. By doing so, teachers promote practice in redefining problems from dissimilar perspectives. The goal is to create a community of students who *are “united in a shared experience of trying to make meaning of their life experience”* (Mezirow, 1997, p. 6).

Teachers need to provide students with chances to contribute successfully in dialogue. Dialogue includes evaluating beliefs, feelings, and values, and has the aim of evaluating reasons behind opposing interpretations through critical inspection of evidence, arguments, and alternate points of view (Mezirow, 1997). Students get the opportunity to validate how and what they understand, as well as develop well-informed judgments concerning a belief. Teachers can encourage critical reflection and experience with

discourse through the implementation of methods including metaphor analysis, concept mapping, consciousness raising, life histories, and participation in social action (Dirkx *et al.*, 2006).

Mezirow (1997) indicates that it is the role of the educator to encourage discovery learning through the application of classroom approaches such as group projects, role play, case studies, and simulations (*cf.* 3.4.2). These methods enable transformative learning by helping students examine concepts in the context of their lives and analyse the justification of new knowledge. Transformative learning requires a specific process to be followed and this process becomes the enabler.

The educator becomes a facilitator once the goal of learning is for students to construct knowledge about themselves, others, and social norms. Therefore, students play an important role in the learning environment and process (Dirkx *et al.*, 2006). Students must create norms within the classroom that include civility, respect, and responsibility for helping one another learn (Mezirow, 1997).

3.2.3.5 Experiential learning theory

Experiential learning is the practice of learning from personal and environmental experiences (Breunig, 2009; Kolb, 2014; Kolb in Merriam, Caffarella, & Baumgartner, 2012; McCarthy & McCarthy, 2006; Svingby & Nilsson, 2011). Experiential learning is separate from rote or didactic learning, in which the student plays a moderately inactive function. It is linked to, but not identical with other types of active learning such as action learning, adventure learning, free choice learning, cooperative learning, and service-learning (Beard, 2010; Itin, 1999).

Kolb (2014) states that in order to gain genuine knowledge from an experience, the student needs to possess four abilities:

- The student must be eager to be actively involved in the experience.
- The student must be capable of reflecting on the experience.
- The student must possess and utilise analytical skills to conceptualise the experience.
- The student must possess decision making and problem solving skills in order to utilise the new ideas gained from the experience (Kolb, 2014).

In addition, reflection that is a crucial part of the experiential learning process that creates a scaffold for further learning, and allows for further experiences and reflection (Kompf & Bond, 2001; Moon, 2004), should be encouraged. Examples of simple, practical questions for facilitators to use in promoting critical reflection in experiential learning, follows below:

- Did you notice...?
- Why did that happen?
- Does that happen in life?
- Why does that happen?
- How can you use that? (Jacobson & Ruddy, 2004).

3.2.3.6 Structural cognitive modifiability theory

The theory of structural cognitive modifiability views the human organism as open, adaptive and amenable for change via learning in any context (Feuerstein, Feuerstein, & Falik, 2010). The aim of this approach is to modify the individual, emphasising autonomous and self-regulated change. Intelligence is viewed as a propensity of the human race to modify itself when confronted with the need to do so, and also as a changeable state rather than a permanent feature (Feuerstein, 1997; Benjamin, 2005; Tzuriel, 2001). According to Benjamin (2005), Feuerstein (1997), and Tzuriel (2001) fragile thinking skills, and behavioural and emotional conditions can be modified through mediated learning (*cf.* 3.2.3.7). In the context of the research, the researcher argued that it would be possible to modify and change any deficiencies in relation to the critical thinking skills, dispositions and standards of reasoning among the research participants.

3.2.3.7 Mediated Learning Theory

Developed by Reuven Feuerstein, the theory on Mediated Learning denotes to the manner in which a mediating agent converts stimuli experienced in a learning environment, usually a parent, teacher, sibling, or other intentioned person in the life of the student (Feuerstein & Feuerstein, 1991). This mediating agent, directed by intention, culture, and emotional investment, chooses, improves, emphasises, and structures the world of stimuli for the student contrarily, according to a strong intention and aims for the

student's improved and effective functioning (Fraser, 2006). The mediator chooses stimuli that are most apposite to his/her intentions, and then frames, screens, and schedules them; their appearance or disappearance is organised to structure the student's experience according to clearly identified and explicit goals. Through this procedure, the student obtains behaviour patterns, consciousness, and strategies that in turn become significant elements in the aptitude to be adapted by further direct exposure to stimuli (Feuerstein & Feuerstein, 1991).

Mediated Learning, according to Feuerstein, should be characterised by the following observable parameters, which are classified as **universal criteria, situational phase specific criteria and integrative orienting belief system criteria** (Feuerstein & Feuerstein, 1991, p. 15-49; Feuerstein *et al.*, 2010, p. 40-57).

The universal criteria are extant in all interpersonal interactions and are essential to generate circumstances for universal development, and extended and elaborated learning. These criteria refer to the following critical elements:

- Intentionality and reciprocity: Interactions with students should be purposeful, focused and directed.
- Transcendence: Learning experiences should be linked to broader application in the outside world.
- Mediation of meaning: The relevance and reasons for learning activities should be clear to students.

The situational or phase specific criteria are related to precise learning situations which deliver opportunities for mediational intervention that cannot take place without the above-mentioned universal criteria being recognised (Falik, 2001). These criteria refer to the following critical elements:

- Mediation of regulation and control of behaviour: The importance of students being able to monitor their own learning progress, making adjustments in their responses and developing skills and insight during learning is highlighted by this critical element.
- Mediation of feelings of competence: It is important for students to develop an optimistic belief in success, to feel capable and confident to accomplish a task.

- Mediation of sharing behaviour: During teaching and learning, students should be involved in activities of cooperation and shared experiences.
- Mediation of individuation and psychological differentiation: It is important to emphasise the uniqueness of each student, but also to accept differences among individuals. Independence as well as diversity among students should thus be valued during teaching.
- Mediation of challenge, novelty and complexity: Students should be challenged with novel and complex experiences. Important, though, is that the learning activities through which the challenge is provided should be structured in such a way that they also receive the support and opportunities to develop the skills for succeeding. If this does not happen, the challenge will defeat the notion of mediating feelings of competence.

The integrative orienting belief system criteria are essential to integrate modifications in functioning into cognitive structures for continuous behavioural alteration and self-perpetuation (Falik, 2001). They denote to the subsequent critical elements:

- Mediation of awareness of the human being as a changing entity: the possibility of self-change and growth among students should be encouraged.
- Mediation of the search for optimistic alternatives: An awareness of selecting from immediate experiences and considering past experiences as influential for growth and changing potential should be facilitated and encouraged.
- Mediation of a feeling of belonging refers social and emotional connections with others.

The theory of Mediated learning experience relates to the study, as the researcher adhered to the above-mentioned criteria in all the interactions with the students during the implementation of the puzzle video game Portal.

3.2.3.8 Tangential learning theory

Tangential learning is the method by which persons self-educate, when a theme is presented to them in a setting that they already enjoy (Armstrong, 2004). For instance, once one has played a music-based video game, a few people may be encouraged to

study how to play an actual instrument, or after watching a television show that references Faust and Lovecraft, some people could be motivated to read the original works of these authors. Consistent with specialists in natural learning, self-oriented learning preparation has confirmed to be an effective instrument for supporting independent learning and thinking (Leland, 2016). This argument relates to the study, as the video game Portal proposes an entertaining manner in which critical thinking skills involved in problem solving could potentially be tangentially learned while the participants are playing the game. The theory that could be posited is, that while the players of the game are having fun, they might become better at critical thinking a lot faster than compared to any other form of learning.

3.2.3.9 Transfer of learning theory

Transfer of learning takes place when students see the value of applying knowledge or skills acquired previously and stored in their memories, to other situations. Research indicates that learning transfer is infrequent and that it occurs most commonly when instruction is "... *cued, primed, and guided...*" (Bransford, Brown, Cocking, Pellegrino, & Donovan, 2000, p. 324).

Various hypotheses and definitions have been advanced for transfer of learning. Firstly, it is speculated that different types of transfer exist, namely near transfer (the application of skill to solve a novel problem in a similar context), and far transfer (the presentation of skill to solve novel problems presented in a dissimilar context) (Perkins & Salomon, 1992).

Secondly, Perkins and Salomon (1992) and Schwartz, Bransford, & Sears (2005) propose that positive transfer happens in circumstances where learning supports original problem solving, and negative transfer happens when previous learning constrains performance on decidedly connected tasks. Thirdly, Schwartz *et al.*, (2005) propose that transferring knowledge into a situation may differ from transferring knowledge out to a situation as a means to reconcile findings that transfer may both be frequent and challenging to promote.

A significant and long research history has also endeavoured to elucidate the circumstances under which transfer of learning might happen. Early research by Ruger (1910) for example found that, the "*level of attention*", "*attitudes*", "*method of attack*" (or

method for tackling a problem), a *"search for new points of view"*, *"a careful testing of hypothesis"* and *"generalization"* were all valuable approaches for promoting transfer (Ruger, 1910, p. 15). To encourage transfer through teaching, Perkins and Salomon (1992, p. 6457) recommend aligning (*"hugging"*) instruction with practice and assessment, and *"bridging"*, or encouraging students to reflect on past experiences or make connections between prior knowledge and current content for effective transfer to occur.

There is disagreement among researchers regarding the transferability of critical thinking skills learned in one context, to new contexts, domains, and disciplines. Some researchers (Halpern, 1998; Willingham, 2008), have a tendency to agree that transferability is unlikely to happen unless students are instructed to explicitly transfer these skills. Students therefore need to be offered opportunities to employ critical thinking skills and abilities in a variety of contexts and subject areas. Furthermore, instruction should accentuate executive functioning or meta-cognitive skills, such as setting goals, planning, and monitoring progress toward goals (Kennedy, 1991). Thirdly, students should be exposed to deep problem structure, because most students' thinking tends to concentrate on the surface structure of problems, or the superficial aspects of tasks (Halpern, 1998; Willingham, 2008).

Hummel and Holyoak (cited in Halpern, 1988, p. 181) highlight the importance of structure sensitivity for the transferability of critical thinking skills. They define structure sensitivity as the ability to *"code and manipulate relational knowledge."* The purpose of structure training is to encourage and allow students to identify a specific problem structure each time they come across it, whether it is presented in math, science, or social studies, and that they then utilise suitable strategies to solve the problems. Structure training entails issuing practice in diverse environments and settings. Halpern (1988) points out that the use of real-world learning activities helps to stimulate the transfer of critical thinking skills. Brown (1990) reasons that domain-specific knowledge may be needed for young children to effectively transfer skills to new problems that display the same deep structure. She commented, *"We conclude that even young children show insightful learning and transfer on the basis of deep structural principles, rather than mere reliance on salient perceptual features, when they have access to the requisite domain-specific knowledge to mediate*

that learning” (Brown, 1990, p. 130). Thus, teaching for transfer may also entail providing adequate instruction on relevant background information.

Arthur, Bennett, Stanush, & McNelly (1998) and Farr (1987) provide the following insights into decay and retention of skill acquisition.

- Training conditions for skills acquisition, should be as similar to the retention conditions as possible for maximum retention.
- The quality and quantity of the skill acquired plays a significant role in decay and long-term retention. If skill acquisition is limited during the training situation, then retention becomes questionable.
- It is important to establish at what stage during training the acquisition of a skill should cease and the retention interval should begin.
- Greater motivational levels among students contribute to greater skill retention over time.
- Students with higher abilities retain more skill because they acquire more during training than lower ability students do in the same amount of time.
- It is important to establish levels of previous skills development to accurately determine retention. Skills that were retained from previous acquisitions will be reinforced during subsequent training and less likely lost, compared to skills that are learned for the first time.

Transfer of learning relates to this particular study as the researcher argued that once the participants involved in the intervention programme develop their critical thinking skills, dispositions and standards of reasoning by playing the puzzle video game, they might be able to transfer those to different contexts. This process is known as far transfer, the application of skill to solve novel problems presented in a different context (Perkins & Salomon, 1992). This argument also applied to the W-GCTA test context, as it was hoped that the participants would transfer and apply the critical thinking skills they possibly learned and developed tangentially through the PVG-CEP to a new, non-tangential, written context. Bruner (cited by Darling-Hammond & Austin, 2003) suggests that teachers can help students transfer their knowledge across dissimilar situations by capitalising on general principles that have been acquired effectively. The researcher

hoped that the students would acquire the general principles of applying critical thinking skills to problem solving numerous puzzles during the PVG-CEP, and that they would be able to apply these skills to dissimilar situations in the W-GCTA.

In summary, the theories of learning discussed above, excluding behaviourism, could promote the development of critical thinking. Behaviourism (*cf.* 3.2.3.1) at its core seeks to maintain order and control through modifying students' behaviour through conditioning, which leads to compliance, and does not encourage critical thinking. This type of learning is enforced through teacher-centred strategies like drill and practice and many other repetitive activities that are merely used to enforce memorisation, which is not the focus of critical thinking. This learning theory was therefore not adopted in this study. In Chapter 4 (*cf.* 4.3.2), the researcher motivates his choice of the various teaching and learning theories that underpinned the design and implementation of the PVG-CEP intervention.

The previous sections explained in depth that some learning theories could support the development of critical thinking. Consequently, the researcher also needed to explore the various teaching methods and strategies applied in formal learning contexts that could potentially assist in developing critical thinking in the context of the study. The following section discusses various teaching methods as well as their associated strategies and techniques that can be applied in a formal classroom context to develop critical thinking, and as postulated by Sitzmann (2011), could hold benefits for being used in conjunction with video game play.

3.3 TEACHING METHODS AND STRATEGIES TO DEVELOP CRITICAL THINKING

A teaching method comprises a specific approach to instruction used by teachers to enable student learning (Westwood, 2008). These methods are determined partly by subject matter to be taught and partly by the nature of the student. Teaching methods refer to systematic ways of doing something; an orderly logical arrangement of steps. Teaching strategies are long term plans of action designed to achieve a particular goal that is envisaged during teaching (Westwood, 2008).

3.3.1 Direct teaching methods and related strategies

According to Arends (2004), Burden and Byrd (2003), Gunter, Estes, & Mintz (2010), Killen (2015), Kramer (2006), Monyai (2006) and Tuovinen and Sweller (1999), direct instruction refers to simple teaching of knowledge and skills using lectures or demonstrations. Direct Instruction is supported by the behaviourist learning theory (*cf.* 3.2.3.1), and supports a realist epistemological approach (Johnston, Woodside-Jiron, & Day, 2001; Schraw & Olafson, 2003; Chai & Khine, 2008) that assumes that there is an impartial body of reasonably unchanging knowledge that is best learnt via experts through transmission and reconstruction (Weinert & Helmke, 1995; Schraw & Olafson, 2003). Direct instruction could be regarded as an effective instructional strategy when the teacher's goal is to: Provide information, teach standard procedures, and to develop step-by-step skills (Arends, 2004; Burden & Byrd, 2003; Kramer, 2006; Monyai, 2006; Tuovinen & Sweller, 1999)

Direct instruction involves the use of the following strategies.

- **Demonstrations:** Making use of examples to conceptualise information more effectively (Bruce, Ross, Flynn, & McPherson, 2009; McKee, Williamson, & Ruebush, 2007; Monyai, 2006).
- **Didactic questions:** Didactic questions have a tendency to be convergent, factual and frequently start with “*what*,” “*where*,” “*when*” and “*how*.” These might also include “*why*” and “*what if*” questions (Arends, 2004, p. 293; McNeill & Wiles, 1990, p. 13).
- **Drill-and-practice:** Tournaki (2003) notes that drill-and-practice involves the organised, and monotonous review of formerly learned ideas in order to increase the level of mastery.
- **Explicit teaching:** Explicit teaching comprises six teaching roles, namely: Regular analysis of work, delivering new material, directing guided practice followed by comment, conducting independent practice, and lastly to review work weekly and monthly (Bligh, 2000; Boyles, 2004).
- **Structured overviews:** Structuring learning material involves making summaries of information to make information more comprehensible for students (Boyles, 2004).

According to the researcher, the greatest disadvantage of direct instruction is its restricted ability to aid students to develop their abilities to think critically fully and to work well in a group setting, as it is mainly a teacher-centred method of instruction, placing the burden of enhancing critical potential in the students solely on the teacher's shoulders. It can also produce passive students who do not take part in the learning process, which is not conducive to the nurturing of critical thinking. Direct teaching could however be used effectively if critical thinking is explained and modelled to students, and then infused into lessons (Abrami *et al.*, 2008; Zhao, Pandian, & Singh, 2016).

Indirect instructional teaching methods and strategies are discussed in the proceeding section.

3.3.2 Indirect teaching methods and related strategies

In contrast with the direct instruction method, indirect instruction is mainly student-centred (Borich, 2003; Kramer, 2006), and sets out to provide an abundant level of student contribution to, and involvement in perceiving, examining, drawing inferences from information, creating hypotheses, as well as promoting inquisitiveness, and inspiring problem solving (Arends, 2004; Borich, 2003; Kramer, 2006).

Indirect instruction supports cognitive (*cf.* 3.2.3.2) and constructivist (*cf.* 3.2.3.3) learning theories, which interpret learning as a procedure during which the student dynamically applies thinking skills to construct novel ideas or concepts founded upon current and previous knowledge or experience (Kim, 2005). Kim (2005) states that the teacher acts as a facilitator who inspires students to discover principles for themselves and to construct knowledge by working to solve realistic problems. Indirect instruction reinforces a contextualist epistemological approach where students can construct knowledge independently or in collaboration with peers to promote shared understanding (Schraw & Olafson, 2003; Chai & Khine, 2008).

Indirect instruction includes the following among its strategies:

- **Case study:** A case study involves a detailed investigation of an event (Monyai, 2006; Yin, 2009), to explore causation and underlying principles (Shepard & Greene, 2003; Monyai, 2006).

- **Cloze procedure:** Chatel (2001) opines that cloze procedure is a system in which words are removed from a passage, and students need to add words to complete and create meaning from the text.
- **Concept attainment:** Concept attainment necessitates that a student establishes attributes of categories of information by identifying examples that contain and do not contain the attributes (Gunter *et al.*, 2010; Joyce & Weil, 2000).
- **Concept formation/development:** According to Gunter *et al.* (2010) as well as Joyce and Weil (2000) concept formation offers students the opportunity to discover concepts by making links and seeing associations between items of information. This strategy can assist students to develop and improve their ability to recall and distinguish between key ideas, to see commonalities and identify relationships, to articulate concepts and generalisations, to explain how they have structured information, and to present evidence to support their organisation of specific information (Gunter *et al.*, 2010; Joyce & Weil, 2000).
- **Concept mapping:** A concept map is a diagram presenting the relationships between concepts. Concept maps are graphical, visual tools for consolidating and representing knowledge (Novak & Cañas, 2006).
- **Reading for meaning:** According to Miller (2002), reading for meaning is an indirect instructional strategy where the reader reads with the commitment to understand the information offered.

In sum, the researcher argues that indirect instruction provides possibilities to enhance critical thinking as students are dynamically involved in constructing or building knowledge which requires the development and application of thinking skills. Employing case studies or concept maps for example, bring depth and breadth to a learning experience, which could aid in the enhancement of developing critical thinking.

The next section clarifies the nature of teaching and learning environments where independent instruction is used.

3.3.3 Independent teaching methods and related strategies

According to Borich (2003), Ognibene (2007) and Philpott (2009), independent instruction represents a plethora of instructional strategies which are purposefully applied to increase

the development of individual student initiative, self-reliance, self-regulation and self-improvement.

Independent instruction is framed within the cognitive (*cf.* 3.2.3.2) and constructivist (*cf.* 3.2.3.3) learning theories (Wallace, Ross, Davies, & Anderson, 2007), and students need to acquire cognitive skills to select and assess information in contrast to the manipulated environment that behaviourists emphasise (Wallace *et al.*, 2007). Independent instruction favours a relativist epistemological approach, which accepts that each student constructs a unique, personal knowledge base that is dissimilar, but equal to that of other students (Bruner, 1961; Cobern, 2000; Johnston *et al.*, 2001; Schraw & Olafson, 2003; Chai & Khine, 2008).

Independent teaching might involve the use of one or more of the following strategies.

- **Assigned questions:** Assigned questions are those prepared by the teacher to be answered by individuals or small groups of students (Prince & Felder, 2006), or student generated questions. Students discuss their responses among one another or with the teacher. Particular positions or points-of-view should be supported by evidence.
- **Computer-assisted instruction:** Computer-assisted instruction refers to instruction or remediation presented on a computer (De Beer, 2010; Van Rooyen & Van der Merwe, 2008). Computer programmes can allow students to progress at their own pace and work individually or solve problems in a group. Computer-assisted instruction usually does not move ahead until students have mastered the skills, which could be considered behavioristic in nature (De Beer, 2010; Sessoms, 2008; Van Rooyen & Van der Merwe, 2008).
- **Essays:** For Warburton (2006), an essay is a portion of writing which is frequently written from an author's individual point of view. Killen (2015) adds that writing can promote different types of learning, such as: Understanding of concepts or principles, the ability to describe, inform predict, make comparisons or persuade.
- **Homework:** Homework or homework assignments denote to tasks allocated to students by their teachers to be finalised typically outside the class (Bennett & Kalish, 2006).

- **Research projects:** Freiberg (2002) specifies that research projects are extremely effective for nurturing and extending skills such as, recording information, sequencing and organising ideas, and using language to inform others (Freiberg, 2002).
- **Problem solving:** Problem solving is a student-centred pedagogy in which students learn about a subject through the experience of solving open-ended problems that do not have clear solutions (Schmidt *et al.*, 2011). Problem solving addresses the necessity to encourage lifelong learning through the practice of enquiry and reflection (Hung, 2011; Schmidt *et al.*, 2011). Problem solving is viewed as a constructivist teaching strategy (*cf.* 3.2.3.3) because it highlights collaborative and self-directed learning while being reinforced by tutor facilitation (Barrett, 2010; Dolmans, De Grave, Wolhagen, & Van Der Vleuten, 2005; Hmelo-Silver & Barrows, 2006; Hung, 2011; Schmidt *et al.*, 2007; Wells, Warelw, & Jackson, 2009; Yew & Schmidt, 2012). A specific problem solving strategy was employed within this study, namely the GROW model (*cf.* Table 1.1). The GROW model (or process) is a simple method for goal setting and problem solving (Gorell, 2013). It was utilised during the PVG-CEP intervention as a tool to assist the research participants with the structuring or planning of the the problem solving situations posed in the video game.
- **Enquiry-based learning:** Enquiry-based learning is a strategy of active learning that begins by posing questions, problems or scenarios, instead of merely presenting established facts or depicting a smooth path to knowledge acquisition (Dostál & Gregar, 2015; Killen, 2015). Particular learning processes that individuals are involved in throughout enquiry-based learning that promote the development of critical thinking include among others, connecting explanations to the knowledge obtained from the investigative process, and creating an argument and justification for explanations (Dostál & Gregar, 2015; Haury, 1993; Killen, 2015; Wilhelm & Wilhelm, 2010).

In conclusion, independent instruction supports the development of inferential thinking, deductive reasoning skills, as well as the ability to evaluate arguments that stand central to the development of critical thinking. It encourages students to strive for more than superficial learning of information (Kuhltau, Maniotes, & Caspari, 2007).

The next section elucidates on the use of interactive instruction as a teaching method.

3.3.4 Interactive/participative teaching methods and related strategies

According to Sessoms (2008), interactive instruction depends significantly on discussion and sharing between participants. Students can learn from each other and teachers to develop social skills and thinking skills, to consolidate their thoughts and to develop cogent arguments (Arends, 2004; Kramer, 2006).

Interactive instruction supports constructivist learning theory (*cf.* 3.2.3.3), which regards learning as a procedure in which the student dynamically constructs or builds original ideas or concepts based upon present and past knowledge or experience (Kim, 2005). Aligned to the view of social constructivists, interactive teaching supports the opinion that knowledge is constructed when individuals participate socially in talk and activity about common problems or tasks (Johnson, 2006; Maxim, 2010; Powell & Kalina, 2011). Interactive instruction supports a contextualist worldview, according to which it is presumed that students collaboratively construct communal comprehension (Hung, 1999; Johnston *et al.*, 2001; McCaslin & Hickey, 2001; Schraw & Olafson, 2003; Chai & Khine, 2008; Werstch, Del Rio, & Alvarez, 1995).

Interactive instruction might include the following strategies.

- **Brainstorming:** Brainstorming is a large or small group activity that inspires children to focus on a theme and its understanding by adding to the free movement of ideas (Furnham & Yazdanpanahi, 1995; Monyai, 2006; Santanen, Briggs, & De Vrede, 2004).
- **Cooperative learning groups:** Cooperative learning is a type of group work with the focus on cooperation to reach a shared goal. It necessitates each student to be involved in his/her own learning process and also to take accountability for the other members of the group to learn (Joubert, Bester, & Meyer, 2008; Monyai, 2006). Students learning cooperatively take advantage of one another's resources and skills (asking one another for information, evaluating one another's ideas, monitoring one another's work) (Chiu, 2004; Monyai, 2006). According to Killen (2015), cooperative learning seems to help students develop skills to do research, think creatively and critically, and solve problems collaboratively.

- **Debate:** Darby (2007) and Roy and Machiette (2009) view debating as an organised challenge of argumentation in which two opposing individuals or teams defend and attack a given suggestion. Debate coerces students to contemplate not only the facts of a situation, but the consequences as well. Participants think critically and strategically about both their own and their opponent's position (Roy & Machiette, 2009).
- **Discussion:** A discussion is an oral investigation of a topic, object, concept or experience (Arends, 2004; Gunter *et al.*, 2010). All students require recurrent opportunities to produce and share their questions and ideas in small and entire class settings (Arends, 2004). Discussions encourage the exchange of ideas (Gunter *et al.*, 2010), thinking critically about issues, and developing the skills of analysis, synthesis and evaluation (Brookfield, 2012).

To sum up, the interactive and constructive nature of collaborative learning provides opportunities for students to develop critical thinking skills through sharing information with others, comparing diverse perspectives, consolidating their own thoughts and coherently formulating arguments.

Figure 3.1 below, summarises the gist of the section discussed in relation to teaching methods and teaching strategies that promote the development of critical thinking.

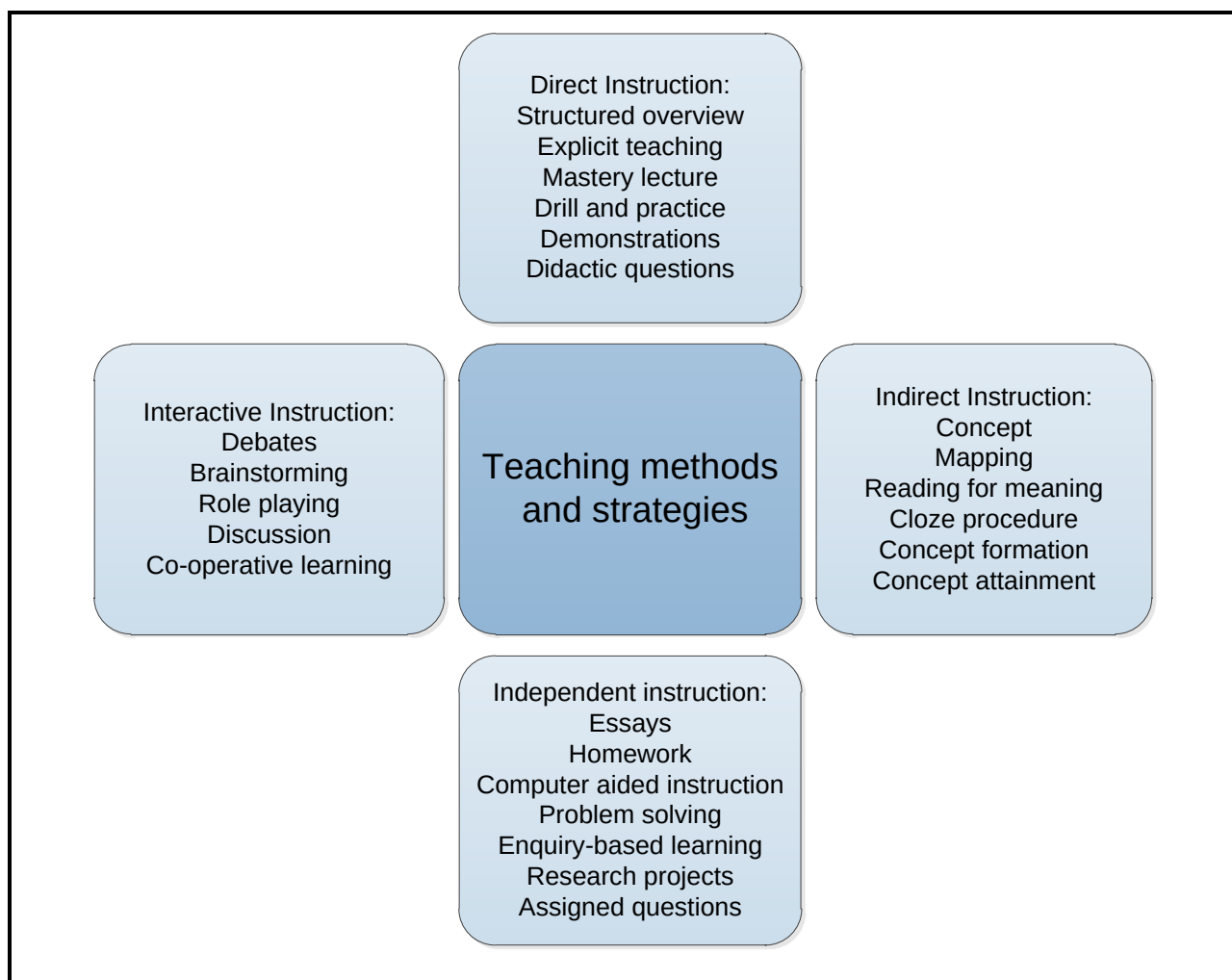


Figure 3.1: Teaching methods and strategies

In summary, the four main teaching methods and their respective strategies as outlined by Figure 3.1 above, excluding direct instruction, all hold benefits for developing critical thinking. The researcher is of the opinion that direct instruction holds limited potential for developing critical thinking as it does not allow for independent, critical thinking on the students' part, as they are merely regarded as receivers of information. Indirect instruction that allows students to discover meaning for themselves played an important role in the researcher's study. In addition, as problem solving stood central to the researcher's study independent instruction underpinned the implementation of the PVG-CEP. In the case of the study, each participant was involved in the intervention programme independent of one another and therefore played the game, which involved problem solving, on their own, allowing for independent instruction. Although interactive instruction can also develop critical thinking, it was not used in this study aside from the interaction between

the researcher and the participants that was driven by researcher questions during the puzzle video game play.

As the PVG-CEP intervention also involved the development of critical thinking dispositions and standards for reasoning, the researcher explored possible strategies that could benefit the development of the critical thinking dispositions and standards for reasoning on which the research focused.

3.3.5 Strategies to develop critical thinking dispositions and standards for reasoning

To the best knowledge of the researcher, literature does not provide explicit guidance in applying strategies that could develop dispositions and standards for reasoning. Generic examples of ways to deal with the teaching of dispositions were found in the work of Anderson (2010) and Costa and Kallick (2009b).

Table 3.1 below, summarises some of the strategies highlighted by Anderson (2010) and Costa and Kallick (2009b) to nurture the development of the critical thinking dispositions on which the study focused, namely: Systematic working ways, accuracy and persistence, on which the study focused.

Table 3.1: Strategies to nurture the development of critical thinking dispositions

Critical thinking dispositions	Strategies to nurture development
Systematic working ways	• Making students aware of rules and criteria for success, directions, time constraints, and purposes before engaging them in learning activities. • Pausing frequently during the completion of learning activities and asking students to reflect on and share their progress. • Letting students describe their pathways used to solve a problem.
Accuracy	• Making use of peers to check work for correctness. • Constantly checking work against the success criteria given at the outset of a task. • Checking one's own work again and again.

Critical thinking dispositions	Strategies to nurture development
Persistence	- Teaching students more than one way to solve a problem. - Making a list of causes that could cause one to get stuck, and possible strategies to overcome these.

The researcher could not locate any literature that provides guidance in the development of the standards for reasoning on which the research focused, apart from the purposeful use of questioning as proposed by Paul and Elder (2006) in Table 3.2 below.

Table 3.2: Questioning to develop standards for reasoning

Standards for reasoning	Questioning to nurture development
Clarity	- Could you elaborate further? - Could you give me an example? - Could you illustrate what you mean?
Relevance	- How does this relate to the problem? - How does this bear to the question? - How does that help us with the issue?
Logic	- Does all of this make sense together? - Does your first paragraph fit in with your last paragraph? - Does what you say follow from the evidence?

In the context of the study, the researcher employed the GROW model (Gorrell, 2013) (*cf.* Table 1.1) as strategy to support the development of the critical thinking dispositions and the standards for reasoning. The researcher also argued that the GROW model could promote the development of the critical thinking dispositions on which the research focused in the following ways:

- **Systematic working ways:** The model provided a planned and organised way going about actions, and enabled the students to have a systematic pathway to guide their problem solving.
- **Accuracy:** The steps in the model provided opportunity to constantly check work against the goal that needed to be achieved.

- Persistence: The steps in the model provided possibilities to stop and reflect on obstacles stopping the student getting from where they were to where they wanted to go.

The researcher made use of purposeful probing questioning (*cf.* 2.7.2.3) whilst the participants were busy solving the puzzle problems to understand the clarity, relevance and logic of their reasoning.

As the study involved students participating in a puzzle video game intervention in a formal classroom setting with an instructor/researcher, it was important for the researcher to take note of the classroom characteristics that should be adhered to, in order promote the development of critical thinking. The following section describes the nature of classrooms that are conducive to the development of critical thinking.

3.4 CREATING CLASSROOMS CONDUCTIVE TO THE DEVELOPMENT OF CRITICAL THINKING

Considering the importance of spanning the bridge between ambition and accomplishment in the area of critical thinking, Browne & Freeman (2000) propose a list of characteristics that differentiate classrooms which frequently inspire critical thinking from those that do not. According to Browne & Freeman (2000), teachers can prompt critical thinking by including definite design characteristics into their classes. These include: Frequent evaluative questions, the encouragement of active learning, and creating developmental tension, that align with teaching framed by cognitive and constructivist principles (*cf.* 3.2.3.2, 3.2.3.3).

3.4.1 Frequent evaluative questions

Critical thinking is largely a participatory endeavour. As understood by Brookfield (2012) Browne & Freeman (2000), and Green and Murriss (2014) the principal behavioural characteristic of critical thinking classrooms is that the classroom is teeming with an abundance of questions, asked by the teacher and students. Critical thinking necessitates comprehension or an understanding of information. Teachers can offer a substantial benefit to the students just from asking “why” questions. Other questions that can move thinking to a deeper level comprise the following:

- What words or phrases are used in an ambiguous form?
- What evidence is provided for the claims in the reasoning?
- What important information is missing from the reasoning used by the author?
- What other conclusions can reasonably be drawn based on the evidence provided? (Koenig, 2010).

3.4.2 Encouragement of active learning

According to Bean (2011), teachers in higher education tend to view themselves as specialists of knowledge and students as the enquirers. Consequently, the one with the knowledge communicates and the one enquiring listens (Bean, 2011), failing to offer students the occasion to practice using the knowledge under the observation of a skilled mentor. For the teacher to advance active learning and critical thinking necessitates mindfulness of the fragility of oral communication. Providing students with recurrent chances for practicing skills and attitudes permit them to experiment with critical thinking (Bean, 2011).

3.4.3 Developmental tension

An additional unique characteristic debated by Browne and Freeman (2000, p. 308) is “*creating a little developmental tension.*” This can be facilitated through controversial debates. Controversy is a sort of academic conflict where two or more students’ information, ideas, and conclusions are irreconcilable and they attempt to come to an agreement. Controversy is distinct since it increases the likelihood that evaluative thinking will take place (Browne & Freeman, 2000). According to Mathews and Lowe (2011), controlled academic controversy improves students’ skills to support a certain perspective. The researcher concludes that assessing controversies in the classroom, will enable teachers to endorse an atmosphere of reflection that can result in approval or refutation of information through coherent evaluation, and permit students to contradict ideas more.

The researcher incorporated the above mentioned characteristic during the implementation of the PVG-CEP intervention. One of the teaching and learning theories that stood central to the implementation of the intervention, was Mediated Learning (*cf.*

3.2.3.7), which supports the involvement of a mediator who facilitates the learning process instead of transmitting knowledge. Mediated Learning links with the characteristics mentioned above in the sense that the mediator, or in this study's case, the researcher, asked evaluative questions constantly in order to gauge relevancy and clarity in terms of the feedback given by the participants. This intervention programme also allowed for active learning, as the participants were required to meta-cognitively evaluate their performance and actively strove to utilise systematic working ways by working according to the GROW problem solving model. Developmental tension was guaranteed within the intervention programme due to the very nature of the video game Portal. The difficulty of the game created a form of controversy, in which doubt arose in the mind of participants when they made mistakes in trying to solve the puzzles.

As part of informal and non-formal learning, the following section discusses the role of games-based learning, with specific reference to video games, and in particular, the puzzle video game Portal, to develop critical thinking.

3.5 THE ROLE OF GAME-BASED LEARNING TO DEVELOP CRITICAL THINKING

3.5.1 Introduction

Video games have become exceedingly fascinating to teachers and researchers since their complexity has improved significantly over the last decade. Studies specify that the benefits of straight forward video games are common in classrooms (Pho & Dinscore, 2015; Trybus, 2010), and can be classified as serious games or ordinary game-based learning (Djaouti, Alvarez, & Jessel, 2011)

The following section briefly addresses serious games and game-based learning as two distinct concepts in relation to the study.

3.5.2 Serious games and game-based learning

The two concepts relate to the study, as the video game Portal could be considered a game-based learning platform, and to a lesser extent, a serious game, as the game was not intended for pure entertainment in the context of the study.

It is crucial to understand that while all serious games incorporate game-based learning, not all game-based learning can be called serious games. According to Djaouti *et al.* (2011), a serious game or applied game is a game intended for a principal purpose other than pure entertainment. The "serious" adjective is usually added to denote to video games used by industries like defence, education, scientific exploration, health care, emergency management, city planning, engineering, and politics (Djaouti *et al.*, 2011). Serious games are a sub-genre of serious storytelling, where storytelling is applied *"outside the context of entertainment, where the narration develops as an arrangement of patterns impressive in quality ... and is part of a thoughtful progress"* (Lugmayr *et al.*, 2017, p. 15707). The aforementioned description highlights the features of simulation, usually containing flight simulation and medical simulation, but also highlights the additional pedagogical value of fun and competition.

Game-based learning denotes to the appropriating of definite gaming principles and relating them to real-life settings to engross users (Trybus, 2010). The motivational psychology involved in game based learning permits students to participate with educational materials in a lively and vigorous manner (Pho & Dinscore, 2015). Game-based learning does not only involve games for students to play, it also plans for learning activities that can sequentially introduce concepts, and facilitate users towards an end objective. Old-fashioned games can integrate competition, points, incentives, and feedback loops. According to Pho and Dinscore (2015), game-based learning has become increasingly popular in higher education as a way to engage students in learning.

Subsequently, the next section provides a brief conceptualisation of what video games, as part of game-based learning, entails.

3.5.3 Video games: A conceptualisation

Rabin (2005) defines a video game as an electronic game that involves interaction with a user interface to generate visual feedback on a video device such as a television screen or computer monitor. The word 'video' in video game traditionally referred to a raster display device, but as of the 2000s, it implies any type of display device that can produce two- or three-dimensional images. Certain theorists categorise video games as an art form, but this designation is controversial (Rabin, 2005).

According to Lowood (2009), the electronic systems used to play video games are known as platforms; of which personal computers and video game consoles are examples. These platforms vary from big mainframe computers to minor handheld computing devices. Specific video games such as arcade games, house the video game mechanisms in a bulky, typically coin-operated chassis. These games were common in the 1980s in video arcades, but have gradually decayed due to the widespread availability of affordable home video game consoles (e.g., PlayStation 4, Xbox One and Nintendo Wii U), as well as video games on desktop and laptop computers and smartphones (Rabin, 2005).

The input device utilised for games, also referred to as the game controller, differs across platforms. Common controllers comprise gamepads, joysticks, mouse devices, keyboards, the touchscreens of mobile devices, and buttons, or even, with the Kinect sensor, a person's hands and body (Lowood, 2009). Players normally view the game on a video screen or television or computer monitor, or occasionally on virtual reality head-mounted display goggles. There are regularly game sound effects, music and, since 2010 voice actor lines which come from loudspeakers or headphones have been included (Miller, 2005). Some games in the 2000s include haptic, vibration-creating effects, force feedback peripherals and virtual reality headsets. In 2010, the video game industry became of increasing commercial significance, with development spearheaded chiefly by the emerging Asian markets and mobile games, which are played on smartphones. As of 2015, video games generated sales of USD 74 billion annually worldwide, and were the third-largest segment in the entertainment market of the United States of America, behind broadcast and cable television (Miller, 2005).

The following section provides a succinct overview of the history of video games.

3.5.3.1 History of video games

Table 3.3 summarises the main developments in the history of video games, and presents some examples of video games linked to the main developments.

Table 3.3: History of video games

Year	Main development trends	Examples of video games
1947 - 1972	Electronic devices with various display formats Games divided into three main categories: • Training and instructional programs; • Research programmes in fields such as artificial intelligence • Demonstration programmes intended to impress or entertain the public	OXO a tic-tac-toe computer game Tennis for Two Spacewar Pong Nim (Egenfeldt-Nielsen, Smith, & Tosca, 2015, Mirolo & Di Vano, 2013, Lowood, 2009; Rabin, 2005)
1972 - 1983	Coin-operated video games. Arcade machine games. Video games growing as a mainstream hobby.	Computer Space Magnavox Odyssey Atari's Pong Space Invaders Atari 2600 (Egenfeldt-Nielsen <i>et al.</i>, 2015; Gamer, 2007; Gee, 2003b; Kent, 2010; Lowood, 2009; Miller, 2005; Schilling, 2003; Staff, 2007; Whittaker, 2004)
1983-1998	The 1990s saw the revival and decay of arcades, the conversion to 3D video games, better-quality handheld games, and computer gaming	Doom, Pokemon Red and Blue on Game Boy Tomb Raider (Egenfeldt-Nielsen <i>et al.</i>, 2015; Miller, 2005)

Year	Main development trends	Examples of video games
1998 -2013	Mobile-phone gaming, online gaming, PC games. The launch of the top-selling Wii console, in which the user could control the game actions with real-life movement of the controller; the rise of casual PC games marketed to non-gamers; and the emergence of cloud computing in video games.	World of Warcraft Angry Birds for mobile phones Steam cloud gaming platform (Whittaker, 2004)
2013 -	The generation of consoles emerged. Better graphics, more competitive multiplayer elements emerged. New game genres emerged, such as Tower Defense games (DOTA 2 and League of Legends) and Battle Royale games (PUBG and Fortnite).	Nintendo's Wii U Nintendo 3DS, Microsoft's Xbox One, Sony's PlayStation 4 PlayStation Vita (Egenfeldt-Nielsen <i>et al.</i> , 2015; Miller, 2005; Whittaker, 2004)

The next section highlights some trends in the playing of video games.

3.5.3.2 Trends in playing video games

The Entertainment Software Association (2010) accounts that globally 17% of video game players are boys under the age of eighteen and that 36% are women over the age of eighteen, with 48% of all gamers being women of all ages. Globally, the typical age of gamers is 31. A survey of 1 102 children between 12 and 17 years of age discovered that of these children, 14% of girls and 50% of boys preferred games with an "M" (mature) or "AO" (adult-only) rating (Gentile, Saleem, & Anderson, 2007; Irvine, 2008).

In the South African context, research conducted by Amoru and Molomo (2012) revealed that both genders appear to dislike cognitively challenging games. Females seem to prefer puzzles, adventures, fighting and management games, and males prefer games with first person shooters, role playing, strategy games and competitive multi-player games. Males appear to be better at games that require mental rotation skills, and both genders seemingly benefit from video games similarly in relation to memory and perceptual organisation.

Research conducted internationally by Gentile *et al.* (2009) and Schulzke (2009) focused on the subsequent effects of video games on players. An overview of the negative and positive effects of video games follows in the subsequent sections. It was important for the researcher to consider, whether the effects of the puzzle video game that he wanted to employ in the context of the study, would not bear too many negative effects.

3.5.3.3 Video game controversies and negative effects

According to Freedman (2003), video game controversies relate to whether the content of video games alter the behaviour and attitudes of a player. Debates among scholars remain contentious and, as of yet, no clear consensus has been reached either for or against effects, whether positive or negative, in the context of video games (Etchells & Chambers, 2014).

Some negative consequences of video game playing are elucidated below.

Violence and aggression

Research suggests violent video game play relates with a temporary rise in aggression levels, and a decrease in prosocial behaviour (caring about the welfare and rights of others (Adachi, & Willoughby, 2011; American Psychological Association, 2015; Anderson & Bushman, 2001; DeWall, Anderson, & Bushman, 2011; Anderson & Dill, 2000; Bartholow, Sestir, & Davis, 2005; Funk *et al.*, 2002; Gentile & Anderson, 2003; Ferguson & Kilburn, 2009; Kirsh, 1998; Konijn, *et al.*, 2007; Kooijmans, 2004; Sherry, 2001), as well as contributing to reduced feelings of empathy (Funk, Baldacci, Pasold, & Baumgardner, 2004; Grizzard, Tamborini, Lewis, Wang, & Prabhu, 2014; Konrath, O'Brien, & Hsing, 2011)

Opposed to the aforementioned, Sherry (2007) conducted a meta-analysis of studies about video game violence, which revealed that violence and aggression as consequences of video game play, were minimal. In fact, many studies indicate no link between video game playing and aggressive behaviour (Ballard, Visser, & Joycoy, 2012; Bennerstedt, Ivarsson, & Linderöth, 2012; Bensley & Van Eenwyk, 2001; Elson, Breuer, Van Looy, Kneer, & Quandt, 2015; Ferguson, 2015; Griffiths, 2005; Kutner & Olson, 2008; McCarthy, Coley, Wagner, Zengel, & Basham, 2016; Sauer, Drummond, & Nova, 2015;

Sherry, 2001; Von Salisch, Vogelgesang, Kristen, & Oppl, 2011). In particular, nonviolent games seem to increase empathy and prosocial behaviour among the participants (Gentile *et al.*, 2009).

A study by Przybylski, Deci, Rigby, & Ryan (2014) examined the impact of violent content and frustration on hostility among video game players. In a series of experiments, Przybylski *et al.* (2014) concluded that frustration, but not violent content, increased player hostility. One longitudinal study from 2014 suggests that violent video games are associated with very small increases in risk taking behaviour over time (Hull, Brunelle, Prescott, & Sargent, 2014).

Sexual themes

Tolerance of sexual themes and content in video games differ among countries (Gabbiadini, Riva, Andrighetto, Volpato, & Bushman, 2016). Controversy over sexual themes occurred in the United States. For example, in June 2005, a complete portion of unused code was located within the main script of *Grand Theft Auto: San Andreas*, permitting the player to simulate sexual intercourse with the main character's girlfriends. This mode, entitled *Hot Coffee*, could be retrieved in the computer version via mod, and via Action Replay codes in the PS2 and Xbox versions (Thorsen, 2005). The scene was left on the disc and could be accessed by altering a few bytes of the game's code via hex editor. This feature drove the Entertainment Software Rating Board to amend the rating of *San Andreas* on 20 July 2005 to "adults only". Furthermore, the game was withdrawn from sale in several stores (Thorsen, 2005).

The game, *RapeLay*, a Japanese eroge with a plot, which focuses on the player's character stalking and raping a mother and her two daughters, also created controversy (Lah, 2010). Campaigns against the selling of the game followed, and it was prohibited in several nations. *RapeLay*'s publisher, which intended the game only to be available in Japan, removed it from distribution (Lah, 2010).

Portrayal of gender

Some researchers have stated their concerns that video games may have the effect of supporting sexist stereotypes (Miller & Summers, 2007; Walling, 2002). An older study

by Dietz (1998), found that of thirty-three games that were examined, 41% did not depict female characters, 28% sexually objectified women, 21% portrayed violence against women, and 30% did not represent the female population entirely. At present however, studies indicate in particular, an increased presence of strong female characters in video games (Hartmann & Klimmt, 2006).

Research conducted by Miller and Summers (2007) established that gender stereotypes pervade most video games: Male characters (52%) were more probable than females (32%) to participate in physical aggression; nearly 20% of female characters were hyper-sexualised in certain ways, while 35% of male characters were exceedingly muscular. Females are frequently constructed as visual objects in need of protection who wait for male liberation, whereas men are portrayed with more power.

Lesbian, gay, bisexual and transgender characters

Lesbian, gay, bisexual, and transgender (LGBT) characters have been depicted in some video games since the 1980s. LGBT content has been subject to changing rules and regulations by game companies (Sheff, 2011). These rules are generally instances of heterosexism, where heterosexuality is normalised and homosexuality is subject to additional restriction or mockery (Brathwaite, 2006). Sexual orientation and gender identity were important in some console and computer games, with the tendency being toward larger visibility of LGBT identities, particularly in Japanese popular culture (McLellan, 2000), and games marketed to LGBT consumers (Shaw, 2015).

Portrayal of race

Video games could affect the learning of young players about race and urban culture (Brophy-Warren, 2009; Everett & Watkins, 2008), and encourage prejudiced hate crime (Thorsen 2003). The portrayal of different races other than Caucasian in certain video games such as the Grand Theft Auto series, Custer's Revenge, 50 Cent: Bulletproof, and New York has been controversial (Brophy-Warren, 2009; Everett & Watkins, 2008).

Portrayal of countries

War-themed video games such as Medal of Honor: Warfighter and Call of Duty: Black Ops II have been condemned for how they depict Arab people and mainly Islamic countries like Pakistan (Brown, 2013).

Addiction

Video game addiction is the extreme or obsessive usage of computer and video games to such an extent that they inhibit normal daily life. Cases have been described in which users play impulsively, separating themselves from family and friends or from other kinds of social interaction, and focus virtually exclusively on in-game achievements rather than broader life events (Han, Kim, Lee, Min, & Renshaw, 2010; Hauge & Gentile, 2003).

Online harassment

An additional issue that can happen through gaming is online harassment or bullying (Coloroso, 2004). A particular example of harassing behaviour happening within a game can be found in Xbox Live services. With its online chat and party system, this leaves the service open to unwanted harassment, trolling, or bullying to happen between players. To address these concerns, Microsoft made improvements with reputation levels for a player's Xbox Live account. The system is set to warn, then punish bad behaviour in hopes of better regulating Xbox Live accounts (Coloroso, 2004).

Davenport (2002) concludes that the anonymous nature of the internet might be a factor of encouraging anti-social behaviour. This type of behaviour expands to other parts of the internet separate from gaming, such as online forums, social media sites, etcetera. Lack of accountability for one's actions on the internet might encourage others to engage in harassing behaviour. Without minimal threat of punishment, some might find it easier to carry out negative behaviour over online gaming (Davenport, 2002).

Criminal activity

Some shared criminal incidents comprise online casino scams, phishing, cell phone dialler's, malware in illegal downloads (Bardzell *et al.*, 2007), and money laundering (Richet, 2013).

Religion and video games

While religion is seen as a serious theme, video games are considered entertainment (Wagner, 2012). As such, the use of religion and religious themes in video games can occasionally be provocative. For example, *Hitman 2: Silent Assassin* (2002) generated controversy owing to a level presenting the killing of Sikhs within a representation of their most holy site, the Harmandir Sahib (Campbell & Grieve, 2014).

Apart from the controversial and negative connotations attached to video games, a number of positive effects are cited in the literature. The proceeding section outlines the various positive effects of video games.

3.5.3.4 Positive effects of video games

Numerous researchers assert that video games are mainly beneficial to social and cognitive development (All *et al.*, 2016; Granic *et al.*, 2014; Wouters, Van Nimwegen, & Van der Spek, 2013; Wouters & Van Oostendorp, 2017), as well as psychological well-being (Ewoldsen *et al.*, 2012; Ferguson, 2007). Some of the benefits of video games are elucidated below.

Cognitive skills

The research of Johnson and Schelsinger (2007) recognise the cognitive benefits of playing video games for pattern recognition, systems thinking, and patience (Johnson & Schelsinger, 2007). In addition, some experiments have specified increases in cognition and problem solving skills in professional gamers (Johnson & Schelsinger, 2007). A common notion is that video games are for persons who are lazy, but in reality, they benefit children with spatial navigation, reasoning, memory and perception (Greenfield, 1994; Nauert, 2013). A broader summary of the cognitive benefits of video gaming includes the following:

- Increased attentional capacity (All *et al.*, 2016; Granic *et al.*, 2014; Green & Bavelier, 2012).
- Advanced resolution in visual processing of information and improved rotation abilities (Uttal *et al.*, 2013).

- Cognitive skills gained via video games are generalised to settings outside games (Bavelier *et al.*, 2012; Granic *et al.*, 2014).
- Filtering irrelevant information more efficiently (Bavelier *et al.*, 2012)
- A study conducted by Bavelier *et al.* (2018) revealed that video game play had a strong impact on perception, spacial orientation and attention, a medium impact on the ability to multi-task, and a weak impact on inhibition and verbal cognition.
- Studies conducted by Baniqued *et al.* (2013) and Martinovic *et al.* (2014) reported that in relation to cognitive processes, video games have the strongest influence on perception, memory and executive functioning (basic cognitive processes such as attentional control, cognitive inhibition, working memory, and cognitive flexibility).

The researcher did not find any benefits specifically mentioned in relation to the development of critical thinking. It could therefore be argued that the present research aimed to address a gap in the field of research.

Visual, coordination and motor skills development

Green and Bavelier (2003) mention that action video game players have improved hand-eye coordination and visual-motor skills, such as resistance to distraction, sensitivity to information in the peripheral vision, and aptitude to count temporarily presented objects in comparison to non-players. Moreover, through the expansion of the PlayStation Move, Kinect and Wii, video games can support the development of motor skills via full body movement (Johnson, 2006).

Relief from stress

Granic *et al.* (2014) and Olson (2010) suggest that video games may offer relief from stress, and provide support in dealing with emotions, frustration, and coping with failure and anxiety in adaptive ways in order to achieve goals. As video games are a favoured pastime among many students, having a game that promotes positive emotions will help to alleviate stress in the classroom, and make the environment fun and enjoyable (All *et al.*, 2016; Connolly, Boye, MacArthur, Hainey, & Boyle, 2012; Granic *et al.*, 2014).

Physical rehabilitation

Researchers use video games to, among other things, deliver physical rehabilitation, promote disease self-management, distract from discomfort, and intensify physical activity (Primack *et al.*, 2012). In addition, research done by Scholten, Malmberg, Lobel, Engels, and Granic (2016) show that video game rehabilitation can be utilised to improve the physical health of children with developmental delays.

Education

According to Sherry (2001), teachers progressively utilise educational video games in the classroom as a motivational apparatus. Appropriate video games support children to achieve everything from basic grammar to difficult math without the drudgery of old-school flash cards (Posso, 2016; Sherry, 2001).

According to All *et al.* (2016), Connolly *et al.* (2012), and Granic *et al.* (2014), through game play students could learn to motivate themselves and push themselves to achieve goals and work harder to improve their performance academically, similarly as they would do to improve their performance and achieve the goals of their video game play.

The effect of game play on problem solving skills seems to be contentious (Bavelier *et al.*, 2018). Little training in the application of problem solving skills is given to game players and they have to explore solutions to problems by making use of previous experiences and their instincts (Granic *et al.*, 2014), as well as learn through trial and error (Prensky, 2012). Granic *et al.* (2014) consequently stress that they are not certain if games actually improve problem solving skills, or if people with better skills display better performance in solving open-ended problems in game play.

Pro-social behaviour

Some researchers theorise positive effects of playing video games in relation to prosocial behaviour (Anderson *et al.*, 2010; Benedetti, 2008; Boxer, Groves, & Docherty, 2015; Boyle *et al.*, 2016; Cumberbatch, 2004, Ferguson & Garza, 2011; Gentile *et al.*, 2007; Sternheimer, 2003). Social games that rely on interactions with other individuals could promote healthy relationships and better communication between fellow students, teachers and others outside of school. Playing violent video games have considerably

more hurtful behaviours in children than in the children who played prosocial games (Saleem, Anderson, & Gentile, 2012). Playing prosocial games affects a children's social cognition, because the games alter their attitudes (Saleem *et al.*, 2012).

Ewoldsen *et al.* (2012), Granic *et al.* (2014) and Olson (2010) suggest that video games can have the following social benefits for children, for instance, video games can deliver a topic of discussion and something over which children can connect with, and can assist them when making friends. In addition, playing video games can increase a child's self-esteem when they are struggling in one aspect of their life, but are able to do something correctly in a video game. Children can also learn to take on leadership roles within a multi-player online game (Olson, 2010).

Mental health disorders

Video games, whether they are designed to be beneficial or not, can be utilised to lower anxiety levels of those who grieve from chronic anxiety issues (Hsieh, Lee, & Lin, 2016).

Considering the positive and negative effects of playing video games in relation to the video game Portal that was used in the study, the researcher argued that mainly positive effects could be linked to the use of the video game Portal. Portal is rated for all ages, presents no obscenities and no sexual or violent game play of any kind. As the main character is a woman, it should be seen as a positive portrayal of the female gender in a main role. The purpose of the game is to solve puzzles and is designed to make one think; allowing for educational development while playing as well. The video game Portal therefore in the researcher's opinion, contains no negative aspects that could harm or offend any player (*cf.* 3.5.4.3).

As the present research focused on the application of a puzzle video game, the following section explores the puzzle video game genre and its numerous sub-genres.

3.5.4 Puzzle video games and its subgenres

Puzzle video games are a genre of video games that accentuate puzzle solving (Rollings & Adams, 2006). The types of puzzles can test several problem solving skills containing logic, pattern recognition, sequence solving, and word completion. The player may have

unlimited time or chances to solve a puzzle, or there may be simple puzzles made difficult by needing to finish them in a real-time, as in Tetris (Rollings & Adams, 2006).

3.5.4.1 Puzzle video games

Puzzle video games centre on logical and abstract tasks, though regularly the games add time-pressure or additional action-elements. While numerous action games and adventure games include puzzles such as acquiring unreachable items, a true puzzle game focuses on puzzle solving as the primary game play activity (Rollings & Adams, 2006). Puzzle games usually involve shapes, colours, or symbols, and the player must directly or indirectly manipulate them into a specific pattern (Miller, 2005).

Rather than offering a random assortment of puzzles to solve, puzzle games characteristically offer a sequence of connected puzzles that are a deviation on a single theme. This theme could include pattern recognition, logic, or understanding a process (Miller, 2005). These games typically have a simple set of rules, where players operate game pieces on a grid, network or other interaction space. Players must unravel clues in order to accomplish specific victory conditions, which will then allow them to advance to the next level. Completing each puzzle will usually lead to a more difficult challenge, although certain games avoid exhausting the player by offering easier levels between more difficult ones (Rollings & Adams, 2006).

3.5.4.2 Types of puzzle games

There is a large variety of puzzle games. Certain puzzle games feed to the player a random assortment of blocks or pieces that they must organise in the correct way, such as Tetris, Klax and Lumines (Thompson, 2007). Others present a pre-set game board or pieces, and challenge the player to solve the puzzle by achieving a goal (e.g. Bomberman, The Incredible Machine). Puzzle games are often easy to develop and adapt, being implemented on dedicated arcade units, home video game consoles, personal digital assistants, and mobile phones.

The subsequent section briefly elaborates on some examples of puzzle video games.

Action puzzles

An action puzzle or arcade puzzle requires that the player operates game pieces in a real-time setting to solve the puzzle (Nelson & Strachan, 2009). Action puzzles comprise several sub-sets of puzzle games. Firstly, it includes falling-block puzzles such as Tetris and KLAX (Nelson & Strachan, 2009). It includes games with characters moving through an environment, controlled either directly (Lode Runner) or indirectly (Lemmings) (Ward, 2005). It also includes other action games that require timing and accuracy with pattern-matching or logic skills, such as the first-person Portal (Thompson, 2007).

Hidden object game

A hidden object game (also referred to as hidden picture), is a genre of puzzle video games in which the player needs to locate items from a list that are concealed within an image (Juul, 2007).

An early hidden object game was Alice: An Interactive Museum. Computer Gaming World reported in 1993 that one disadvantage of the game was searching through screen after screen for 'switches'. After a while one develops a case of 'clickitus' of the fingers as one *"repeatedly punches that mouse button like a chicken pecking at a farmyard"* (DeMaria & Wilson, 2003, p. 2). Other early incarnations are the video game adaptations of the "I Spy" books published by Scholastic Corporation since 1997.

Publishers of hidden object games include Sandlot Games, Big Fish Games, Awem Studio, SpinTop Games, and Codeminion (Juul, 2007). Examples of hidden object game series include: Awakening, Antique Road Trip (both by Boomzap Entertainment), Dream Chronicles (PlayFirst), Mortimer Beckett (RealArcade/GameHouse), Mystery Trackers (by Elephant games), Hidden Expedition and Mystery Case Files (both by Big Fish Games) (DeMaria & Wilson, 2003).

Reveal the picture game

A reveal the picture game is a kind of puzzle game that comprises of piece-by-piece revealing of a photo or image. A free online example is PicTAPr, which divides an image into 16 square pieces (Juul, 2007).

Physics game

A physics game is a type of puzzle video game where the player needs to use the game's physics to finish each puzzle, which has science as a subject at its core. Physics games utilise realistic physics to make games more difficult (Wolf, 2008). The genre is particularly widespread in online flash games and mobile games. Teachers have used these games to demonstrate principles of physics (DeMaria & Wilson, 2003). Popular physics games include: The Incredible Machine, World of Goo, Crayon Physics Deluxe, Angry Birds, Cut the Rope, Peggle, Portal, Portal 2, and Monster Strike (DeMaria & Wilson, 2003).

Tile-matching

In tile-matching video games, the player operates tiles in order to make them vanish according to a matching condition. The genre started with 1985's Chain Shot!. It comprises games of the *"falling block"* variety such as Tetris, games that need pieces to be exchanged such as Bejeweled or Candy Crush Saga, and games in which pieces are shot on the board such as Zuma (DeMaria & Wilson, 2003). In several recent tile-matching games, the matching criterion is to place a given number of tiles of the same type so that they adjoin each other. That number is often three, and the corresponding sub-set of tile-matching games is referred to as *"match-three games"* (Wolf, 2008).

Traditional puzzle

There have also been numerous digital versions of traditional puzzle games, containing solitaire and mahjong solitaire. Even familiar word puzzles, number puzzles, and association puzzles have been modified as games such as Dr Kawashima's Brain Training (Juul, 2007).

The proceeding section will outline the Portal video game series used in the study, that could be regarded as a sub-genre of puzzle video games that comprise action elements and the application of physics principles. The game's setting and characters, as well as its game play will be presented. The concluding section discusses Portal's use in an educational setting.

3.5.4.3 Portal games

Portal is a series of first-person puzzle-platform video games designed by Valve Corporation (referred to onwards as Valve). Both Portal 1 and Portal 2 were utilised in this study. The two main games in the series, Portal (2007) and Portal 2 (2011), centre on a woman, Chell, forced to undergo a series of tests within an Aperture Science Enrichment Center performed by a malicious artificial intelligence computer, Genetic Lifeform and Disk Operating System (GLaDOS), that controls the facility (Ramadge, 2011). The aim of these tests is to determine the practical usage of a portal gun device and how it can be utilised in diverse circumstances. Each test includes utilising the **Aperture Science Handheld Portal Device** - the **portal gun** - that generates a human-sized wormhole-like link between almost any two flat surfaces (Larstuk, 2011). Players must solve physical puzzles and challenges by opening portals to manoeuvring objects, and themselves, through space (Mittell, 2012). This allows complex flinging manoeuvres (*cf.* Figure 3.3), to be used to cross wide gaps or perform other feats to reach the exit for each test chamber. A number of additional mechanics, for example lasers, light bridges, tractor funnels, and turrets (*cf.* 4.4.4), are present to support or hamper the player's objective to reach the exit.

Both games, Portal 1 and Portal 2, have obtained near-universal acclaim, and have sold millions of copies that also garnered mostly positive critical reviews (Larstuk, 2011, Mittell, 2012). In addition to the challenging puzzle elements, both games are praised for their dark humour, and musical songs (Mittell, 2012). A number of spin-off media have been developed alongside the games, and several of the game elements have become parts of Internet memes (Ramadge, 2011).

Setting and characters

The Portal games take place in the fictional **Aperture Science Enrichment Centre**. Aperture Science was created by the fictional character, Cave Johnson, who initially made shower curtains for the United States military. Following his success with the making of shower curtains, he began to focus on experimental physics as a new direction. Johnson attained the rights to an empty salt mine in the Upper Peninsula of Michigan, where they started construction of a complex set of underground offices, laboratories,

facilities, and test chambers for research and experiments. Ultimately, Johnson's research chanced upon the innovation of portal technology that included developing a prototype to the Portal Gun that Chell wields (*cf.* Figure 3.2). Johnson's experiments, which were mostly dangerous and lethal, involved the country's finest, as well as paid volunteers, and he eventually compelled his own personnel to join in portal testing (Ramadge, 2011).

During his experimentation, Johnson became poisoned from exposure to moon dust, a key component of the paint needed for the portal technology, and became increasingly deranged (Larstuk, 2011; Nunneley, 2011). Close to the point of his death, Johnson ordered his lifelong associate Caroline, to be the first test subject for a mind-to-computer transfer. Her personality would ultimately form the core of GLaDOS.

A certain period after Johnson's death, the old sections of the facility were vitrified, and a more contemporary facility constructed above those remnants. GLaDOS had to manage the facility and observe the tests, but researchers found that GLaDOS had wicked inclinations, threatening to kill the whole staff before it [GLaDOS] was shut down in time (Mittell, 2012).

The Aperture researchers built a number of "personality cores" that could fit onto GLaDOS to inhibit her from turning against them. The first game contains three cores, the Morality, Curiosity, and Intelligence Cores (Leone, 2010). In Portal 2, three more such cores are presented comprising the irrelevant Fact Core, the brave Adventure Core, and the space-obsessed Space Core (Mittell, 2012).

Notwithstanding this, on the day GLaDOS was formally activated (coincidentally on Take Your Daughter to Work Day), she turned against the researchers and murdered almost everybody in the facility with deadly amounts of neurotoxin gas. One employee Doug Rattmann lived due to his schizophrenia and suspicion of GLaDOS (Leone, 2010). In trying to find a way to overthrow GLaDOS, he discovered Chell, one of the human subjects with a high level of tenacity who was kept in cryogenic storage within the Aperture centre, and arranged for the events of Portal to happen by moving her to the top of GLaDOS' testing list.

The player-character Chell is woken by GLaDOS for testing (Mittell, 2012). Chell repels GLaDOS' lies and verbal tricks and succeeded to overthrow GLaDOS' core, which generated a devastation that generated a portal implosion and sent Chell to the surface, unconscious (Ramadge, 2011). Rattmann, a minor character, who aided Chell by writing warning messages and instructions to maintenance areas on the facility walls, and had witnessed the final encounter, escaped the Aperture. On escaping, he observed a robot dragging Chell's body back into the facility. He sacrificed his escape to guarantee that Chell is put back into unspecified cryogenic storage (Leone, 2010). He himself is critically injured but seems to make it to an alternative cryogenic chamber, though his ultimate fate is not revealed.

Portal 2 takes place many years later after the proceedings of the first game (twelve years after Aperture Science Abandonment). The Aperture facility has collapsed into disrepair without GLaDOS. One of the personality cores named Wheatley, awakened Chell from her sleep but unintentionally roused GLaDOS, who had redundantly backed up her [GLaDOS] personality (Ramadge, 2011). Though they [Chell and Wheatley] overthrow GLaDOS by putting Wheatley in the place of GLaDOS, Wheatley is overcome with power, and transported Chell and GLaDOS (temporarily reduced to a small computer powered by a potato), to the old core of Aperture where GLaDOS remembered her connection to Caroline, the old personal assistant of Cave Johnson, the creator of Aperture Science (Mittell, 2012). They [Chell and GLaDOS] return to the surface where they are obliged to overthrow Wheatley, before Wheatley's incompetence with the Aperture systems causes the facility reactors to become dangerous and detonate. GLaDOS is reverted to her correct place and returns the facility to normal. GLaDOS then allows Chell to leave the facility, recognising that the idea of trying to kill her is too much of an inconvenience, and turns to two robots of her own creation, Atlas and P-Body, to locate a mythical store of additional human subjects kept in cryogenic sleep for her to continue testing on (Leone, 2010). Chell however, had to find a way out of a number of chambers.

Game play of Portal

In Portal, the player controls Chell (Figure 3.2), who is challenged to find a way out of a number of chambers using the Aperture Science Handheld Portal Device, or portal gun, under the watchful supervision of GLaDOS (Figure 3.2). In order to find her way out, Chell

has to complete puzzles in the different chambers using the portal gun, with the proposition from GLaDOS of receiving cake when all puzzles are complete.



Figure 3.2: Chell and GLaDOS

Some important Portal game principles observed by Bramwell (2007), Larstuk (2011) and Shute, Ventura, & Ke (2015) comprise the following:

- With the portal gun it is possible to create two orange and blue portal ends that enable a visual and physical connection between two sites in three-dimensional space. The portal ends are regarded as entrances or exits. If an object enters through one portal, it will exit through the other.
- Some physics principles play an important role in the game, namely the redirection of momentum. According to this principle, a moving object will pass through an exit portal in the same direction that the exit portal is facing. The object will also exit the portal with the same speed with which it passed through the entrance portal (Shute *et al.*, 2015). In the game itself, the player can jump down to a portal on the floor, and emerge through a wall, flying over a gap or another obstacle. This allows the player to launch objects, or Chell, over great distances in a vertical and horizontal direction, referred to as flinging in the context of the game (*cf.* Figure 3.3). Generally, one uses gravity to build up one's momentum when one falls into a portal, which flings one out of the other side to gain speed and distance, that could not be generated by normal jumping and

running. A leapfrogging effect can be used by placing portals in series during this flinging, gaining further momentum with each use (Shute *et al.*, 2015).

- If portal ends are not on lateral flat surfaces, the player will be reoriented in an upright position when passing through with respect to gravity after leaving a portal end.
- Chell and all other objects in the game that can fit into the portal ends will pass through the portal. A portal shot cannot pass through an open portal; but will deactivate or create a new portal in an offset position. If a portal end is created, an existing portal of the same colour is deactivated.
- Each Portal chamber has an exit door that must be found, frequently necessitating that certain circumstances have been met such as having weighed down a large button with a **Weighted Cube** (*cf.* 4.4.4), effectively (Larstuk, 2011). Solving the puzzling situations to reach an exit door requires the use of the **Aperture Science Handheld Portal Device**, the portal gun. The gun can shoot two portals, coloured differently for identification (*cf.* Figure 3.3), on any flat surface that is painted with a specific paint containing moon dust. Once both portal ends are placed, the player can walk the character between them, or carry objects with the portal gun through them.
- Moving objects, glass, special wall surfaces, liquids, or areas that are too small will not be able to hold portals securely. Chell can sometimes use cubes to climb on, or press down large buttons that open doors or activate mechanisms.
- Portal ends can be repositioned as often as necessary, but certain actions, such as walking through **Emancipation Grills** (*cf.* Figure 4.3) will cause the portals to disappear (Larstuk, 2011). Emancipation grills, exist at the end of all, and within some of the test chambers. Passing through an emancipation grill will deactivate active portals and decompose any object moving through. They also do not enable portals to be fired through.
- Chell can be killed by various other threats in the test chambers, such as turret guns, bouncing balls of energy, and toxic liquid (*cf.* Figures 4.3, 4.4). She can also be killed by objects falling through portals, and by crushers that appear in certain levels. Portals will also permit light and other items to move through them, and several puzzles encompass the use of portals to control rebounding energy balls, lasers, bridges, and tractor beams to access different places or direct items to particular containers that

must be triggered to expose the level's exit (Larstuk, 2011). Portal 2 introduces **Mobility Gels** (cf. Figure 4.4) that can paint surfaces, including turrets and cubes, that can move through portals though not directly by the player. The gels can create a surface that repels the player (Repulsion Gel), increases the player's speed (Propulsion Gel), or allows the surface to accept portals (Conversion Gel) (Shute *et al.*, 2015).

- As the game proceeds, the challenges become more complicated, and puzzles have to be solved either with as little time, the fewest footsteps, and the least number of portals, possible. Levels are also made more complex by adding more obstacles to overcome.
- Portal is played by using flinging (Shute, *et al.*, 2015) in order to get to unreachable positions that one cannot get to without using this technique. Two examples of flinging within Portal are depicted in Figure 3.3 below.

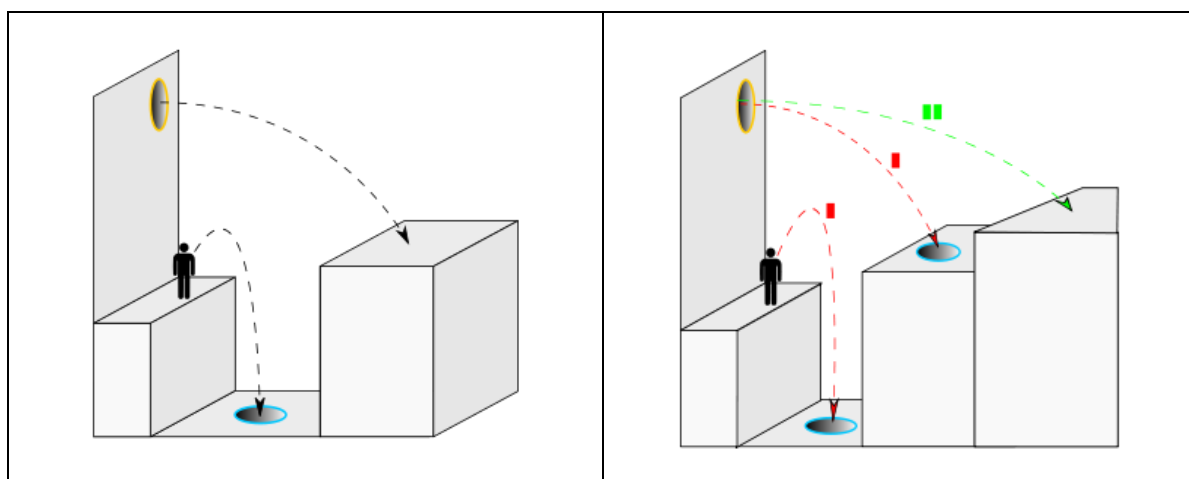


Figure 3.3: Flinging in Portal

On the left, the player has positioned portals on the floor of the ditch and the wall overhead. By hopping into the blue one in the ditch, they will exit the orange one with the same degree of speed, clearing the ditch and landing on the other end (Shute *et al.*, 2015). On the right, the player has primarily positioned the blue portal in the ditch and the orange on the wall. Subsequently jumping into the blue and exiting the orange (red path), they use the portal gun to position the second blue one on the ledge, acquiring more momentum before dropping into it and exiting the orange portal with more velocity (green track) as to land on the higher platform (Shute *et al.*, 2015).

- The player manipulates the central character Chell by running, jumping, and interacting with switches or other devices. The player-characters are able to endure great drops, but can be killed by falling in the toxic water of the facility, crushed to death, passing through laser grids, or shot at constantly by turrets (Shute *et al.*, 2015).

Portal in education

The use of Portal games has been established in educational settings outside of game development. The first game was acclaimed as a model of instructional scaffolding where the student is initially given an environment to learn new tools with adequate hand-holding, but these facets are gradually taken away as the student proceeds (Schiller, 2008). One college, Wabash College in Crawfordsville, Indiana, introduced Portal as part of required coursework. The game was used as an example of Erving Goffman's dissemination on dramaturgy, *The Presentation of Self in Everyday Life* (Yamasaki, 2016).

Gabe Newell, the Chief Executive Officer of Valve, detailed Valve's purpose to direct Portal and Portal 2 concerning education. Newell specified that Valve *"doesn't see [a] divide between making a game that can do well and be educational"* (in Klepek, 2011, p. 2012). Valve works with schools to design lesson plans with the game in mind. In one instance, Valve brought in students to observe them interacting with the game in an educational environment (Goldman, 2010), and endorsed Portal for free use by any user during September 2011 (Pittman, 2013).

At the 2012 Games for Change Festival, Newell (in Klepek, 2011, p. 2012) said that the reply to efforts to direct Portal towards education, was commended by teachers. Efforts included a *"Teach with Portals"* programme that was publicised at the Festival. The effort is assembled on a standalone *"Puzzle Maker"* that integrates the level editor for Portal 2 that was released as free content for the game in early 2012. Valve constructed the *"Puzzle Maker"* with the assistance of teachers, as to make it suitable for lesson plans. The *"Puzzle Maker"* is not limited to physics, but designed to be modular so that other fields, such as fundamental electronics or chemistry, could be included (Yamasaki, 2016).

The following section outlines the possibility of developing critical thinking skills, dispositions and standards for reasoning with Portal.

3.5.5 Developing critical thinking skills with Portal

According to Rice (2007), higher order, critical thinking is essential for working in a virtual interactive environment (VIE) presented by puzzle video games, such as Portal. Cognitive VIEs are software products intended to foster higher order thinking by users.

Rice (2007) asserts that **virtual** implies that intricate three-dimensional graphics are utilised to create a form of Virtual Reality (VR) that McLellan (2002, p. 457) demarcates as “*through the window*,” or “*desktop VR*”. The characteristics of complex three-dimensional virtual environments set apart cognitive VIEs from more basic computer games. Computer text-based games, which do not include graphics at all, would not be labelled VIEs owing to their lack of VR elements (Rice, 2007).

Games which integrate two-dimensional, or basic three-dimensional graphics with slight interaction would also not be considered VIEs, or at least not cognitive VIEs (Rice, 2007). However, the complex nature of intricate three-dimensional environments offers numerous affordances for students to participate in higher level learning (Rice, 2007). The concept of affordances that point to how things work in the environment becomes apparent through sensory prompts (Gibson, 2014). According to McLellan (2002), Gibson’s theory of affordances specifies active perception and exploration happening in virtual environments, and rendering them beneficial as a teaching tool.

Interactive specifies that participation necessitates broad player interaction, typically involving reading, clicking on appropriate icons, appropriate mouse manoeuvres, controlling virtual objects, keyboard input, and feasibly speech and hearing interaction (Rice, 2007). The interaction is not merely for mechanical effects (as in arcade games) but it develops mental processes, triggering the player to vigorously learn novel knowledge and combine existing knowledge for new purposes (Gee, 2003b). Some or most of the interaction might (but not prerequisite by definition), include other people or programmed nonplaying characters (NPCs) also existing in the gaming environment (Rice, 2007).

Environment indicates the context within which the game takes place. Cognitive VIEs will have intricate virtual environments permitting consistent interaction over long periods of time, such as Portal (Rice, 2007). The environments will regularly be virtually

enormous, highly engaging, and will permit and inspire players to explore comprehensively (Rice, 2007). The environment might integrate features of a virtual community such as those found in persistent worlds, or massively multiplayer online role playing games. Moreover, a cognitive VIE will frequently include features of a narrative, to better position students within the environment and help in their suspension of disbelief (Laurel, 1991; Ryan, 2001).

Most of the VIEs teachers will come into contact with are commercially designed software games, such as Portal. VIEs are occasionally known as simulations (Rice, 2007), that involve the unfolding of a case study in a social or physical reality, with participants playing legitimate roles linked to responsibilities and constraints (Gredler, 2004). The interactions inside the environment frequently could be considered high fidelity simulations (Rice, 2007). Gredler (2004) continues, that a high fidelity simulation models interaction between a student and a complex real-life situation, and indicates that the simulation offers abundant data and feedback to players, permitting numerous means of completion (Rice, 2007).

It ought to be noted that the distinction amongst simple computer games and cognitive VIEs is crucial. The significant distinction is that cognitive VIEs deliver appropriate opportunities for complex interactions, making them applicable environments within which higher order learning (such as the development of critical thinking) could happen (Rice, 2007). Numerous popular titles, such as strategy games like Age of Empires or Portal in the video game marketplace could be thought of as cognitive VIEs (Rice, 2007).

Gee (2003a) argues that VIE computer games engross students in two foundational cognitive tenets, namely the competence principle and the expertise principle. Positive computer games coerce players to work hard toward conclusion, providing opportunities for achievement that are challenging to attain, but not completely unattainable (Rice, 2007). Players are inspired by extreme stimulating and frustrating engagement, as this type of engagement leads to improved learning opportunities (Rice, 2007).

Commercially successful games engage users in the expertise principle by compelling them to entirely absorb required details in order to be successful (Rice, 2007). Many computer games necessitate total mastery of a particular level before allowing the user

to proceed to a following level (Rice, 2007). The video game Portal also requires that each level be mastered before proceeding. Complete mastery of gaming elements, demonstrates use of the expertise principle (Gee, 2003a). Research conducted by Shute, *et al.*, 2015) specifically point to the merits of Portal 2 in relation to developing expertise in problem solving, spatial skills, and persistence.

The researcher is not aware of any merits of Portal for nurturing the critical thinking dispositions and standards for reasoning, mentioned in the literature. It is therefore the intention of this study to explore the potential of Portal to also develop those dispositions and standards for reasoning that are crucial for critical thinking.

The following section summarises the gist of Chapter 3.

3.6 CHAPTER SUMMARY

The chapter began with a discussion on teaching for critical thinking in formal, informal and non-formal learning contexts (*cf.* 3.2.1, 3.2.2), as they all applied to the context of the research. Learning in a formal context refers to organised and chronologically graded learning linked to a formal curriculum, and takes place in an educational institution. Informal learning does not include a formal curriculum and can be regarded as experiential learning (*cf.* 3.2.3.5), that involves learning from daily life activities and experiences in the environment. The environment can include family, neighbours, play, the library, mass media, and video games. Non-formal learning does not lead to a formal qualification, but develops and enhances knowledge and skills through among others, attending workshops and seminars. Interest usually drives involvement in non-formal learning.

A number of theories of teaching and learning and their relation to the development of critical thinking (*cf.* 3.2.2) were foregrounded. Behaviourism (*cf.* 3.2.3.1) can be summed up as dealing with student behaviour and how to manipulate it through conditioning. Cognitivism (*cf.* 3.2.3.2), can be described as a theory that focuses on assisting students to develop thinking skills for selecting, assessing and manipulating information. Constructivism (*cf.* 3.2.3.3) is grounded in the notion that students construct their own meaning and understanding through scaffolding instruction and active involvement in learning. Transformative learning theory (*cf.* 3.2.3.4) posits that individuals change their

frames of reference by critically reflecting on their assumptions and beliefs and consciously make and implement plans that bring about new ways of defining their worlds. Experiential learning theory (*cf.* 3.2.3.5) focuses on learning through experiences and hands on learning, while reflecting on the learning action. Structural cognitive modifiability (*cf.* 3.2.3.6) emphasises that a human being is open, adaptive and amenable for change via learning in any context. According to mediated learning a mediator organises the learning environment for the student to optimise conditions for effective learning (*cf.* 3.2.3.7). Tangential learning is built on the premise that learning involves self-education when the learning context contains elements of enjoyment (*cf.* 3.2.3.8). Transfer of learning theory postulates that it is possible to transfer the application of a skill acquired in one context to another similar context (near transfer). In addition, the application of a skill can also be applied to another context that differs from the one in which the skill was acquired (far transfer) (*cf.* 3.2.3.9). The researcher found that all the theories, except for behaviourism, had tenets that related to the implementation of the PVG-CEP intervention (*cf.* 4.3.1.1).

The various teaching methods and strategies to develop critical thinking were discussed (*cf.* 3.3). Direct teaching methods and strategies (*cf.* 3.3.1) refer to a teacher-centred approach to teaching, which views students as passive recipients of knowledge. In contrast to direct teaching, indirect teaching methods and strategies (*cf.* 3.3.2) support cognitive and constructivist learning theory, which involves a more student-centred approach to teaching, and views students as active participants in the learning experience. Independent instruction (*cf.* 3.3.3) that emphasises problem solving and enquiry-based learning, supports cognitive and constructivist learning theory, according to which students have to acquire cognitive skills to independently select, assess and manipulate information. Problem solving and enquiry-based learning can be utilised to develop critical thinking and self-directed learning skills. The interactive teaching method and strategies (*cf.* 3.3.4) view learning as a social construct that involves students cooperating with each other in group settings. Some of the strategies that could promote the development of critical thinking dispositions and standards for reasoning involved working according to clearly defined success criteria, checking for correctness and reflection guided by questions (*cf.* 3.3.5).

The chapter explored some characteristics of classrooms conducive to the development of critical thinking (*cf.* 3.4.1). These characteristics include the asking of frequent evaluative questions, encouragement of active learning and developmental tension (*cf.* 3.4.1.1 – 3.4.1.3), which were made visible by the researcher during the implementation of the PVG-CEP intervention.

The final section of the chapter comprised a detailed analysis of the role of serious games and game-based learning to develop critical thinking (*cf.* 3.5). Serious games or applied games are games intended for a principal purpose other than pure entertainment, while game-based learning denotes to the appropriating of definite gaming principles and relating them to real-life settings. Game-based learning does not only involve producing games for students to play, but also planning learning activities that can introduce concepts, and facilitate users towards achieving an end objective (*cf.* 3.5.2).

A summary of the role of video games to develop critical thinking (*cf.* 3.5.3) revealed two schools of thought, namely one that highlights controversies and negative effects such as violence, aggression, bullying, sexism (*cf.* 3.5.3.3), and another that emphasises the educational value of games, their cognitive and emotional benefits, and potential to relieve stress, and promote pro-social behaviour (*cf.* 3.5.3.4).

A discussion on puzzle video games, which is a genre of video games that emphasises puzzle solving that includes the application of logic and pattern recognition (*cf.* 3.5.4), clarified its relevance for education. Puzzle video games comprise a number of sub-genres, namely action puzzles, hidden object games, reveal the picture games, physics games, tile matching, traditional puzzles (*cf.* 3.5.4.2), and portal games (*cf.* 3.5.4).

Playing the Portal game (*cf.* 3.5.5, 3.5.4.3) mainly involves the player playing as a test subject named Chell, who needs to traverse a series of test chambers in order to escape a facility controlled by an Artificial Intelligence called GLaDOS. The primary function of this game is to solve puzzles in the test chambers using a handheld portal device, which can be fired onto specific surfaces. Two coloured portals can be fired from this device, visually represented by two distinct colours, orange and blue. These portals are linked, meaning that if you go through the orange portal, you will exit the blue portal. This,

combined with several puzzle mechanisms, lead to novel and challenging puzzles that need to be solved using critical thinking.

Finally, arguments were presented for using Portal to develop critical thinking. Some of these arguments included Cognitive VIEs, which are software products intended to foster higher order thinking, such as critical thinking, by users. The researcher believes that Portal is an example of a puzzle video game played in a VIE (Rice, 2007) (*cf.* 3.6.4.3).

The next chapter, Chapter 4, discusses the specific details surrounding the implementation of the PVG-CEP intervention utilised in the study.

CHAPTER 4

THE PUZZLE VIDEO GAME – COGNITIVE ENRICHMENT PROGRAMME (PVG-CEP)

4.1 INTRODUCTION

This chapter provides a synopsis of the PVG-CEP intervention that was employed in the context of the research, and reports on the subsequent issues.

4.2 Intervention research

- 4.2.1 The purpose of intervention research
- 4.2.2 The stages of intervention research

4.3 The nature of the Puzzle Video Game – Cognitive Enrichment Programme

- 4.3.1 The focus of the PVG-CEP
- 4.3.2 The theoretical framework underpinning the design and implementation of the intervention programme
- 4.3.3 The teaching methods and strategies utilised during the implementation of the intervention programme
- 4.3.4 The implementation features of the PVG-CEP

4.4 Game instruction to the research participants

- 4.4.1 Mechanics
- 4.4.2 Devices: Handheld portal device
- 4.4.3 Structures
- 4.4.4 Test chamber mechanics
- 4.4.5 Teaching and learning principles underpinning the playing of Portal

4.5 Observation and assessment criteria

4.6 Chapter summary

As the focus of the study was on establishing the potential benefits of a PVG-CEP for the development of critical thinking among first-year BEd students, a discussion regarding the details of the intervention needed to be carried out, in order to locate the intervention

within the different phases that intervention research comprise of. The next section provides detailed information about the intervention.

4.2 INTERVENTION RESEARCH

4.2.1 The purpose of intervention research

De Vos and Strydom (2011) and Fraser, Rishman, Galinsky, & Day (2009) concur that intervention research involves studies that create and test approaches that provide human services. In this study, the intervention programme aimed to provide a human service by helping students to develop their critical thinking skills (*cf.* 2.3.2), critical thinking dispositions (*cf.* 2.3.3), and standards for reasoning (*cf.* 2.3.6) during the intervention.

The ensuing section will explain the six stages of intervention research, as they applied to the present research.

4.2.2 The stages of intervention research

Intervention research encompasses six stages (De Vos & Strydom, 2011). In the context of the research study, the researcher applied the first four stages. For the purpose of comprehensiveness, all the stages comprising intervention research will be shortly clarified underneath.

4.2.2.1 Stage 1: Problem analysis and project planning

Identifying and involving clients

According to De Vos and Strydom (2011), intervention research involves an issue of contemporary interest to the researcher, as well as clients/participants in society. In this study, the clients/participants assisted by the intervention were the first-year BEd student teachers whose critical thinking skills, based on the W-GCTA pre-test results, (*cf.* 6.3, 6.4) seemed to be in need of development. Critical thinking skills are important for students at Higher Education level to among others, solve problems, engage in argumentation, and analyse and evaluate information (Grosser & Nel, 2013) (*cf.* 1.1), and could therefore be regarded as an issue of contemporary interest.

Gaining entry and cooperation from settings

De Vos and Strydom (2011) agree that cooperation and collaboration with the participants, aid in providing a sense of ownership of the research study. Discussions with the potential participants support the participants in understanding what is being proposed and what the likely benefits are. An independent person, selected by the researcher, announced to all potential participants (BEd first-year students), that the PVG-CEP would be offered to four purposively selected and willing participants during the first semester (*cf.* 5.6). A description of what the intervention would involve and the reason for taking part in the intervention followed. The response from the potential participants was very optimistic as they understood that this intervention strategy might be of great benefit to them in their current and future studies.

Identifying concerns of the population

De Vos and Strydom (2011) clarify that researchers must circumvent projecting external and personal viewpoints of problems and solutions, and ought to focus on issues of significance to the population and subsequently to the community instead. The researcher acknowledges that the current study bears significance for the development of critical thinking among students at school, as well as for student teachers at tertiary level. The researcher argues that student teachers need to become critical thinkers themselves before they will be able to teach the students whom they will teach one day to think critically. Presently, the CAPS objectives that have to be achieved at school level, of which the development of critical thinking skills forms part, appear to not be achieved, which is disconcerting for the population at large (*cf.* 1.1).

Analysing concerns or problems identified

The follow questions should facilitate the procedure of analysing a problem on which an intervention wishes to focus: *“What is the nature of the problem? What are the negative and positive repercussions of the problem for the population and community? Who will benefit? and How will the participants benefit?”* (De Vos & Strydom, 2011, p. 478).

In relation to the questions above, the researcher responded as follows. The CAPS was implemented in 2011 and intends to explicitly produce students who are able to identify

and solve problems and make decisions using critical and creative thinking. The CAPS implementation has mostly shifted teaching from being largely knowledge-driven to being more student-centred and problem based, that necessitates the application of critical thinking skills, which several teachers seemingly find problematic to teach (*cf.* 1.1).

In order to execute the thinking processes that underpin the CAPS curriculum objectives effectively, dispositions such as accuracy, persistence, perseverance, open-mindedness, and self-confidence in reasoning are also required (*cf.* 2.3.3). In addition, the execution of all thinking should adhere to universal standards for reasoning, namely logic, clarity, breadth, depth, significance and clarity (*cf.* 2.3.6).

The direct benefits for participants will probably be the following:

- They might acquire critical thinking skills, dispositions and standards for reasoning with the PVG-CEP to enable them to think critically more effectively.
- Another benefit could be that participants might become acquainted with a strategy (puzzle video games) that they could use when they start teaching, to encourage the development of critical thinking.

Setting goals and objectives

The final process in Stage 1 is to set attainable and quantifiable goals and objectives. Goals refer to the outcomes desired by the community. Objectives refer to the explicit changes in programmes or practices to attain the envisioned goals (De Vos & Strydom, 2011).

In this research study, the main aim of the research was to investigate the merits of the PVG-CEP for enhancing the development of critical thinking skills, dispositions and standards for reasoning (*cf.* 1.5).

4.2.2.2 Stage 2: Information gathering and synthesis

Using existing information sources

De Vos and Strydom (2011) as well as Fraser and Galinsky (2010) agree that the literature review consists of an examination of selected empirical research and reported

practice to categorise probable resources, risks, as well as promotive and protective factors connected to the particular problem being studied. De Vos and Strydom (2011) specify that intervention research ought to contribute to the development of new knowledge and insight about a topic under investigation.

The researcher consulted a number of research studies related to the development and improvement of the critical thinking skills that focused on pre-service teachers. Various studies document the effects of specific teaching strategies on the development of critical thinking skills of pre-service teachers. None of the studies, however, documents the merits of puzzle video games (*cf.* 1.1) for developing critical thinking among pre-service teachers. Research evidence proposes that complex puzzle video games afford participants exceptional participatory learning, along with opportunities to participate in higher order thinking skills, such as critical thinking (Rice, 2007) (*cf.* 3.5.4.3).

De Vos and Strydom (2011) indicate that studying natural cases is a valuable source of information. Interviews for example, with individuals who have experienced this problem/issue, offer perceptions into which interventions might be effective and which variables must be considered (De Vos & Strydom, 2011).

In this research study, the opinions of colleagues within the Faculty of Education at the North-West University who observed the same lack of critical thinking skills, dispositions and standards for reasoning among students, in conjunction with the literature review conducted, additionally served as natural examples that highlighted the need to focus this research on the development of critical thinking skills, dispositions and standards for reasoning.

Identifying functional elements of successful models

Once information has been gathered, researchers ought to analyse previous efforts and programmes to solve problems or issues, and recognise possibly valuable elements in previous efforts that could be incorporated into a new intervention (De Vos & Strydom, 2011; Fraser & Galinsky, 2010).

The researcher could not find any indication of other efforts that were successful in developing the critical thinking and problem solving skills of pre-service teachers using

Portal. A number of international studies however indicated that purposeful efforts to utilise video games for cognitive stimulation appear to be effective (All *et al.*, 2016; Bavelier *et al.*, 2012; Bavelier *et al.*, 2018; De Araujo *et al.*, 2015; Granic *et al.*, 2014; Hung *et al.*, 2012; Kadam *et al.*, 2012; Lin & Chen, 2016; Smith & Middleton, 2003; Wouters & Van Oosterndorp, 2017). The researcher also identified two studies that indicated that the use of games mainly advances lower cognitive skills such as perception and memory (Baniqued *et al.*, 2013; Martinovic *et al.*, 2014), as higher order thinking skills for example, critical thinking skills, appear difficult to measure (Arias, 2014).

Given the limited research studies internationally and nationally that testify to the effective development of critical thinking skills, dispositions and standards for reasoning through the use of puzzle video games, the researcher decided to explore the merits of, in particular, the Portal puzzle video game for developing critical thinking skills, dispositions and standards for reasoning among pre-service teachers. The researcher argued that his study could make a contribution to theoretical knowledge in the field of critical thinking development.

4.2.2.3 Stage 3: Design

De Vos and Strydom (2011) contend that researchers need to design a way of observing the procedures related to the problem/issues, discover a method to conclude the extent of the problem/issues and identify the results once the intervention has been applied.

Quasi experimental research within an embedded mixed method experimental research design (Creswell, 2014) was utilised within this study (*cf.* 5.4). The four participants in the experimental group received the PVG-CEP, once a week for two hours across 13 weeks. A number of data collection instruments were employed to establish the merits of the PVG-CEP for developing critical thinking skills, dispositions and standards for reasoning. The W-GCTA pre-test and post-tests prior to and after the implementation of the PVG-CEP were administered by an independent psychologist to the participants of the experimental and control groups. Observations were also conducted during the course of the implementation of the PVG-CEP, and the researcher was assisted by a co-observer in order to provide a source of verification for the data gathered. Follow-up one-on-one semi-structured interviews were also conducted with the experimental group after the

completion of the PVG-CEP, to gauge their perceptions regarding their experiences with the PVG-CEP (*cf.* 5.7).

The following procedural programme was followed during the first semester of 2018, across 13 weeks with individual time slots for the four participants in the experimental group, as indicated in Table 4.1 below. Due to time constraints, the participants in the control group did not receive the PVG-CEP intervention.

Table 4.1: PVG-CEP procedural programme

Participant	Recruitment	Pre-test data	Intervention programme					
			Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Participant 1	09-Feb-18	16-Feb-2018	19-Feb-2018	26-Feb-2018	5-Mar-2018	12-Mar-2018	19-Mar-2018	26-Mar-2018
	09:00	09:00	8:00-10:00	8:00-10:00	8:00-10:00	8:00-10:00	8:00-10:00	8:00-10:00
	11B - 123	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101
	Recruitment	W-GCTA Test	Introduction to Portal	Portal 1 chamber 0 - 9	Portal 1 chamber 10-19	Portal 2 Chapter 1	Portal 2 Chapter 2	Portal 2 Chapter 3
Participant 2	09-Feb-18	16-Feb-2018	21-Feb-2018	28-Feb-2018	7-Mar-2018	14-Mar-2018	21-Mar-2018	28-Mar-2018
	09:00	09:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00
	11B - 123	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101
	Recruitment	W-GCTA Test	Introduction to Portal	Portal 1 chamber 0 - 9	Portal 1 chamber 10-19	Portal 2 Chapter 1	Portal 2 Chapter 2	Portal 2 Chapter 3
Participant 3	09-Feb-18	16-Feb-2018	22-Feb-2018	1-Mar-2018	8-Mar-2018	15-Mar-2018	22-Mar-2018	29-Mar-2018
	09:00	09:00	9:00-11:00	9:00-11:00	9:00-11:00	9:00-11:00	9:00-11:00	9:00-11:00
	11B - 123	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101
	Recruitment	W-GCTA Test	Introduction to Portal	Portal 1 chamber 0 - 9	Portal 1 chamber 10-19	Portal 2 Chapter 1	Portal 2 Chapter 2	Portal 2 Chapter 3
Participant 4	09-Feb-18	16-Feb-2018	22-Feb-2018	1-Mar-2018	8-Mar-2018	15-Mar-2018	22-Mar-2018	29-Mar-2018
	09:00	09:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00
	11B - 123	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101
	Recruitment	W-GCTA Test	Introduction to Portal	Portal 1 chamber 0 - 9	Portal 1 chamber 10-19	Portal 2 Chapter 1	Portal 2 Chapter 2	Portal 2 Chapter 3

	Intervention programme							
Participant	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week13	Post-test data
Participant 1	7-May-2018	14-May-2018	21-May-2018	28-May-2018	4-Jun-2018	11-Jun-2018	18-Jun-2018	22-Jun-2018
	8:00-10:00	8:00-10:00	8:00-10:00	8:00-10:00	8:00-10:00	8:00-10:00	8:00-10:00	09:00
	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101
	Portal 2 Chapter 4	Portal 2 Chapter 5	Portal 2 Chapter 6	Portal 2 Chapter 7	Portal 2 Chapter 8	Portal 2 Chapter 9	Portal 2 Co-op	W-GCTA Test
Participant 2	9-May-2018	16-May-2018	23-May-2018	30-May-2018	6-Jun-2018	13-Jun-2018	20-Jun-2018	22-Jun-2018
	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	09:00
	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101
	Portal 2 Chapter 4	Portal 2 Chapter 5	Portal 2 Chapter 6	Portal 2 Chapter 7	Portal 2 Chapter 8	Portal 2 Chapter 9	Portal 2 Co-op	W-GCTA Test
Participant 3	10-May-2018	17-May-2018	24-May-2018	31-May-2018	7-Jun-2018	14-Jun-2018	21-Jun-2018	22-Jun-2018
	9:00-11:00	9:00-11:00	9:00-11:00	9:00-11:00	9:00-11:00	9:00-11:00	9:00-11:00	09:00
	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101
	Portal 2 Chapter 4	Portal 2 Chapter 5	Portal 2 Chapter 6	Portal 2 Chapter 7	Portal 2 Chapter 8	Portal 2 Chapter 9	Portal 2 Co-op	W-GCTA Test
Participant 4	10-May-2018	17-May-2018	24-May-2018	31-May-2018	7-Jun-2018	14-Jun-2018	21-Jun-2018	22-Jun-2018
	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	11:00-13:00	09:00
	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101	11B - 101
	Portal 2 Chapter 4	Portal 2 Chapter 5	Portal 2 Chapter 6	Portal 2 Chapter 7	Portal 2 Chapter 8	Portal 2 Chapter 9	Portal 2 Co-op	W-GCTA Test

4.2.2.4 Stage 4: Developing a prototype or preliminary intervention

De Vos and Strydom (2011, p. 483) agree that this phase includes the “*development of a prototype or preliminary intervention concept, carrying out a pilot test and applying design criteria to the intervention concept*”.

During this phase, the researcher initiated the intervention programme to establish preliminary findings regarding its merits for developing critical thinking.

Conducting a pilot test

De Vos and Strydom (2011) and Fraser and Galinsky (2010) emphasise that pilot tests are designed to conclude whether an intervention will be effective. Pilot tests assist in determining the effectiveness of the intervention programme. Any problems, which could arise, or amendments suggested by participants during pilot testing, ought to form part of the intervention process (De Vos & Strydom, 2011). As the current study served the purpose of a pilot study, the observations made throughout the implementation of the intervention and the findings will be used to refine and adapt the implementation of the PVG-CEP (*cf.* 7.7). The pre- and post-test results of the experimental and control group were used as a control measure to establish the possible impact of the intervention.

4.2.2.5 Stage 5: Evaluation and advanced development

The researcher envisages to assess the merits of the PVG-CEP on a larger scale, using true experimental research in different contexts, after refining and adapting the intervention once the present study is complete. Follow-up research will enable the researcher to conclusively establish the merits of the PVG-CEP for developing critical thinking skills, dispositions and standards for reasoning among first-year pre-service teachers.

4.2.2.6 Stage 6: Dissemination

De Vos and Strydom (2011) concur that once the intervention has been field-tested, it is ready to be disseminated to the community and other target groups. The findings should be published in academic journals, read by practitioners, consumers and policy-makers (Fraser & Galinsky, 2010). The researcher will pay attention to wider dissemination of the

research findings in relation to the merits of the PVG-CEP to enhance the development of critical thinking, after the implementation of the intervention in true experimental contexts. As part of the present study, the preliminary findings obtained from the pilot study will be published in academic, peer-reviewed journals, and communicated at relevant conferences. The following section provides some detail about the nature of the PVG-CEP intervention programme.

4.3 THE NATURE OF THE PUZZLE VIDEO GAME – COGNITIVE ENRICHMENT PROGRAMME

In this section, the researcher highlights how the preceding literature review informed the design, nature and implementation of the PVG-CEP programme. The coining of the name of the intervention, a PVG-CEP, links to the combined application of a puzzle video game and teaching and learning principles (*cf.* 4.3.2, 4.4.5) that promoted the development of critical thinking. Guided by the literature reviews in Chapters 2 and 3, this section summarises the focus of the PVG-CEP, the theoretical underpinnings, teaching and learning strategies utilised during the implementation of the PVG-CEP, and implementation features of the PVG-CEP.

4.3.1 The focus of the PVG-CEP

On conclusion of the literature review in relation to the conceptualisation of critical thinking (*cf.* 2.3), the researcher formulated his own conceptualisation for the purpose of the study (*cf.* 2.3.7). According to the researcher's conceptualisation, the study foregrounded the following elements of critical thinking:

- Cognitive skills: Making inferences, recognising assumptions, making deductions, doing interpretations and evaluating arguments.
- Dispositions: Systematic working ways, accuracy, persistence.
- Standards for reasoning: Clarity, logic, relevancy.

Although not measured intentionally during the study, the meta-cognitive skill of self-regulation played an important role in reflecting about the correctness of the application of the aforementioned elements during the puzzle video game play.

According to the pre-test results, the researcher argued that all of the mentioned cognitive skills appeared to be fragile among the participants (*cf.* 6.3), and therefore included the development of all the skills in the PVG-CEP. The participants were not given any instruction in the application of the aforementioned elements of critical thinking, as it was envisaged to establish if the puzzle video game could contribute to the development of the mentioned elements.

4.3.2 The teaching and learning theories underpinning the design and implementation of the intervention programme

Considering the learning theories discussed in Chapter 3, the researcher identified tenets of a number of teaching and learning theories appropriate for underpinning the design and implementation of the PVG-CEP.

Cognitivism (*cf.* 3.2.3.2) was regarded as important for the present study that involved the development of critical thinking during active involvement in puzzle game play, as it postulates that during learning students should actively participate in acquiring, manipulating and retrieving information.

Constructivism (*cf.* 3.2.3.3) focuses on students building knowledge and meaning themselves, scaffolding concepts and ideas and making connections. This theory supports the development of critical thinking, and was adopted in the intervention programme, as participants were expected to construct their own knowledge of the puzzle video game intervention, in order to proceed in solving the puzzle problems.

The transformative learning theory (*cf.* 3.2.3.4) allows for individuals to change their frames of reference by critically reflecting on their assumptions and beliefs and consciously making and implementing plans that bring about new ways of defining and thinking about their worlds. This process is fundamentally rational and analytical, which supports the development of critical thinking, and aligns well with the study. Participants had to reflect on their assumptions when solving the puzzle video game problems, and devise new plans to solve problems if current assumptions to solving problems proved to be invalid.

Experiential learning theory (*cf.* 3.2.3.5) holds the belief that learning comes from experiencing different situations and allowing students to actively explore different settings aside from the classroom. This theory was fundamental to this study as the participants used their experiences of the puzzle video game to solve puzzles problems independently.

The research was built of the premise of structural cognitive modifiability theory (*cf.* 3.2.3.6) which postulates that fragile or deficient thinking skills and processes, including critical thinking skills, dispositions and standards of reasoning, can be reversed.

By means of mediated learning (*cf.* 3.2.3.7), the learning experiences during the puzzle video game intervention were intentionally structured and guided to enable students to acquire the desired skills, dispositions and standards for reasoning.

Tangential learning posits that learning will occur if it is presented in an interesting and enjoyable context, for example using an entertaining video game as in the context of the study (*cf.* 3.2.3.8).

Finally, transfer of learning theory (*cf.* 3.2.3.9) underpinned the implementation of the PVG-CEP intervention, as the researcher hoped that the skills and behaviours that the participants possibly learned and developed in the puzzle video game context, would be transferred to the W-GCTA test context.

The following section discusses the teaching method and strategies that underpinned the implementation of the intervention programme.

4.3.3 The teaching methods and strategies utilised during the implementation of the intervention programme

The four main instructional methods: direct instruction, indirect instruction, independent instruction and interactive instruction and their related teaching strategies, were discussed in Chapter 3 (*cf.* 3.3), and outlined in Figure 3.1. Excluding direct instruction, all other instructional methods held potential for developing critical thinking skills, dispositions and standards for reasoning in the context of the Portal puzzle video game.

The direct instruction strategy appears not to be effective for developing critical thinking, as it does not emphasise independent thinking on the students' part, and students are mostly regarded as receivers of information. This strategy was not employed in the intervention programme. Indirect instruction can develop critical thinking, as it allows students to discover meaning for themselves by among others, applying critical thinking skills. Indirect instruction therefore played an important role in the implementation of the intervention programme, where participants had to discover meaning for themselves in order to solve the puzzle video game problems. Independent instruction also seems to hold potential for promoting critical thinking, by involving students in independent problem solving and enquiry-based learning. In the case of the study, each participant was involved in the intervention programme independent of one another, and played the game on their own, allowing for independent problem solving and enquiry.

Interactive instruction can also develop critical thinking, but unfortunately, it was not used in this study aside from the interaction between the researcher and the participants. No participant-to-participant interaction characterised the implementation of the intervention programme, as it was the purpose of the research to observe growth and development of the critical thinking skills, dispositions and standards for reasoning among individual participants.

The GROW problem solving model (Gorell, 2013), promotes an independent, student-centred pedagogy where students solve open-ended problems (Schmidt *et al.*, 2011) that do not have a clear solution (Hung, 2011). The GROW model supported the development of the critical thinking dispositions on which the research focused (*cf.* 4.3.1). As part of a mediated learning approach, purposeful questioning was used by the researcher during the solving of the puzzle problems to explore the systematicity, accuracy and persistence with which the participants worked on the puzzle problems, as well as the clarity, relevance and logic of the participants' reasoning in explaining their working ways during the solving of the puzzle problems.

Although the intervention took place in a formal classroom learning environment, the implementation of the PVG-CEP intervention was not aligned to achieving curriculum-related objectives. The researcher therefore involved the participants in informal, self-

directed, experiential learning by employing a non-formal way to develop critical thinking, by using a puzzle video game (cf. 3.2.1 – 3.2.2).

4.3.4 The implementation features of the PVG-CEP

The PVG-CEP did not have to fit into a time-limited schedule as it was not bound by specific subjects within any curricula. However, the researcher had to strive to obtain results/findings in the time he and the first-year students had available, namely one semester comprising thirteen weeks.

The researcher employed a single-group design, namely one group of four participants following one another, as participants had to take part in the intervention at different time slots due to logistical and time constraints. The intensive nature of the intervention required that individual attention was given to participants, and could therefore not be implemented in a group.

The intervention programme made use of the video games Portal 1 and Portal 2. Portal 2 is far more advanced and a longer game than Portal 1, adding new elements that make it more challenging. In order to enable the participants to feel comfortable in taking part in the PVG-CEP, they had to be prepared by the researcher. For this purpose, game instruction played an important role. The game instruction provided to the participants, is summarised in the following section.

4.4 GAME INSTRUCTION TO THE RESEARCH PARTICIPANTS

Game instruction was provided to all the participants during week 1 of the intervention. The researcher adhered to some guidelines in relation to best practices for implementing game-based learning, as specified by All *et al.* (2016), Green and Bavelier (2012) and Wouters, Van Nimwegen & Van der Spek (2013).

- The instructor should only give procedural help and information about the implementation of the game. Participants were not given any instruction in the application of the critical thinking skills, dispositions and standards for reasoning.
- Individual development was more important to the researcher than establishing the general effectiveness of the game among a group of participants.

- Previous game experience and computer skills needed to be identified, as these could influence the effectiveness of the outcome of the game play.
- Single players were used, as they, according to research, achieve higher learning gains than those playing in groups.
- Games combined with instructional methods seem to deliver greater effects (in the context of the study, the GROW problem solving model was used) in relation to the formulation of knowledge and the production of higher levels of learning. Instruction in how to use the GROW problem solving model was provided to all the participants during week 1. Each participant received a copy of the GROW solving model to utilise during game play.

The research participants received continuous instruction in the mechanics and concepts central to the Portal game throughout the intervention.

4.4.1 Mechanics

Using mechanics makes up the meat of the puzzles in the Portal series. The different devices, structures, cubes, gels, and hazards are placed strategically around the test chambers (*cf.* 4.4.2, 4.4.3, 4.4.4). The mechanics of both Portal 1 and Portal 2 were discussed in the first week of the intervention programme, in which the researcher demonstrated the first level of the game and outlined the various mechanics and how they function within the game. This acquainted the students with how to play the game and to master the basic skills early on. Throughout the intervention, many opportunities were provided via the game self, where participants were first introduced to certain mechanics in order to become acquainted with their use, before engaging in real problem solving game play (*cf.* 4.4.5). The following information was included in the training of the participants during the first week of the intervention.

4.4.2 Devices: Handheld portal device

The Aperture Science Handheld Portal Device or Portal Gun is the experimental tool intended to position two portals that items or objects can pass through. This is the key apparatus players are armed with to finish puzzles in the test chambers (see Figure 4.1 below).



Figure 4.1: Handheld portal device

The handheld Portal device is intended to generate and place portals on any white surface that is permanent, flat and large enough. Once the device is fired, a highlighted projectile will be produced from the barrel. If the projectile hits a usable surface, a portal of the equivalent colour will be shaped. If a portal of the additional colour is previously employed, the two portals will be connected. If a portal of the identical colour is previously placed, it will be collapsed and the new portal will be utilised in its place, regulating the player to the usage of simply two portals at any given time. Nothing will occur if a portal is fired at an enemy or other object. The glass chamber and a light on the top of the device will radiate with the colour of the formerly positioned portal. The handheld Portal device also has the capability to pick up and operate items right in front of it.

4.4.3 Structures: Test Chambers

Test Chambers (see Figure 4.2 below) are an integral part of the Portal series and the Aperture Science Enrichment Centre. Through the Security Cameras secured onto the walls of test chambers at several points, GLaDOS (*cf.* 3.5.4.3) can track a subject's movements and progress.

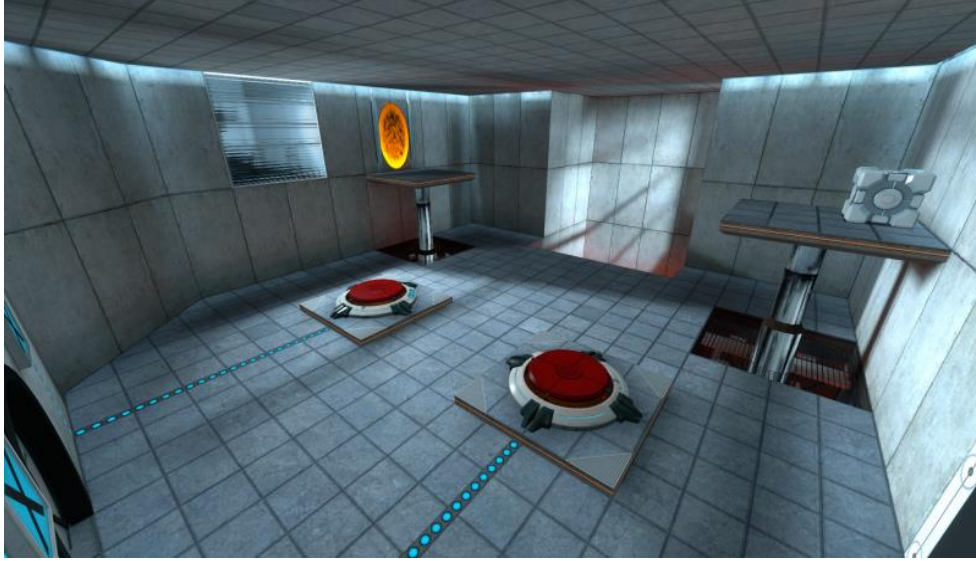


Figure 4.2: Test chambers

There are hundreds and more test chambers throughout the Enrichment Centre, which can be easily reconfigured and recycled to form another new test chamber. In Portal 2, these chambers can be swiftly created by GLaDOS with the usage of robotic arms carrying panels and combining them with other panels to form a ceiling, floor, and walls.

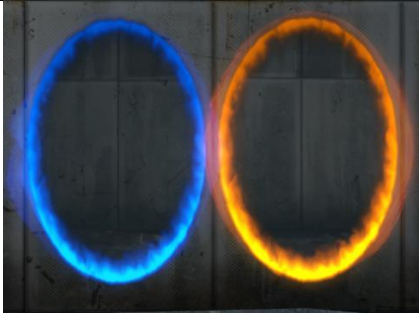
Aesthetically, these chambers bear resemblance to a hospital with its sterile environment, due to the lighting used within chambers, and the black and white colouring of the walls, floors, and ceilings.

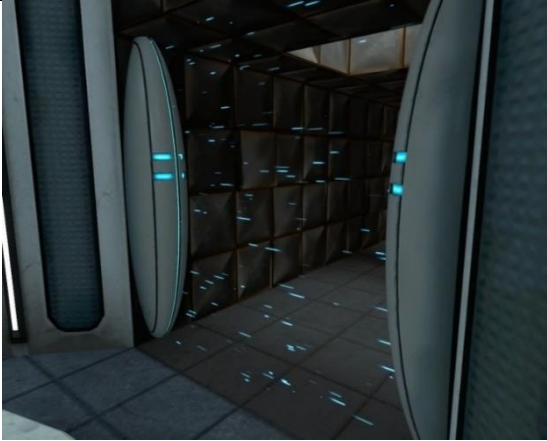
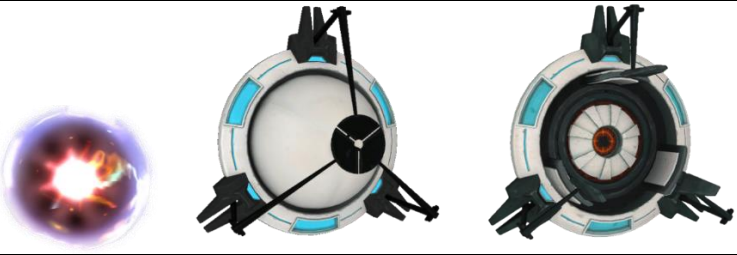
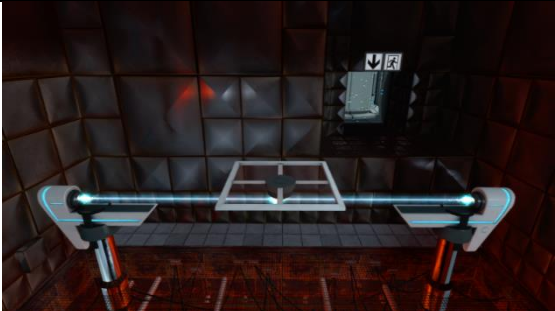
4.4.4 Test chamber mechanics

An explanation of the test chamber mechanics related to Portal 1 and Portal 2 provided to the participants, follow in the subsequent sections.

4.4.4.1 Portal 1

Figure 4.3 below summarises the test chamber mechanics involved in Portal 1

Portals - The central mechanic of the game, the "<i>worm holes</i>" utilised to finish the test chambers.	
Cubes - A versatile item utilised to press buttons, block undesirable forces, or to stand upon.	
The Heavy Duty Super-Colliding Super Button can be pressed by the player or held with a cube. The button acts like a switch, turning on and off different things (opening doors for instance).	
The Vital Apparatus Vent distributes the cubes into the chambers.	

A Material Emancipation Grill appears at the conclusion of test chambers and is utilised to prevent players from getting items out of the chamber.	
A Victory Lift is a vertical variation of the Unstationary Scaffold that routinely rises if a player is standing on it, and descends if vacant.	
A High Energy Pellet is an energy ball that needs to be put in its receptacle to power other objects.	
An Unstationary Scaffold is a platform utilised for transport alongside a rail.	

Turrets, also called military grade turrets, are utilised for zone restriction. They fire bullets at players that enter their field of view.	

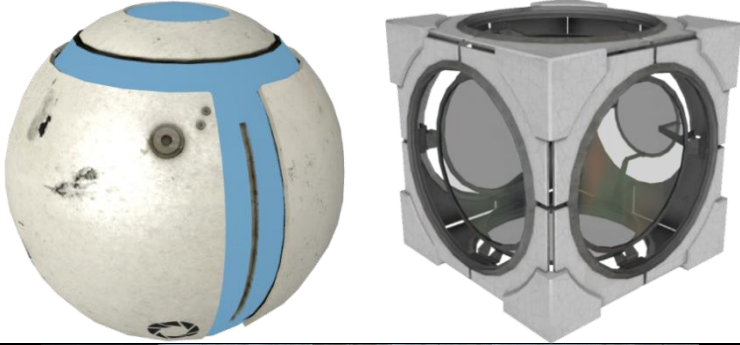
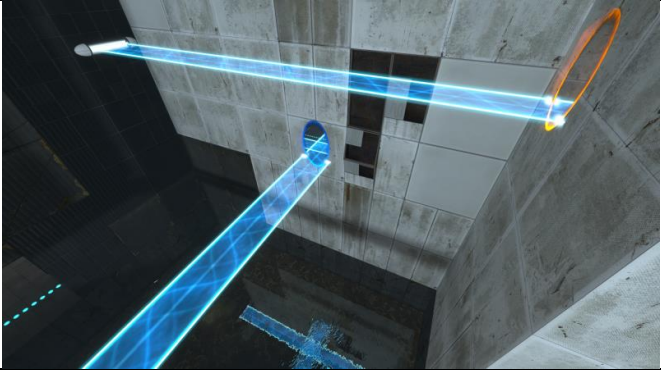
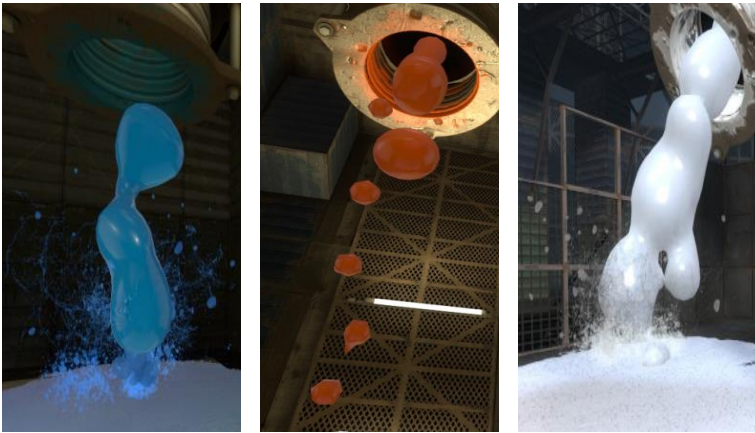
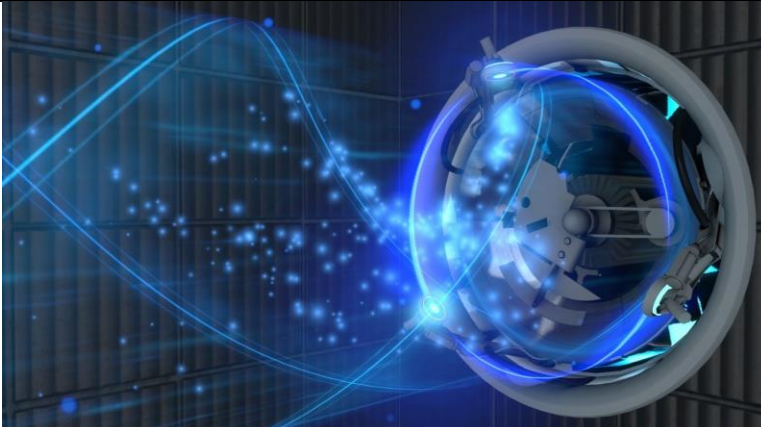
Figure 4.3: Portal 1 (Adapted from Demaine, Lockhart, & Lynch, 2016)

The following section elaborates on the test chamber mechanics involved in Portal 2.

4.4.4.2 Portal 2

Figure 4.4 below, summarises the test chamber mechanics involved in Portal 2.

An Aerial Faith Plate is a launcher that tosses the player and any items at a stable arc.	
A Thermal Discouragement Beam is a laser beam fired in a straight line. It needs to be evaded or relayed utilising a Discouragement Redirection cube, in order to solve particular laser based puzzles in order to finish the chamber.	

Edgeless Safety and Discouragement Redirection Cubes can be utilised to hold down buttons, in order to open doors or trigger platforms.	
A Hard Light Bridge is a semi-translucent, solid 'sheet' of light, that can act as a bridge or wall, in order to cross otherwise inaccessible paths.	
Gels (Propulsion, Repulsion and Conversion) can cover areas and apply diverse effects. The propulsion gel, when walked upon, makes the character move extremely fast. The repulsion gel, when hopped upon, recoils the character very high up into the air. The conversion gel, when covering walls or floors, allows the character to shoot portals onto its surface.	
Excursion Funnels are utilised for traversing across pits for which no other path exists. While within this funnel of energy, items will not be influenced by gravity and will travel lengthwise along the trail of the funnel.	

Edgeless Safety Cube Receptacles are utilised for inserting Edgeless Safety Cubes into these containers to trigger different types of objects in order to open doors and progress through the chambers.

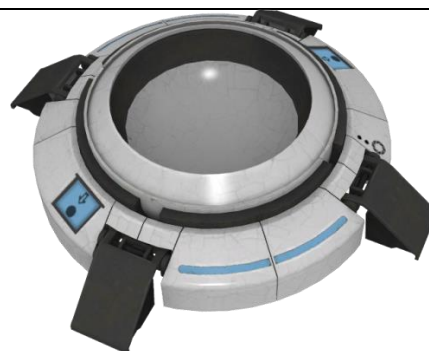


Figure 4.4: Portal 2 (Adapted from Demaine *et al.*, 2016)

A number of teaching and learning principles that underpin the playing of Portal, are explained in the next section.

4.4.5 Teaching and learning principles underpinning the playing of Portal

An important consideration for employing the Portal puzzle game in the study links to the fact that the game play reinforces a number of important teaching and learning principles identified by Schiller (2008), and Valve Software (2007) that the researcher regarded as beneficial for the development of critical thinking. According to Schiller (2008), Portal testifies to being a video game that employs robust teaching and learning strategies (Schiller, 2008).

The teaching and learning principles are clarified briefly:

Scaffolding: In support of constructivist teaching and learning principles (*cf.* 3.2.3.3), Portal comprises structured and discrete learning activities that scaffold (Kompf & Bond, 2011; Moon, 2004) the achievement of learning goals, as in each new level, the tutorial nature of the game is slowly removed and more challenges are presented. Aligned to mediated learning theory (*cf.* 3.2.3.7), game players also received support from the researcher and the game itself, in learning specific skills and concepts. Navigating puzzles using portals between points is the core game-play mechanic skill that needs to be mastered. Although each lesson is independent, consecutive lessons expect of game players to apply or modify the skills obtained and developed in previous lessons. In early chambers, the game designers provide a lot of support for players. The puzzles are designed so that there is only one possible solution, and the solution requires the use of the skill being taught. This simplicity helps to highlight the learning objectives, but as

players gain skill and confidence, the environment grows more complex and players face puzzles with multiple possible solutions (Valve Software, 2007). As the game progresses, support is taken away and players are free to make independent choices and practice skills in creative ways.

In the context of the game, scaffolding takes place as follows:

- Providing a slow introduction to playing the game and becoming familiar with concepts.
- Initially, portals are created by the game and players walk through the portals to experience how the portals operate.
- The player is given a portal gun that allows them to open portals that link only to portals created by the computer.
- After players become comfortable with generating portals, they are allowed to acquire a portal gun that creates both linked sides of a portal.

An incremental, engaging and a challenging approach to learning: The game is not extremely difficult at the beginning levels, so that participants do not feel overwhelmed. As participants become more skilled, levels of complexity and difficulty increase gradually, so that participants can remain engaged and challenged, thus supporting tangential (*cf.* 3.2.3.8) and experiential learning theory (*cf.* 3.2.3.5). Gradually increasing difficulty, provides opportunities for skills to be reinforced. Mediation of challenge, is an important component of mediated learning (*cf.* 3.2.3.7), which played an important role in the implementation of the PVG-CEP.

Enhancing focus by eliminating distractions: The game removes anything that might distract a player from acquiring a skill or concept. When the player is introduced to the button-box mechanic for example, it is done in a simplistic manner. The player is placed in a room that only contains a floor button, a weighted box, and a door, with no other distractions. In this way, it is easy for a player to conclude that if weight is placed on the button, it will enable the door to open. Removing distractions enables game players to quickly acquire skills and concepts that will reduce trial and error attempts in solving problems. As the game play advances, the button-box mechanic is not presented in a

simplistic environment any longer, as it is assumed that the player now understands how it works.

Mandatory pausing: Pausing avoids rushing through the game play and not noticing important clues that assist in solving the puzzle game problems. In the game context, the pauses are referred to as gates that indicate that a player may not advance if certain conditions are not adhered to. According to the researcher, mandatory pausing is beneficial for developing self-regulation skills (*cf.* 2.3.2) to enhance the accuracy (*cf.* 2.3.3) of behaviour and action.

The PVG-CEP intervention was implemented across 13 weeks. Appendix K provides an overview of the intervention.

During the problem solving activities, observations were conducted against pre-determined criteria (*cf.* Appendix H) in relation to the development of critical thinking skills, critical thinking dispositions and universal standards for reasoning (*cf.* Figure 2.2), on which the research focused.

The following section clarifies the observation criteria applied in the study.

4.5 OBSERVATION CRITERIA

The undermentioned descriptions guided the researcher's observation of the students' application of the critical thinking skills, dispositions and standards for reasoning during their involvement in the intervention activities.

- **Inferences:** The skill to make inferences was measured while the participants were playing the video game Portal by observing how the participant managed to come to conclusions regarding the various puzzles, and whether or not those conclusions were correct. Therefore, if participants repeatedly failed to solve puzzles, or continuously applied incorrect steps to solve problems, they would score low for making inferences.
- **Recognising assumptions:** The game Portal deliberately tests one's assumptions by making tests more difficult as you progress, in which certain puzzle solutions that worked in previous puzzles no longer applied in the later ones. It was important that

participants had to adapt to new puzzle situations, which had to be reflected in their feedback to the researcher.

- **Deductions:** The puzzles often require players to think in an abstract manner, in which the solution is not directly obvious, and advanced or complex steps are required to solve the puzzle problems. Deductive reasoning skills are needed to analyse the puzzle environment and to figure out what to do to solve the puzzle. If the participants could seamlessly apply their solutions and not require too much time to complete the puzzle, then it was assumed that high levels of deductive reasoning were evident.
- **Interpretations:** Each puzzle in Portal has a unique environment, with different obstacles and hazards to overcome, such as lasers, pits and turrets that fire at the game player. In order to traverse and navigate these treacherous environments, it is important to interpret one's surroundings, in order to make sense of what obstructs one moving forward. To solve these puzzles requires interpreting how things work and what relationships they have with one another. If the participant was able to effortlessly navigate the puzzles as well as to make connections with different puzzle mechanics, then it was argued that high levels of interpretive skill were evident.
- **Evaluating arguments:** The participants' approaches to solving the puzzles and how they responded to failed attempts at solving the puzzles were observed. Participants normally do not solve the puzzles correctly the first time. The observers observed how the participants would improve on their mistakes and how they tackled follow-up problems. Additionally, it was important that the participants provide reasons for the steps taken during problem solving and reflect about whether the steps taken, were correct.
- **Systematic working ways:** Systematic working ways refer to plans that people adopt in order to work in a step by step fashion in order to achieve a certain outcome. In the case of the study, it involved using the GROW problem solving model when approaching the puzzles in the video game Portal. This criterion was measured by looking at how frequently the participant consulted the GROW model. The participant ought to apply previously used and internalised strategies and reflect an awareness of rules and operations.

- **Persistence:** This criterion was observed by looking at whether the participants had the willingness to persist even when the puzzles in the game became very difficult: to not give up and to keep on trying, and to request limited assistance from the researcher to solve the puzzle problems. Participants were also told that if they felt that they could not progress, then they could leave the game at any time. If this occurred, then low scores for persistence were measured.
- **Accuracy:** Accuracy was measured in terms of how accurately the participants played the game, and how accurately their solutions to the puzzles were performed. Striving for accuracy can be defined as determining if there are errors; measuring at least twice before acting; cultivating a need for precision, commitment and expertise
- **Logic:** Logic was evident in how the participants were able to solve the puzzles or not, because successful completion of any puzzle in the game requires logic in order to solve them. Therefore, if a participant got stuck and could not progress without assistance, or mistakes were repeated, the researcher argued that it implied problems with logic reasoning. Logic reasoning implies selecting, sorting, combining and de-selecting information and ideas until the information and ideas make sense.
- **Clarity:** Clarity criteria were measured according to the quality of the feedback given in the programme while playing the video game Portal. Participants were expected to provide constant feedback regarding what they saw and what they were thinking when faced with the various puzzles throughout the game. Therefore, in order to determine the clarity of the feedback, it was essential that the participants provided feedback. If no feedback is given, no clarity can be measured. Clarifying involves being clear when communicating and writing; attempting to be precise when communicating and writing; evading generalisations, misrepresentations, simplifications and omissions.
- **Relevancy:** Relevancy in the context of the study refers to participant's ability to give quality feedback, in which only relevant details are provided and irrelevant information is ignored or omitted. This was measured in terms of the verbal feedback provided by the participants while they were playing the video game Portal, determining whether information was connected to or had any bearing on the issue at hand.

The observation criteria checklist that was utilised throughout the intervention programme is provided in Appendix H.

4.6 CHAPTER SUMMARY

Chapter 4 briefly elucidated and defined the six phases of intervention research. In the context of the study, the researcher implemented four steps, namely problem analysis and project planning, information gathering and synthesis, design, and early development and pilot testing (*cf.* 4.2).

The PVG-CEP focused on developing a number of elements that comprise the development of critical thinking, namely cognitive critical thinking skills (making inferences, recognising assumptions, making deductions, doing interpretations and evaluating arguments), dispositions (persistence, accuracy, systematic working ways), and standards for reasoning (clarity, logic, relevancy). In addition, self-regulation as metacognitive skill guided the application of the aforementioned elements, to identify and remedy mistakes made during the application of the elements (*cf.* 4.3.1). The design and implementation of the 13-week PVG-CEP was underpinned by cognitive, constructivist, transformative, experiential, structural cognitive modifiability, mediated learning, tangential learning and transfer of learning theories (*cf.* 4.3.2). The intervention was enriched by means of an independent teaching strategy, namely the GROW problem solving model, to guide the solving of the puzzle game problems (*cf.* 4.3.3).

An explanation of the mechanics, devices, structures and test chamber mechanics involved in the puzzle video game (*cf.* 4.4.1 – 4.4.4) was provided. In addition, important teaching and learning principles that accompany the implementation of Portal, such as scaffolding, employing an incremental, engaging and a challenging approach to learning, eliminating distractions during learning, and pausing, were highlighted (*cf.* 4.4.5).

Lastly, the observation criteria that were employed within the study were discussed and their link to the game play of Portal made explicit (*cf.* 4.5).

The next chapter, Chapter 5, focuses on the empirical research design.

CHAPTER 5

EMPIRICAL RESEARCH DESIGN

5.1 INTRODUCTION

This chapter aims to provide a comprehensive overview of, and motivation for the research methodology employed during the research study, by extending the succinct information provided in Chapter 1. The chapter addresses the following issues:

5.2 Research Framework

5.3 Research Aim, Objectives and Variables

5.3.1 Aim and objectives

5.3.2 Variables

5.4 Research Design

5.4.1 Embedded mixed method experimental research

5.5 Strategy of Enquiry

5.5.1 Quantitative strategy of enquiry: Quasi experimental research

5.5.2 Qualitative strategy of enquiry: Case study

5.6 Research Participants

5.6.1 Sampling for the quantitative study

5.6.2 Participants for the qualitative phase of the study

5.6.2.1 Interviews

5.6.2.2 Observations

5.7 Data Collection

5.7.1 Quantitative data collection instruments

5.7.1.1 Watson-Glaser Critical Thinking Appraisal

5.7.2 Qualitative data collection instruments

5.7.2.1 Observations: Rating scale

5.7.2.2 Anecdotal records

5.7.2.3 Semi-structured interviews

5.8 Role of the Researcher

5.9 Data Analysis and Interpretation

- 5.9.1 Quantitative W-GCTA test data
- 5.9.2 Qualitative observation data
- 5.9.3 Qualitative interview data

5.10 Rigour

- 5.10.1 Quantitative study: reliability and validity
 - 5.10.1.1 Reliability of W-GCTA
 - 5.10.1.2 Validity of the quantitative research design
 - 5.10.1.3 Validity of the quasi-experimental research
- 5.10.2 Validity of the quantitative research design
 - 5.10.2.1 Trustworthiness of the interviews
 - 5.10.2.2 Trustworthiness of the observations

5.11 Ethical considerations

- 5.11.1 Ethical issues in terms of the research problem
- 5.11.2 Ethical issues in terms of the purpose and questions
- 5.11.3 Ethical issues in terms of data collection
- 5.11.4 Ethical issues in terms of data analysis and interpretation
- 5.11.5 Ethical issues in terms of writing and disseminating the research

5.12 Chapter summary

The following section addresses the research framework for the study.

5.2 RESEARCH FRAMEWORK

A research framework is referred to as a set of beliefs (worldviews) that influence the research process and direct the researcher in choosing a specific research design (quantitative, qualitative or mixed-method) (Creswell, 2009).

Before the researcher could finalise his decision regarding a suitable research framework, he had to consider answers to his ontological, epistemological and methodological assumptions related to his research (Creswell, 2009; Maree & Van der Westhuizen, 2007).

In relation to ontological assumptions, the researcher argues that social reality can be understood from an external or internal point of view (Maree & Van der Westhuizen, 2007). In this study the researcher wanted to understand the development of critical thinking from an external viewpoint, by observing its development across a 13-week intervention, and by talking to research participants about their experiences with the intervention. In addition, an internal point of view was adopted by examining the test results of the participants in relation to the application of critical thinking skills.

Epistemological assumptions, according to Maree and Van der Westhuizen (2007) refer to adopting an objective or subjective role when collecting data. The researcher took on an objective and subjective stance to data collection by employing a test to objectively measure the participants' critical thinking development, as well as observations to subjectively observe the growth and development of critical thinking during the implementation of an intervention. In addition, subjective data were also gathered by talking to the participants about their experiences with the PVG-CEP.

Methodological preferences deal with paradigmatic assumptions that impact the choice of research methods (Maree & Van der Westhuizen, 2007). The researcher believed that both numerical test data (quantitative), observations (qualitative) as well as the words of the participants (qualitative), would enable him to understand the phenomenon under investigation, which again pointed to the pragmatic framework as being the most suitable for the study.

The assumptions of the researcher guided him towards adopting pragmatism as the research framework. According to Creswell (2014), pragmatism is the philosophical worldview that underpins mixed methods research. Pragmatism can be defined as being concerned with applications, including working solutions to problems (Creswell, 2009), by collecting quantitative and qualitative data.

The researcher applied an intervention to investigate a possible solution for developing critical thinking. In order to best understand the development of the critical thinking skills, dispositions and standards for reasoning of the participants, the researcher argued that he had to collect objective, numerical evidence to determine how well developed the critical thinking skills, dispositions and standards for reasoning of the research

participants are before and after the PVG-CEP intervention. In addition, he argued that he also had to obtain subjective, qualitative evidence by observing participants' behaviour during the intervention to gain deeper insight into the nature and quality of the development of their critical thinking skills, dispositions and standards for reasoning. Moreover, interviews with the participants would provide a qualitative and subjective understanding of the participants' experiences with the intervention.

The pragmatic framework influenced the research aim and objectives, as well as the choice of the research design, the research strategy and the data collection methods.

5.3 RESEARCH AIM, OBJECTIVES AND VARIABLES

5.3.1 Aim and objectives

In support of the objective, quantitative and subjective, qualitative nature of the pragmatic framework that guided the researcher's study, the main aim of the study was two-fold: Firstly, to determine how sophisticated first-year BEd students are in the application of critical thinking, and secondly, based on the findings, to establish and explore how a PVG-CEP supports the development of critical thinking among first-year BEd students.

The main aim was operationalised in the following objectives:

- To understand the elements of critical thinking.
- To understand why critical thinking is important for first-year BEd students.
- To establish how critical thinking could be developed effectively.
- To establish what role puzzle video games play in developing critical thinking.
- To identify which puzzle video games would be best suited to develop critical thinking.
- To determine how effective BEd students are at applying critical thinking skills before and after taking part in the PVG-CEP intervention.
- To explore how effective BEd students are at applying critical thinking dispositions and standards for reasoning at the onset and end of the PVG-CEP intervention.
- To explore the student participants' perceptions and experiences regarding the development of their critical thinking skills through a puzzle video game.

- To develop novel guidelines for including the use of puzzle video games during teaching to develop critical thinking among first-year BEd students.

5.3.2 Variables

The researcher acknowledges that a variety of intervening variables, such as motivation, culture, language, interest and ability, can have an impact on the development of critical thinking (Mukwambo, Ngcoza, & Chikunda, 2015). However, for the purpose of this study the focus was on the impact of the PVG-CEP intervention on the development of the participants' critical thinking skills, dispositions and standards for reasoning. Due to the small sample, it was not possible to employ statistical procedures to establish the impact of intervening variables on the development of critical thinking. Furthermore, it was also not the purpose of the study to determine the impact of these intervening variables on the development of the participants' critical thinking. The researcher merely wanted to establish and explore how the PVG-CEP possibly contributes to the development of critical thinking, and based on the findings make recommendations that could be followed up in more controlled studies with more participants.

The **dependent variable** in this study was therefore identified as **critical thinking**, while the **independent variable** was the PVG-CEP intervention.

5.4 RESEARCH DESIGN

An embedded mixed method experimental research design (Creswell, 2014) was utilised within this study.

5.4.1 Embedded mixed method experimental research

The embedded mixed method experimental research design has qualitative data embedded within an experimental design (Creswell, 2014) (*cf.* Figure 5.1). The priority of the design is established by the quantitative, experimental methodology, and a qualitative dataset that is subservient within the methodology (Creswell, 2014). Quantitative pre- and post-test data prior to and after the implementation of an intervention were collected only in relation to the development of the critical thinking skills of the participants. Qualitative, descriptive, observation data, of which the interpretation was guided by a four-point scale,

were gathered in order to examine the nature of the development of critical thinking skills, dispositions and standards for reasoning during the implementation of the intervention. Qualitative interview data were also collected after the intervention to follow up on the experiences of the participants after completing the intervention.

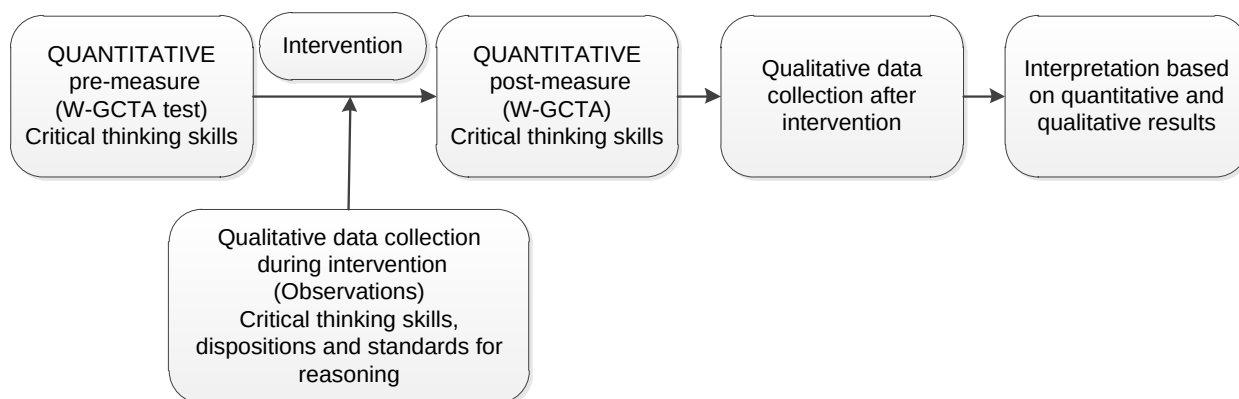


Figure 5.1: Embedded mixed method experimental research (Creswell, 2014)

The embedded design departs from the premise that a single data set is not sufficient to answer the research questions, as the research questions require different types of data (Delport & Fouché, 2011). The quantitative data, regarded as the primary source of data in relation to the critical thinking skills, objectively quantified the participants' ability to apply critical thinking skills before and after the intervention. However, in order to be effective at applying the critical thinking skills, the participants also have to be effective at the application of critical thinking dispositions and standards for reasoning (Elder & Paul, 2008), of which the growth and development were described qualitatively as the intervention unfolded. There was no instrument available to the researcher to quantitatively assess the ability of the participants to apply the dispositions and standards for reasoning. In addition, the application of the critical thinking skills that were quantitatively assessed with the W-GCTA, was also observed, and qualitatively described during the implementation of the intervention. The qualitative data collection played an important role to establish the development of the dispositions and standards for reasoning at the outset and conclusion of the intervention. At the conclusion of the intervention, the experiences of the participants with the intervention were qualitatively gauged by means of semi-structured interviews.

5.5 STRATEGY OF ENQUIRY

The following strategies of enquiry were applied in the quantitative and qualitative components of the study.

5.5.1 Quantitative strategy of enquiry: Quasi-experimental research

Quasi-experimental research aims to evaluate interventions but does not use randomisation to select participants. Quasi-experiments aim to demonstrate causality between an intervention and an outcome in non-randomly selected experimental and control groups (Creswell, 2009; Creswell, 2014; Leedy & Ormrod, 2013, Maree & Pietersen, 2016).

Figure 5.2 indicates that a baseline assessment with the W-GCTA that comprised five sub-tests was followed by the 13-week puzzle video game intervention during which observation data were collected. The W-GCTA was repeated as a post-test after the intervention, to establish whether improvement occurred between the first and last baseline data collection.

Pre-test					Observations													Post-test				
Baseline data before intervention					Intervention data													Baseline data after intervention				
1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5

Figure 5.2: The quasi-experimental research design

Figure 5.2 indicates that the data collection for the experiment took place in three phases, namely a quantitative pre- and post-test phase, and a qualitative phase during the implementation of the PVG-CEP intervention.

5.5.2 Qualitative strategy of enquiry: Case study

The researcher used a case study as strategy of enquiry to gather data for the qualitative component of the research. A case study examines a bounded system or a case over time in depth, employing multiple sources of data found in the setting. The case may be a programme, an event, an activity or a set of individuals bounded in time and place

(McMillan & Schumacher, 2014; Nieuwenhuis, 2007a, 2016, a, b), and involves an intensive and holistic description and analysis of data in relation to the case (Merriam, 2009). In this study, multiple case studies were used that involved a comprehensive within-case analysis as well as a cross-case analysis of the data (Merriam, 2009). In the context of this study, the case could be described as the eight first-year BEd students at the North-West University who were included in the experimental and control groups (a group of individuals bounded in time and place). The researcher put aside all prejudgments and collected data on how individuals made sense out of a particular experience or situation (McMillan & Schumacher, 2006), through intensive observations and interviews. The researcher also included quantitative data as part of the four experimental case studies, as a case study should entail a detailed description of an individual, which could include both quantitative and qualitative analyses (Yin, 2009).

The researcher regarded a case study as appropriate to the study as he wished to gauge a specific group of students' experiences (bounded case) regarding the merits of the PVG-CEP over time for developing critical thinking. Moreover, the qualitative study also aimed to explore the nature and the progressive development and growth of the students' critical thinking skills, dispositions, and the standards for reasoning during the implementation of the intervention, by means of observations. In addition, by employing interviews, the researcher would be able to explore the participants' experiences with the PVG-CEP qualitatively.

The use of a case study did not allow the researcher to conclusively determine whether a statistical causal relationship exists between the development of critical thinking skills and the use of a puzzle video game (Yin, 2009).

5.6 RESEARCH PARTICIPANTS

The following section outlines the particular sampling procedures for this study.

5.6.1 Sampling for the quantitative study

The target population for this research was all first-year level BEd students in South Africa. As it was not possible to do research with all these students, the study population only included first-year BEd students in the Faculty of Education at the North-West

University, on the Vaal Triangle Campus. Due to time and logistical constraints, a non-probability, convenient, purposive sample of eight first-year BEd students from the North-West University on the Vaal Triangle Campus were used. Non-probability sampling is a sampling technique where the samples are gathered in a process that does not give all the individuals in the population equal chances of being selected (Leedy & Ormrod, 2005; Strydom, 2011).

Purposive sampling refers to selecting participants for a specific purpose (Leedy & Ormrod, 2005; Strydom 2011). In the case of this study, the researcher purposively focused on first-year BEd students. The sample could also be considered convenient, as the participants were located on the same site where the researcher works. The researcher therefore had easy access to the participants. First-year students were chosen, as possible deficiencies and weaknesses in relation to the development of critical thinking could be identified at the outset of their studies at Higher Education level, and action plans to address the deficiencies and weaknesses during their four years of study be put in place before they complete their studies and enter their teaching careers.

The eight participants were purposively selected, based on the results of the Toets vir Akademiese Geletterdheid (TAG)/Test for Academic Literacy (TALL) that first-year students write to identify the extent of academic preparedness before they start their studies at a higher education institution (Van Der Silk & Weideman, 2008). The test does not exclusively assess the development of critical thinking, but addresses a number of critical thinking skills such as making deductions, formulating definitions, identifying cause and effect relationships, and distinguishing between main ideas and detail (Van der Silk & Weideman, 2008, 2009), which are regarded as important for academic preparedness. The researcher obtained permission to select the participants for the study based on their TAG/TALL results (*cf.* Appendix D).

The TAG/TALL test results are reported as a percentage and the researcher requested the assistance of the colleague involved with the administration of the test to do the selection of the eight students based on the following guidelines:

- two students with the highest scores in the percentage range 80-100 (category 1);
- two students with the highest scores in the percentage range 70-79 (category 2);

- two students with the highest scores in the percentage range 60-69 (category 3); and
- two students with the highest scores in the percentage range 50-59 (category 4).

The researcher thus ensured that he included participants who were perceived to be at different levels of academic preparedness, in the research. If there were more than one student with similar percentages in any of the four groups, random selection was employed to identify only two students in each of the groups. The identified students were approached to find out if they would be willing to take part in the research. Some of the identified students were not willing to participate, and the selection of students continued until two willing students were identified in each of the four groups above.

Four of the students, one in each of the above mentioned groups, formed part of the experimental group who received the intervention, and the other four students formed part of the control group who did not receive the intervention. The students were assigned randomly to the experimental and control groups.

The students who were included in the experimental group needed to have basic computer literacy skills. In addition, three other exclusion criteria were applied, namely that any students who were taught by the researcher could not participate, as well as students who played the video game Portal before. In addition, students who did not pass the TAG/TALL test (those who achieved less than 50%), were not included in the research.

5.6.2 Participants for the qualitative phase of the study

5.6.2.1 Interviews

A purposive criterion sample (Nieuwenhuis, 2007b; Strydom & Delport, 2011) applied for the qualitative phase (interviews), as only the four student participants who were part of the experimental group were involved in the interviews. This type of sampling procedure implied that the four participants were selected purposively at the outset of the study, as they complied with certain criteria in relation to the results of the TAG/TALL test (Nieuwenhuis, 2007b).

5.6.2.2 Observations

Only the four student participants who were part of the experimental group were observed during the intervention. The four participants were purposively selected (Nieuwenhuis, 2007b) at the outset of the study, based on specific results obtained during the TAG/TALL test.

Table 5.1 summarises the biographical characteristics of the participants who took part in the study.

Table 5.1: Biographical characteristics of the participants

Participant	Age	Gender	Ethnic group	TAG/TALL result
Experimental group				
1	18	Male	African	86%
2	18	Female	African	76%
3	18	Female	African	64%
4	18	Male	African	56%
Control group				
5	19	Male	Coloured	82%
6	19	Male	African	78%
7	18	Female	African	65%
8	18	Female	African	56%

5.7 DATA COLLECTION

Due to the quantitative and qualitative nature of this study, different data collection instruments were used.

5.7.1 Quantitative data collection instruments

The next section clarifies the use of the W-GCTA.

5.7.1.1 Watson-Glaser Critical Thinking Appraisal

The researcher is not aware of a comprehensive and standardised national or international test that holistically measures the application of critical thinking skills, dispositions and standards for reasoning. The choice therefore fell on using the W-GCTA (UK version) (Watson & Glaser, 2002a) that comprehensively measures the application of critical thinking skills. The test, however, does not measure the application of critical thinking dispositions or how well thinking complies with the intellectual standards for reasoning.

The W-GCTA consists of five tests, designed to find out how well a person is able to reason logically and analytically. Researchers in the field of critical thinking, who are familiar with the W-GCTA, give the instrument a high rating. Fisher and Scriven (1997) express their opinion by saying that the test is the most widely used worldwide. Some reasons related to the high quality of the instrument are ascribed to the following factors (Watson & Glaser, 2002b):

- It has a development and refinement history of at least 50 years.
- It is a widely evaluated and standardised test.
- It measures critical thinking by means of practical issues in original settings.
- It has succeeded in incorporating all theoretical aspects of critical thinking such as: Defining problems, selecting information for solving problems, recognising stated and unstated assumptions, formulating and selecting hypotheses, drawing conclusions and judging the validity of inferences.
- It has been reviewed on several occasions to increase its clarity, to update its word usage and to eliminate stereotypes.
- It is known for its enduring quality, technical robustness and high performance.

As mentioned in previous research studies with first-year BEd students (Grosser & Lombard, 2008; Lombard & Grosser, 2008; Grosser & Nel, 2013), additional considerations for selecting the W-GCTA include that the instrument is (i) designed to determine the skill aspect of critical thinking by using “*general scenarios*”; (ii) is not subject-related; (iii) and those who take the test need no pre-knowledge. Furthermore,

the degree of foreignness to the South African situation could be regarded as minimal, whereas the cognitive processes needed for the completion of the test correlate with those expected in the execution of academic tasks at university (Grosser & Lombard, 2008; Lombard & Grosser, 2008; Grosser & Nel, 2013), and, according to the researcher, with the cognitive processes involved in solving the problems in the PVG-CEP.

The developers of the W-GCTA claim that the test is appropriate for participants who have completed a basic formal education (Watson & Glaser, 2002a). As all of the research participants managed to complete their schooling careers successfully, the researcher regarded the use of the W-GCTA as apposite. The developers of the test indicate that a reading ability of at least a 15 year old is required to complete the test (Watson & Glaser, 2002a). The researcher cautiously assumed that the research participants complied with the minimum reading ability. The passing of the TAG/TALL test taken by students on admission to the university also indicates if the students are capable of continuing their studies in English. Not all students passed the TAG/TALL test, and the researcher made sure to only sample students from those who passed the test.

The W-GCTA comprises five sub-tests containing 80 multiple-choice test items with one correct answer. Each sub-test contains 16 items that each measures different but interdependent aspects related to the execution of critical thinking. A total score of 80 can be achieved (16 marks per sub-test). These five sub-tests focus on the following constructs, which align well with the core cognitive and meta-cognitive critical thinking skills as identified in the literature (*cf.* 2.3.2), as well as with the researcher's conceptualisation of critical thinking that was applied in the study (Figure 2.2), that was based on the viewpoints of Facione (2000, 2009), Paul & Elder (2007), as well as Watson and Glaser (2002a) (*cf.* 2.3.7). The five sub-tests are:

- Drawing inferences, in which respondents have to evaluate inferences drawn from a series of factual statements (cognitive skill).
- Recognising assumptions (cognitive skill), where respondents are required to identify unstated assumptions in a series of statements.
- Making deductions (cognitive skill), where respondents have to determine whether certain conclusions necessarily follow from information in given statements.

- Doing interpretations (cognitive skill), where evidence is weighted to decide if generalisations based on data are warranted.
- Evaluating arguments (cognitive skill), where respondents are required to distinguish between strong, relevant arguments and weak irrelevant arguments (Watson & Glaser, 2002b).
- During the application of the aforementioned cognitive skills, the meta-cognitive skill of reflecting about and self-regulating one's own thinking for effectiveness and to correct mistakes, play an important role (self-regulation is not explicitly measured by the W-GCTA, and was also not explicitly measured during the study. However, according to the researcher, shoddy thinking could point to being ineffective in self-regulation).

The focus of the general scenarios in the sub-tests include neutral topics and controversial issues. The neutral topics include issues that do not expect people to have strong feelings, such as the weather or scientific facts. The controversial issues, on the other hand, focus on political and social matters that elicit definite and strong feelings (Watson & Glaser, 2002b). The developers suggest that the test be used as a test of power, rather than as a test of speed. The time for administering the test was utilised as indicated by the authors, namely 60 minutes: 50 minutes for completion by participants and between five to ten minutes for dealing with administrative matters, such as explaining the test procedures. A registered psychologist assisted the researcher in administering the test and scoring and interpreting the test results.

5.7.2 Qualitative data collection instruments

The proceeding section provides detail on the observations and interviews that were employed for collecting qualitative data.

5.7.2.1 Observations: Rating scale

A pre-determined four-point rating scale (Cohen *et al.*, 2007) with qualitative descriptive criteria (*cf.* Appendix H) was used to judge the skills, dispositions, and standards for reasoning that were observed. **High-inference** observations, which include judgements about observed behaviours, as well as **low-inference** observations, where specific

behaviours were observed without making judgments, were used (McMillan & Schumacher, 2006). The observations focused on the nature and quality of the application of critical thinking skills, dispositions and universal standards for reasoning during the implementation of the intervention. The four-point scale with qualitative criteria descriptors was used to guide the observations (*cf.* Appendix H). Line graphs were used to visually display trends over time (Riley-Tillman & Burns, 2009) in relation to the development of critical thinking, thus summarising the effect of the PVG-CEP intervention.

According to Cohen *et al.* (2007), a pre-determined and structured observation schedule is more efficient if the observation entails the recording of the *incidence, presence, quality* and *frequency* of behaviours which compare one situation with another. The researcher was mainly concerned with incidences of behaviour that would reveal the nature and quality of the development of the participants' critical thinking skills, dispositions and universal standards for reasoning across 13 weeks.

Lincoln and Guba (1985) suggest that a variety of elements or types of observations be used in an observation study. The researcher used a pre-determined schedule, accompanied by more detailed descriptions of the events, behaviour and activities that happened (Cohen *et al.*, 2007). The quantitative scale merely guided the researcher in compiling a qualitative account that revealed evidence in relation to growth, decay or retention of the critical thinking skills, dispositions and standards for reasoning among the research participants.

5.7.2.2 Anecdotal records

To complement the observations, the researcher also compiled anecdotal records. Since the researcher was continuously involved in the intervention, anecdotal records (*cf.* Appendix G) were composed for each participant across the 13-week intervention, in relation to the critical thinking skills, dispositions and standards for reasoning. The researcher used short, narrative descriptions to write down all behaviour or events related to the cognitive functioning of each participant (Nieuwenhuis, 2007c).

Anecdotal records are brief, open-ended comments that provide rich detail about a participant or specific event (Boyd-Batstone, 2004), without containing any self-reflective comments (Nieuwenhuis, 2016b). The researcher ensured that all relevant detail about

the participants was written down as soon as possible after they had occurred in order not to forget information (Daniels, Beaumont, & Doolin, 2008). The anecdotal records included reactions and comments of the participants (Strydom, 2002).

Anecdotal records were utilised to record explicit observations of each participant's behaviours, skills, dispositions and standards for reasoning as they related to the solving of problems in the puzzle video game. The anecdotal records presented continuous, accumulative information on participant performance (Boyd-Batstone, 2004).

Some advantages that guided the researcher's choice for using observations were that observations would provide first-hand, valid and authentic information about the participants' application of critical thinking skills, dispositions and standards for reasoning. Observations also enabled the researcher to capture non-verbal data.

The researcher took cognisance of the following disadvantages that observations hold, namely making accurate sense of what is observed, and possibly compromising data collection when participants behave in such a way to present themselves more favourably (Babbie & Mouton, 2001; Merriam, 2009). To avoid the aforementioned disadvantages, the use of an independent co-observer, who also made video recordings of the observation sessions, enhanced the possibility of collecting reliable observation data. As the researcher informed the participants that their involvement in the puzzle video game will have no bearing on their academic achievement at university, the researcher argued that the participants would therefore not find it necessary to present themselves more favourably.

Observation context

The observations took place in a classroom setting where the implementation of the intervention required a structured approach (Cohen *et al.*, 2007; Nieuwenhuis, 2007b; McMillan & Schumacher, 2006). The observations were qualitative in nature, and the rating scale with qualitative descriptive criteria that guided the observations were used merely to assist the researcher in avoiding selective attention during the observation by clearly identifying criteria in relation to the critical thinking skills, dispositions and standards for reasoning that had to be observed during the intervention (Cohen *et al.*, 2007) (*cf.* Figure 2.2).

During the intervention, participants were requested to analyse situations within the game and the researcher evaluated their performance and their reasoning ability in terms of, for example, what assumptions and deductions they were making, and the strategies they employed to solve the problems. The researcher ensured to understand and reveal the actions, words, expressions and behaviours of the participants (McMillan & Schumacher, 2006; Strydom, 2002), which involved speaking with and asking questions to the participants. Anecdotal records were compiled while observing the reactions and comments of the participants (Strydom, 2002).

A trained co-observer also compiled observations independently of the researcher, and captured the game involvement of the participant on video. The video recordings were not used for data collection purposes, but merely to verify the observations made by the researcher and co-observer in order to ensure an accurate account of a participant's involvement during the intervention, and to clarify any differences between the observations of the observer and co-observer.

During the observations, the researcher became part of the research process by working with the participants. He played the role of **participant as observer**, as he became part of the situation by mediating the dynamics of the situation in an attempt to understand the development of critical thinking skills, dispositions, and standards for reasoning of the participants (Cohen *et al.*, 2007; Nieuwenhuis, 2007b).

Permission was obtained from the participants for making the video recordings.

5.7.2.3 Semi-structured interviews

Interviews were conducted with the four selected student participants in the experimental group at the end of the intervention, in order to understand their perspectives and thoughts on how they experienced the contribution of the puzzle video game. This data was used to support the quantitative data and qualitative data collected with the W-GCTA and the observations, respectively.

The interviews were semi-structured and were conducted on a one-on-one basis. Semi-structured interviews are worded more flexibly and make use of both closed and open-ended questions, although specific information is desired (Greeff, 2005). The main part

of the interview is guided by questions, which allow the participants to explain their thoughts and opinions, thus allowing the researcher to ask follow-up questions when interesting aspects arise during the interview. Semi-structured, one-on-one interviews were used to gain a detailed picture of participants' experiences (Greeff, 2005). The duration of the interviews was one hour per participant, or until data saturation occurred.

According to Merriam (2009), an interviewer can ask different types of questions to stimulate different responses from an interviewee. Six types of questions are suggested when constructing the interview schedule, and the researcher included questions from each of the following categories:

- Experience and behaviour questions, which relate to the participants' behaviour or actions. Questions such as *"How would you describe your experience playing the puzzle video game Portal?"* (cf. Appendix I).
- Opinion and values questions, relating to the participants' beliefs and opinions. Questions such as *"Did playing this game benefit you in any way? How?"*, as well as, *"Do you believe that playing video games can help you acquire certain knowledge or skills more effectively than in a formal classroom setting?"* could be considered examples of this type of question (cf. Appendix I).
- Feeling questions, relating to the emotional and affective dimensions of the participant. Questions such as *"How did solving the puzzles in the game make you feel?"* could be considered an example (cf. Appendix I).
- Knowledge questions, which elicit a participant's factual knowledge related to the situation. This type of question was not asked, as the purpose of the study was not to gauge the understanding of participants regarding critical thinking or problem solving skills (cf. Appendix I).
- Sensory questions, relating to the senses of sight, hearing, touch. Questions such as *"Please describe in your own words what the puzzle video game Portal (which was played during the intervention programme is all about)"* (cf. Appendix I).
- Background/demographic questions, related to the participants' background. An example of this type of question would be *"Have you ever played a puzzle video game before? What makes them enjoyable for you?"* (cf. Appendix I).

5.8 ROLE OF THE RESEARCHER

In qualitative research, while the researcher plays an instrumental role in data generation and data interpretation, the researcher, as the primary instrument for data collection, also poses a threat to the trustworthiness of the collected data (Theron & Grosser, 2010). The researcher's situatedness can influence the interpretation of the data and encourage compromise, and must therefore be unpacked at the outset of the study (Theron & Grosser, 2010). The following issues, indicated below, were derived from Theron and Grosser (2010) and Merriam (2009), and were addressed in the present study.

Researchers can be influenced by historical, social and cultural experiences. These could include preconceived notions of racial prejudice, in particular because the researcher is Caucasian and participants from other ethnic groups were included in the research. The researcher accepted all students and was friendly with all participants at all times, as he wished to enrich the research findings by including different cultural groups (if possible). In addition, the researcher has lectured to a multi-cultural group of students for a number of years now, and has been able to build firm rapport and establish sound relationships with students from a variety of contexts and experiences.

The status of the researcher could also influence the trustworthiness of the data. This included aspects of age, gender and socio-economic status. Age could have influenced the trustworthiness, as the researcher was older than most of the participants, and it could happen that they might not be willing to share information with a person who they feel is older and more experienced. Moreover, since the researcher is also a lecturer at the research site, the hierarchical relationship may have also compromised data collection. To circumvent the mentioned issues, the researcher only sampled students that he did not lecture, and established a good rapport with the participants that allowed for an open atmosphere to freely share information. The researcher also did not include gender-related issues that could have posed a threat to data collection.

The researcher enters a research field with certain assumptions. With regard to this research, the researcher's thoughts regarding the development of critical thinking were already shaped by personal experience and the consulted literature. To avoid assumptions clouding interpretations of data, the researcher must be open to unexpected

results that go against an assumption. The researcher acknowledges that he assumed that the development of critical thinking would be fragile and deficient among the students, and had to be careful that this assumption did not influence or cloud the interpretation of the qualitative data. To assist in avoiding that these assumptions do not cloud the interpretation of data, the researcher endeavoured to follow the guidelines for trustworthiness as outlined by Babbie and Mouton (2001). Issues such as credibility, transferability, dependability and confirmability were all adhered to (*cf.* 5.10.2.1).

The researcher can also influence trustworthiness if there is a personal connection to the research site. With regard to the sampled participants, none of the students were sampled from the researcher's own classes. Also, an independent person assisted in recruiting all of the participants, to avoid conflict of interest and prevent bias. The researcher thus reduced the chances where participants may have responded in a way to please the researcher, making their responses unreliable.

5.9 DATA ANALYSIS AND INTERPRETATION

The data gathered were analysed in two separate phases, as the research comprised a combined qualitative and quantitative approach. Statistical procedures were used for the analysis of the test responses. A qualitative, descriptive analysis linked to a four-point scale was utilised for the analysis and interpretation of the observation data, and content analyses were applied to the interview data.

5.9.1 Quantitative W-GCTA test data

The following section discusses the various statistical procedures that were undertaken to analyse the quantitative data.

Descriptive statistics

The Statistical Consultancy Services at the North-West University: Vaal Triangle Campus were consulted for assistance with the capturing, analysis and interpretation of all the data that was collected. Descriptive statistics were used to organise and summarise data meaningfully in order to promote an understanding of the data characteristics (Leedy & Ormrod, 2005). Various calculations were done, including frequencies, means, medians,

standard deviations and percentages. This was done in order to determine the application level of the critical thinking skills of the first-year BEd student participants. Interpretations of the data were aligned to the stages of critical thinking development (*cf.* 2.5.1 – 2.5.6).

Inferential statistics

Although the main aim of the study was not to compare the participants in the experimental and control groups with one another, the independent statistician suggested that the researcher employs non-parametric statistics (Ivankova, Creswell, & Plano Clark, 2007; Pietersen & Maree, 2007a) to make tentative conclusions about the merits of the PVG-CEP intervention.

It was important to consider whether parametric or non-parametric statistical procedures should be utilised. In this study where a small sample was utilised (less than 30), the researcher could not assume that the study variable was normally distributed, and made the decision to employ non-parametric statistical procedures (Pietersen & Maree, 2007b, McMillan & Schumacher, 2006).

The Mann-Whitney U test, was used to compare the pre-test and post-test results of the experimental group, with the results of the control group (Pietersen & Maree, 2007b). This test uses the ranks of the study variable rather than the actual values, implying that extreme values will have less influence on the outcome than they would when a t-test is used (Pietersen & Maree, 2007b; Swanepoel *et al.*, 2006).

The Wilcoxon signed-rank test was used to compare the differences between the pre-test and post-test results within the experimental and control groups. The differences between the pre- and post-test scores are ordered and ranks are assigned to them, as the actual values of the differences are not used (Pietersen & Maree 2007b).

If statistical significant differences were noted between groups or results, $p < 0.05$, effect sizes were calculated for the differences. Effect size was utilised to determine the importance and extent of an observed effect in two group experiments (Field, 2005). In the context of this study the “*r*” is employed as a gauge to conclude the strength of the experimental effect. Field (2005) argues that “*r*” is most effective for the calculation of the

influence of value where the results of two focused groups are compared. The following interpretation is applicable to the ascertainment of effect size:

- $r = 0.10$: small effect
- $r = 0.30$: medium effect
- $r = 0.50$: large effect (Field, 2005, p. 4, 7).

According to the independent statistician that assisted the researcher, effect sizes are only reported for results that were statistically significant, which is supported by Leech, Barrett, and Morgan (2005. p. 59), who indicate that *“if the difference between means was not statistically significant it is recommended not to discuss or interpret effect size”*.

5.9.2 Qualitative observation data

Based on the view of Cohen *et al.* (2007), the researcher used a pre-determined and structured observation schedule to record incidences that would reveal the nature and quality of the participants' critical thinking development. The researcher compiled separate timeline graphs for the development of the critical thinking skills, dispositions and the standards for reasoning for each of the individual participants, according to predetermined criteria on a four-point scale (1: Novice; 2: Able; 3: Skilled; 4: Sophisticated) (Anderson, 2012) (*cf.* 2.5.7; Appendix H). In addition, anecdotal records were also compiled during the observations for each of the data collection points during the intervention. According to Thyer (2014), the use of simple line graphs indicates all data points that would reveal changes in the level of data, changes in the slope of data, changes in data variability, and the extent of data-overlap.

The intervention was implemented for 13 weeks, two hours per week for each participant. In Figure 5.3 (below), an example of the predetermined criteria that were used for observing the progressive nature of a student's disposition to work systematically is provided. Criteria were developed for each of the critical thinking skills, dispositions and standards for reasoning addressed during the study (*cf.* Appendix H).

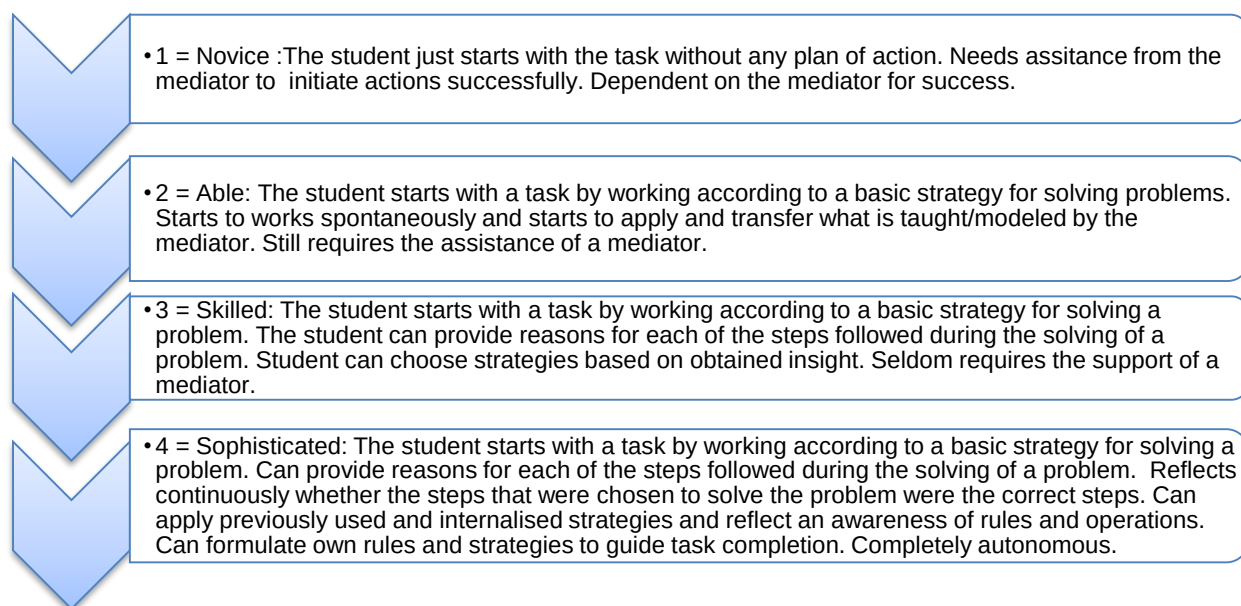


Figure 5.3: Observation criteria for working systematically

(Adapted from Anderson, 2012; Costa, 2009, Feuerstein, Feuerstein, Falik, & Rand, 2002)

Unfortunately, a post-test could not establish if improvements noted for the application of the dispositions and standards for reasoning during the observation, were retained. However, a post-test assessment after the intervention enabled the researcher to see, to some extent, whether observed intervention improvements noted for the application of the critical thinking skills, were probably maintained or whether the application of critical thinking behaviour decayed (Thyer, 2014).

5.9.3 Qualitative interview data

All the interviews were tape-recorded. After the interviews, the tape recordings were transcribed into written format for analysis. Thereafter, the data analysis and interpretation were done by means of an inductive, as well as a deductive content analysis.

Content analysis involves looking at the content of the data and breaking it into certain themes in order to extract meaning. The main method for analysing the data would be to get the thoughts of the participants and to classify these thoughts into certain themes and categories (Leedy & Ormrod, 2005).

Inductive content analysis refers to the identification of codes by the researcher when examining the data. This implies that the data speaks for itself and that no interpretations or bias that is not related to the data is evident (Nieuwenhuis, 2016c).

Although qualitative researchers prefer inductive data analysis, the researcher also worked deductively as existing codes were identified from the literature review before examining the data (Nieuwenhuis, 2016c). The existing codes were used to test existing theory on critical thinking development, and the inductive analysis would assist the researcher to expand on existing theory, if new codes were identified from the words of the participants.

The following steps, as highlighted by Creswell (2009) and McMillan and Schumacher (2006), applied for conducting the inductive content analysis:

- Organising the data collected was the first step for the researcher to start with the interpretation of the data.
- The researcher did not conduct all of the interviews at once. A procedure was followed, which involved analysing the first and second interviews to identify relevant data that said something about the phenomenon under investigation. The relevant data was then coded (open codes), and similar codes were grouped into categories (axial codes) (*cf.* Appendix J).
- Categories were then compared to each other and refined. If different codes emerged, then those codes would be addressed in the remaining interviews that still needed to be conducted.
- The researcher compared the codes and categories constantly to the previously identified codes and categories. It is known as a constant comparative method when doing qualitative content analysis.
- The researcher then compared the different categories that were identified and looked for emerging patterns/themes. A pattern is a relationship among categories of data. In searching for patterns, the researcher tried to understand complex links among various aspects of the participants' situations, mental processes, beliefs and actions.
- The researcher then constructed a visual representation (*cf.* 6.6.9) to organise the information and to indicate the relationships between the various themes.

- The interpretation of the data obtained was done next and integrated into the theoretical framework of the study (deductive analysis) to confirm and/or extend existing theory on the nurturing of critical thinking.

A final interpretation followed, in which the data obtained for the tests, the observations and the interviews were triangulated (*cf.* 6.7). The different sets of data were combined to come to a clearer and deeper understanding of the development of critical thinking while playing puzzle video games.

With the multiple case studies, the researcher aimed to learn as much as possible from each case, but also tried to build abstractions across the different cases (Merriam, 2009) (*cf.* 6.3.5; Tables 6.5, 6.6). The researcher admits that it was a challenge to manage the large volumes of data to ultimately build theory that offers an integrated framework covering multiple cases.

The following section outlines the manner in which rigour was ensured for the study.

5.10 RIGOUR

The proceeding sections outline the procedures to ensure rigour within the study.

5.10.1 Quantitative study: Reliability and validity

The following section discusses the reliability of the W-GCTA test.

5.10.1.1 Reliability and validity of the W-GCTA

The W-GCTA spans more than 50 years of development and refinement. The nature and the content are such that they can be regarded as not constructed for conditions for students in the United Kingdom exclusively. The content of the test comes from newspapers and magazines, and focuses on culturally neutral and familiar topics, that would elucidate strong feelings or prejudices (Watson & Glaser, 2002b).

The researcher acknowledges that the test was only available in English, which could affect reliability, as participants' responses may be influenced negatively if their home language was not English. The students whose home language is Sesotho or any other

African language were expected to take the English version of the test, as they completed their schooling in English.

Reliability was supported by a previous study conducted with first-year BEd students at the same university (Lombard & Grosser, 2008). An exploratory pilot study was undertaken consisting of 50 BEd first-year students. Data revealed a split-half reliability coefficient of 0.566471 and a Guttman split-half reliability of 0.566515. According to the residential Statistical Consultation Services, the two coefficients could be regarded as an acceptable measure to conclude that the W-GCTA complied with reliability criteria for an exploratory study (Lombard & Grosser, 2008). By convention, a lenient cut-off of .60 is common in exploratory research (Garson, 2009).

The W-GCTA complies as follows with criteria for validity:

- Face validity: The W-GCTA contains relevant content and the thinking operations and processes required during test completion, are valued as relevant to critical thinking.
- Content validity: The content validity of the instrument is supported by the fact that the specific test items reflect the various critical thinking constructs as defined by each sub-test. Furthermore, the test measures the capabilities and objectives that are also required for the problem solving scenarios in the puzzle video game that was used as an intervention in the context of the research.
- Construct validity: The construct validity of the W-GCTA is underpinned by the fact that it is a good measure of all the core skills of the construct “critical thinking”, as revealed in the literature. It, however, has a limitation because critical thinking dispositions and the universal standards for reasoning are not assessed.
- Criterion validity: The test has already been used to predict a variety of criteria such as course grades, degree attainment and academic performance (Watson & Glaser, 2002b).

The researcher adhered to the same manual procedure for scoring the test by using the acetate-scoring key provided by the test developers (Watson & Glaser, 2002b). This procedure included the following steps:

- detect and calculate multiple responses, partly erased answers and missed items on each answer sheet;
- obtain the raw score on each answer sheet;
- transform raw scores to t-scores to make comparisons with norm groups; and
- identify appropriate norm groups for a comparison of scores (Watson & Glaser, 2002b).

As the researcher did not intend to make any comparisons with pre-existing norm-groups, t-scores were not utilised and only the raw mean scores obtained for the various sub-tests were calculated. Norm groups for the South African population do not exist.

Scoring for the W-GCTA is carried out in two stages. Firstly, the raw scores are obtained, and secondly, the raw scores are transformed to W-GCTA scores. As the researcher scored by hand, the acetate scoring key provided by the authors of the test, was utilised. The psychologist who assisted the researcher with the administering of the test to the participants, verified the researcher's scoring for each participant.

The authors of the test also suggest the use of a raw score corrected for guessing, that gives a better estimate of a participant's true ability (Watson & Glaser, 2002b). As the score corrected for guessing does not allow "*inspired guessing – assuming that a candidate either knows the right answer or that he does not*" (Watson & Glaser, 2002b, p. 7.16), the researcher decided to only make use of the raw scores without the correction for guessing. According to the authors of the W-GCTA, the test may be used with or without the correction for guessing (Watson & Glaser, 2002b).

The time-span between the pre-test and post-test occasions was not too short so that the participants could remember the test material. Participants also did not receive any test answers which they could remember, and did not have access to the test material to practice and rehearse the answers. The researcher therefore argues that the pre-test could not have influenced the post-test results (Cohen *et al.*, 2007). Furthermore, the puzzle game problems differed from the problems in the W-GCTA, which reduced the risk of training or teaching to the test

The researcher acknowledges the following limitations cited by Cohen *et al.* (2007) that might have influenced the participants' test results.

- The test relied on comprehension and reading ability that could have disadvantaged participants whose Home Language is not English.
- The number of cognitive actions that participants had to apply in solving the test scenario problems, might have been overwhelming, and could have contributed to low-test taking motivation (Bensley *et al.*, 2016).
- A one-hour test might have caused participants to become bored, tired or lose concentration.
- The test focused on the comprehension and interpretation of verbal text, which might not have been the preferred learning modality of participants who prefer and cope better with auditory, visual, or hands-on learning.
- Unpleasant events in the lives of the participants prior to taking the test, could have influenced their performance during the test occasions, and possibly during their involvement in the intervention as well.
- It is important to acknowledge that some participants might excel at performing problem solving tasks in everyday life, but not under test conditions.

5.10.1.2 Validity of the quantitative research design

It was also necessary for the researcher to make sure that the quantitative research component complied with the following validity criteria as identified by Leedy and Ormrod (2005), McMillan and Schumacher (2006), and Pietersen and Maree (2007c).

Statistical conclusion validity

Statistical conclusion validity refers to the appropriate use of statistical tests to determine whether purported relationships are a reflection of actual relationships (Leedy & Ormrod, 2005). In this regard, the researcher sought the assistance of the Statistical Consultation Services at the North-West University, Vaal Triangle Campus. The researcher is therefore convinced that the statistical procedures utilised in this study were appropriate for the study, and correctly applied.

Internal validity

Internal validity explains the extent to which the research design and the data it yields allow the researcher to draw accurate conclusions from the data (Leedy & Ormrod, 2005). In the case of this study, the following can be mentioned: The researcher did not experience any extraneous incidents that affected the results. The researcher however could not control for the influence of variables on the research findings, due to the small number of participants, which poses a limitation to the internal validity of the research.

External validity

External validity refers to the extent to which the conclusions drawn can be generalised to other contexts (Leedy & Ormrod, 2005; McMillan & Schumacher, 2006). The external validity of the study is enhanced by the fact that the study was conducted in a real-life setting (Leedy & Ormrod, 2005). Caution however, was exercised in the final interpretation of the results, as the sample size was not representative of all BEd students across the country, necessitating further research with larger samples to generalise findings.

Construct validity

Construct validity concerns the efficacy of using a particular data collection instrument for research purposes (McMillan & Schumacher, 2006). The researcher is convinced that the use of the W-GCTA to determine the level of first-year BEd students' critical thinking skills could be regarded as appropriate. Furthermore, the observations conducted during the implementation of the intervention programme provided a deeper understanding of the W-GCTA test scores, and supported the construct validity of the study. Interviews could be regarded as a suitable way to explore the participants' perceptions about the use of the puzzle game during the intervention. Moreover, the use of observations could be regarded as acceptable to gain insight into the participants' application of critical thinking skills, dispositions and standards for reasoning.

5.10.1.3 Validity of the quasi-experimental research

According to DiNardo (2010), a quasi-experiment is an empirical study used to estimate the causal impact of an intervention on its target population. Quasi-experimental research

shares similarities with the traditional experimental design or randomised controlled trial, but it specifically lacks the element of random assignment to experimental or control groups (DiNardo, 2010).

Validity of the quasi-experimental research was ensured in the following ways:

Internal validity

In this study, the researcher, who is trained in mediated learning and in the application of Portal (puzzle video game), conducted the implementation of the intervention. The implementation time of the intervention was kept short, focused and intense to reduce the chances of other factors such as history, maturation and experimental mortality affecting the result (Lodico, Spaulding, & Voegtle, 2010). To avoid researcher bias in the assigning of participants to the research, the researcher requested a colleague who was not involved in the research to assist with the allocation of students to the study (Cohen *et al.*, 2007; Lodico *et al.*, 2010).

External validity

As the intervention was a first pilot study, it was conducted at one university with four participants who were not randomly selected. The generalisation of the research findings to the entire population would therefore be limited (Cohen *et al.*, 2007). In order to enhance the external validity, the researcher described the biographical variables as adequately as possible (*cf.* Table 5.1), to make future replications of the experimental conditions possible (Cohen *et al.*, 2007) (*cf.* 5.3.2).

The researcher did not make use of other researchers to implement the intervention, to avoid the influence of experimental effects (Lodico *et al.*, 2010:249). The researcher however acknowledges, that he may have exerted unintentional influence on the outcome of the study. The researcher, however, took care to implement the intervention in a similar manner with all the research participants. In order to avoid differential implementation of the intervention with the four students, the researcher adhered to objective criteria (*cf.* Appendix H) during the implementation of the intervention with both groups of students to ensure identical implementation with all four students (Cohen *et al.*, 2007). The same puzzles were also solved by all the students who took part in the study.

The researcher is aware of the influence of the Hawthorne effect that can contaminate experimental treatments when participants become aware of the fact that they are participants in an experiment where a change in behaviour is desired (Cohen *et al.*, 2007). Simply being part of a study can influence one's feelings, behaviour and attitudes (Lodico *et al.*, 2010). Without deceiving the participants, they were just informed that they would be exposed to a new teaching strategy of which the effects would be monitored regarding the improvement of critical thinking skills. Participants were informed that the outcome of the study would have no influence on their academic results or passing or failing at university.

External validity was further enhanced by the fact that participants were not exposed to multiple treatment interactions to enhance their critical thinking skills (Lodico *et al.*, 2010). The influence of the participants' exposure to normal academic lecturing, could however not be controlled, and might have exerted some influence on the research findings.

5.10.2 Qualitative study: Trustworthiness

The following section provides detail on the trustworthiness procedures that were undertaken in this research study.

5.10.2.1 Trustworthiness of the interviews

The following aspects identified by Lincoln and Guba (1985) and Lincoln and Guba (in Babbie & Mouton, 2001) were adhered to:

Credibility entails the compatibility between constructed realities that exist in the minds of the participants and those that the researcher attributes to them (Babbie & Mouton, 2001; Lincoln & Guba, 1985). Credibility was ensured by making use of materials that can support the research findings, such as a tape recorder or video recorder, but also by getting members in the field to check data and interpretations (Babbie & Mouton, 2001; Lincoln & Guba, 1985). The researcher supported credibility by recording the exact words and actions of the participants during the interviews and intervention, as well as by asking the participants to check and verify whether the researcher's interview transcripts provided a true account of what they said.

Transferability refers to the extent to which findings can be applied to other contexts or to other participants (Babbie & Mouton, 2001; Lincoln & Guba, 1985). Qualitative research does not make generalisations, but the interpretations are related to the specific context of the research. Therefore, what is true for this research may not be true in other contexts. This research did not wish to generalise, because what might be true for this study might be different for participants in other contexts. In this study, the researcher gave a detailed and precise description of the setting in which the research took place and the characteristics of the participants in order to allow the reader to judge the transferability to participants with similar characteristics (Babbie & Mouton, 2009; Lincoln & Guba, 1985) (*cf.* 5.6).

Dependability refers to the consistency and reliability of the findings, and the degree to which the research procedures are documented, allowing someone on the outside to follow, audit and critique the research process (Babbie & Mouton, 2001; Lincoln & Guba, 1985). To ensure this, an enquiry audit was used (Lincoln & Guba, 1985), which examined the documentation, such as the interview notes and interpretations made by the researcher to secure accuracy. The researcher used his promoter and a knowledgeable colleague in the field for this purpose. An example of an audit trail is attached in Appendix J.

Confirmability is the degree to which the findings are the product of the focus of the enquiry and not the biases of the researcher (Babbie & Mouton, 2001; Lincoln & Guba, 1985). To support unbiased findings, the researcher based all interpretations solely on the raw data gathered from the recordings and made use of his promoter and a knowledgeable colleague in the field to verify the verbatim transcripts and the findings to ensure that the researcher was not biased, but based all interpretations only on the data.

5.10.2.2 Trustworthiness of the observations

Four aspects played a critical role in supporting the trustworthiness of the observations.

Credibility

The researcher ensured prolonged engagement by staying in the field until data saturation occurred. Persistent observation, where the researcher aimed to interpret

findings in different ways by looking for multiple influences, also took place. Information was collected about various incidents and behaviours by combining quantitative and qualitative methods of data collection. The researcher also made use of a co-observer with whom he compared and reviewed his perceptions, decisions, insights and analyses (Babbie & Mouton, 2009; Lincoln & Guba, 1985).

Since conducting an observation might be highly subjective, the researcher strove to ensure that his own bias and assumptions did not interfere with his interpretations. In this regard, the use of a co-observer, who observed the participants independently from the researcher, ensured credibility. After each observation session, the observations of the researcher and co-observer were compared against the video recordings, a joint conclusion was reached and a descriptive account capturing the findings, was written. The video recordings were used to clarify disparities noted between the observations of the researcher and co-observer.

In this study, the use of multiple data sources and methods of data analysis assisted in producing trustworthy results (Nieuwenhuis, 2007c). The use of a co-observer also avoided selective data entry and selective memory on the researcher's side (Cohen *et al.*, 2007).

Transferability

The researcher gave a rich detailed and precise description of the setting in which the research took place and the characteristics of the participants in order to allow the reader to judge the transferability of the study to participants with similar characteristics (Babbie & Mouton, 2009; Lincoln & Guba, 1985).

Dependability

To provide the reader with evidence that the data are reliable, the co-observer and promoter critically examined the data, findings, interpretations and recommendations of the researcher for correctness (Babbie & Mouton, 2009; Cohen *et al.*, 2007; Lincoln & Guba, 1985). The video footage that was compiled during the observations enabled the researcher to verify the observation data supported by anecdotal records against the actual account of behaviour during the implementation of the intervention.

Confirmability

The researcher ensured confirmability by constantly comparing the observations made by himself, with the observations of the co-observer (Babbie & Mouton, 2009; Lincoln & Guba, 1985; Nieuwenhuis, 2007c;).

The researcher also conducted a few pilot sessions before the research started, with willing students who were not part of the actual research, to confirm that the observation categories were appropriate, meticulous, distinct and clear as well as utilised efficiently according to the purpose of the research (Cohen *et al.*, 2007). In order to produce results that are believable and convincing, the researcher also reported negative or inconsistent results in order to add to the trustworthiness of the study (Leedy & Ormrod, 2005).

The researcher acknowledged the following important criteria mentioned by Daniels *et al.* (2008) for recording observations.

- The researcher and the co-observer strove to focus objectively on what was observed in each participant's behaviour and did not allow their own ideas, thoughts and emotions to influence their observation. The fixed criteria according to which the observations were conducted, also assisted in enhancing the reliability of the observations.
- The researcher made sure that ensured the environment in which the intervention took place was comfortable and quiet to enable the participants to concentrate and focus on their game play.

In the next section, detailed information is provided on how the researcher complied with ethical principles throughout the study.

5.11 ETHICAL CONSIDERATIONS

The proceeding section outlines the ethical considerations that were adhered to in this study.

5.11.1 Ethical issues in terms of the research problem

During the identification of the research problem, it is important to identify a problem that will benefit the individuals who are studied (Creswell, 2009). The problem being studied must be meaningful. According to the researcher, this study is meaningful as it highlights issues pertaining to critical thinking, an important outcome in South African education, and suggests how critical thinking could be developed utilising puzzle video games.

5.11.2 Ethical issues in terms of the purpose and questions

Researchers need to convey the purpose of a study to the participants (Creswell, 2009), which is done in order to ensure that participants do not get confused or misunderstand their involvement within the research. The purpose of the study was addressed before the researcher gained the written consent of the participants during the recruitment session.

The benefits and risks of the study should also be communicated to participants. These benefits communicated to the participants included the following:

- The possibility of acquiring critical thinking skills with the PVG-CEP to enable one to think critically and solve problems more effectively.
- Another benefit would be that the participants could probably gain knowledge about the use of puzzle video games as a strategy to develop thinking.

The indirect benefits communicated to the participants included the following:

- Researchers at other universities could be informed about the possible benefits of the PVG-CEP to develop critical thinking, and conduct further studies in other contexts to prove the benefits of the strategy for developing critical thinking skills on a larger scale.
- The research findings could be used to make recommendations to the Department of Education, regarding enhancing the teaching practices of teachers with the use of puzzle video games.
- The teaching practice of the greater population of student teachers could benefit if the PVG-CEP holds merits for developing critical thinking. This benefit could be communicated to Faculties of Education at Universities who could consider to

incorporate training in the use of puzzle video games into the teacher education curriculum.

The risks associated with participation in this study that were communicated to the participants included the following:

- Conflict of interest and the power relationship because the researcher was also a lecturer at North West University Vaal Campus.
- Completing a test and taking part in an intervention programme might cause anxiety and stress, and inconvenience.
- Complete anonymity cannot be guaranteed, because the researcher worked individually with the students who took part in the intervention.

The participants were informed that these risks will be mitigated in the following manner:

- Conflict of interest would be minimised as the participants chosen were not students of the researcher himself, i.e. they did not attend any of his lectures.
- Anxiety and stress would be mitigated by informing participants that their participation is voluntary and that they could leave at any time. The researcher would also try to make them comfortable and reassure them that their participation would be beneficial.
- Complete anonymity could not be guaranteed, but the researcher would endeavour that any interpretations and conclusions based on the data will not be divulged to anyone, except to the participants themselves, the co-observer, promoter and independent statistician.

5.11.3 Ethical issues in terms of data collection

Research participants must give their consent before any empirical study is to be undertaken. No participant may be forced to take part in the research. The researcher developed an informed consent form for participants to sign before they engaged in the research (Creswell, 2009) (*cf.* Appendix E). As the participants were 18 years and older, it was not necessary to obtain consent from their parents.

This consent form indicated how and why the participants were selected, the potential risks and benefits of the study, the type of involvement, that participation is voluntary and

how anonymity and confidentiality would be ensured. At the same time the form ensured that participants can withdraw at any time, as well as provided contact details of the researcher should questions arise. The consent forms were also translated into Afrikaans for those participants who speak Afrikaans.

Permission to continue with the research was sought from the Basic and Social Sciences Research Ethics Committee of the North-West University, Vaal Triangle Campus and clearance was granted on 16 February 2017 (*cf.* Appendix B). Permission was also sought from the North-West University Research Data Keeper Committee (NWU-RDGC), which was also granted (*cf.* Appendix C). In addition, the School of Languages provided consent to use the TAG/TALL results of the first-year BEd students (*cf.* Appendix D).

5.11.4 Ethical issues in terms of data analysis and interpretation

The nature of the study makes it impossible to guarantee complete anonymity. Participants were informed about the lack of anonymity before they decided to take part in the study. Confidentiality was guaranteed to the participants, as only the researcher, statistical consultant, and the promoter had access to the data obtained. The co-observer only had partial access to the observation data. Participants were identified by numbers, and no names were used during the capturing, analysis and interpretation of the data.

5.11.5 Ethical issues in terms of writing and disseminating the research

Research must not make use of words or language that are biased against persons due to gender, ethnic group or age differences (Creswell, 2009). Researchers must also avoid falsifying or inventing findings, as such conduct is regarded as scientific misconduct (Creswell, 2009). This research is based on sound data and findings obtained from the actual empirical study.

5.12 CHAPTER SUMMARY

This chapter began by identifying the research framework or paradigm that would be adopted by the current study (*cf.* 5.2). The paradigm selected was the pragmatic worldview, which best suits the study as it wished to solve a problem that entailed the

collection of quantitative and qualitative data, for which a mixed method approach was best suited.

The aim of the study was two-fold, namely to determine how sophisticated first-year BEd students are in the application of critical thinking, and based on the findings, to establish and explore how a PVG-CEP can support the development of critical thinking among first-year BEd students (*cf.* 5.3.1). The researcher could not test for the influence of variables on the research outcomes due to the small sample size (*cf.* 5.3.2). For the purpose of this study the focus was on an initial exploration of the PVG-CEP as independent variable on the dependent variable in this study, namely critical thinking.

An embedded mixed method experimental research design was employed in the study (*cf.* 5.4.1). The priority of the design was established by the quantitative data, and the qualitative dataset played a subservient role in the research design.

As this study was a mixed method study, both quantitative and qualitative strategies of enquiry were used (*cf.* 5.5). As part of the quantitative research component, a quasi-experimental research strategy (*cf.* 5.5.1) comprising a pre-test, intervention and post-test were employed. The qualitative strategy of enquiry (*cf.* 5.5.2) used a case study as strategy to gather data.

The sampling for the quantitative portion of the study (*cf.* 5.6.1) included first-year BEd students in the Faculty of Education of the North-West University, on the Vaal Triangle Campus. Due to time and logistical constraints, a non-probability, convenient, purposive sample of eight first-year BEd-students, who were randomly assigned to an experimental and control group, were used. The participants were selected, based on the results of the Toets vir Akademiese Geletterdheid (TAG)/Test for Academic Literacy (TALL) that first-year students write to identify the extent of academic preparedness before they start their studies at a higher education institution.

The participants for the qualitative phase of the study (*cf.* 5.6.2) included a purposive criterion sample as only the four student participants who were part of the experimental group, were involved in this component. The sample was limited in size due to the intense and in-depth nature of the case studies to be done, where observations across a 13-week intervention were conducted.

Quantitative pre- and post-test data collection before and after the PVG-CEP intervention took place with the W-GCTA (*cf.* 5.7.1.1), that consisted of five tests that measured the application of critical thinking skills, namely making inferences and deductions, evaluating arguments, interpreting information, evaluating information, and recognising of assumptions.

The qualitative data consisted of compiling observations where the researcher played the role of participant as observer. The rating scale observations were accompanied by qualitative descriptors of behaviour, and backed-up by anecdotal records and video recordings (*cf.* 5.7.2.1), to acquire a profound insight into, and understanding of critical thinking and its application among the research participants who took part in the PVG-CEP intervention. Furthermore, semi-structured, one-on-one interviews were conducted with the four participants in the experimental group at the end of the intervention, in order to understand their perspectives about their experiences with the puzzle video game intervention (*cf.* 5.7.2.2).

The researcher considered important aspects in relation to his role as qualitative researcher (*cf.* 5.8), such as historical, social and cultural experiences; researcher status, researcher assumptions, and personal connection to the research site, in order to avoid that data collection was compromised.

The data gathered were analysed in two separate phases, as the research entailed a combined quantitative and qualitative approach (*cf.* 5.9). Statistical procedures (descriptive statistics and inferential statistics) were used for the analysis of the test data. Descriptive statistics were used to organise and summarise data meaningfully in order to promote an understanding of the data characteristics (*cf.* 5.9.1). Interpretations of the data were linked to the stages of critical thinking development (*cf.* 2.5.1- 2.5.6).

Non-parametric inferential statistical procedures were used to make comparisons between the pre- and post-test results obtained with the W-GCTA. The Mann-Whitney U test was used to compare the W-GCTA pre-test and post-test results of the experimental and control group with one another. The Wilcoxon Signed-Rank test was utilised to compare the differences between the pre-test and post-test total results within the experimental and control groups respectively, for each of the five sub-tests (*cf.* 5.9.1).

The scale data obtained from the observations, were converted to qualitative descriptions that captured the nature of the participants' application of the critical thinking skills, critical thinking dispositions and standards for reasoning (*cf.* 5.9.2). The qualitative descriptions were accompanied by time line graphs depicting the development of the critical thinking skills, dispositions and the standards for reasoning for each of the individual participants, according to predetermined criteria on a four-point scale (1: Novice; 2: Able; 3: Skilled; 4: Sophisticated). Anecdotal records were also compiled during the observations for each of the data collection points during the intervention.

All the interviews were tape-recorded. After the interviews, the tape recordings were transcribed into written format for analysis. Thereafter, the data analysis was done by means of an inductive, as well as a deductive content analysis (*cf.* 5.9.3).

The reliability of the W-GCTA that was established in previous research (*cf.* 5.10.1.1). The validity of the quantitative research component (*cf.* 5.10.1.2), was ensured by adhering to criteria for statistical conclusion validity, internal validity, external validity and construct validity. The trustworthiness of the qualitative study was guaranteed (*cf.* 5.10.2), by upholding criteria that guaranteed credibility, transferability, dependability and confirmability during the analysis of data.

A variety of ethical considerations (*cf.* 5.10.11) were taken into account during the research, namely by dealing with ethical issues in the research problem (*cf.* 5.11.1), the purpose and questions (*cf.* 5.11.2), during data collection (*cf.* 5.11.3), during data analysis and interpretation (*cf.* 5.11.4), as well as in writing and disseminating the research (*cf.* 5.11.5).

The following chapter, Chapter 6, presents the data analysis and interpretation.

CHAPTER 6

DATA ANALYSIS AND INTERPRETATION

6.1 INTRODUCTION

This chapter aims to provide a comprehensive analysis and interpretation of the data that were collected during the pre-test, implementation of the intervention programme, post-test, and interview phases during this study. The chapter addresses the following issues:

6.2 Pilot study data

6.3 Data analysis and interpretation: Test and observation data – Experimental group

- 6.3.1 Data analysis: Participant 1
- 6.3.2 Data analysis: Participant 2
- 6.3.3 Data analysis: Participant 3
- 6.3.4 Data analysis: Participant 4
- 6.3.5 Initial findings of test and observation data

6.4 Data analysis and interpretation: Test and observation data – Control group

- 6.4.1 Participant 5
- 6.4.2 Participant 6
- 6.4.3 Participant 7
- 6.4.4 Participant 8

6.5 Data analysis and interpretation –test data: Comparison – Experimental and Control group

- 6.5.1 Comparison: Test totals – Experimental group participants
- 6.5.2 Comparison: Test totals – Control group participants
- 6.5.3 Comparison: Sub-tests – Experimental and control group

6.6 Data analysis and interpretation: Interview data

- 6.6.1 Question 1
 - 6.6.1.1 Experience versus inexperience playing games
 - 6.6.1.2 Games are enjoyable, exciting, challenging, and test your mind
- 6.6.2 Question 2
 - 6.6.2.1 Cognitive stimulation
 - 6.6.2.2 Exploration and navigation
 - 6.6.2.3 Goal driven activities
- 6.6.3 Question 3
 - 6.6.3.1 Positive, enjoyable experience
 - 6.6.3.2 Developmental, exploratory, and thoughtful experience
- 6.6.4 Question 2
 - 6.6.4.1 Enjoyment in general
 - 6.6.4.2 Focus and attention enhanced
 - 6.6.4.3 Cognitive improvement
 - 6.6.4.4 Difficulty and lack of time pose challenges
- 6.6.5 Question 5
 - 6.6.5.1 Cognitive benefits of Portal
 - 6.6.5.2 Goal planning benefits
 - 6.6.5.3 Independent thinking benefits
- 6.6.6 Question 6
 - 6.6.6.1 Solving puzzles lead to excitement, happiness and accomplishment
- 6.6.7 Question 7
 - 6.6.7.1 Attention and focus enhanced
 - 6.6.7.2 Task involvement
 - 6.6.7.3 Improved understanding of game expectations
 - 6.6.7.4 Puzzle games enhance thinking skills
- 6.6.8 Question 8
 - 6.6.8.1 Games motivate learning through fun
 - 6.6.8.2 Engaging and experiential nature of games lead to better learning
 - 6.6.8.3 Formal classes are tedious and repetitive, leading to a loss of concentration
- 6.6.9 Visual representation of the interview data

6.7 Triangulation of data

- 6.7.1 Triangulation: Participant 1
- 6.7.2 Triangulation: Participant 2
- 6.7.3 Triangulation: Participant 3
- 6.7.4 Triangulation: Participant 4

6.8 Formulating tentative hypotheses

6.9 Chapter summary

The following section addresses the pilot study that was conducted using the W-GCTA.

6.2 PILOT STUDY DATA

Before the research commenced, the researcher took cognisance of a previous pilot study conducted with a group of first-year students at North-West University Vaal Campus, to establish the reliability of the W-GCTA UK. The previous study yielded acceptable reliability coefficients (*cf.* 5.7.1.1), and therefore the researcher proceeded with the administering of the W-GCTA UK test.

The next section deals with an integrated analysis and interpretation of the data obtained for the pre- and post-test results, as well as the observations for the participants in the experimental group.

6.3 DATA ANALYSIS AND INTERPRETATION: TEST AND OBSERVATION DATA – EXPERIMENTAL GROUP

The following section focuses on the analysis and interpretation of the sub-test data for the pre- and post-tests in relation to the individual participants in the experimental group. The analysis and interpretation combines the pre-and post-test results with the observations, to derive meaningful findings. This section outlines the results obtained for each of the five critical thinking skills sub-tests within the W-GCTA, namely **making inferences, identifying assumptions, making deductions, doing interpretations** and **evaluating of arguments**. In addition, the analysis and interpretation of the observation data in relation to each of the aforementioned skills, as well as the critical thinking dispositions and universal standards for reasoning on which the study focused, are included in the discussions.

Each sub-test counted out of 16. As the W-GCTA provides no descriptive guidelines for interpreting the test results in relation to the nature of the development of critical thinking, the researcher formulated the following guideline for the purpose of the study, that was

linked to the development of a critical thinker according to the view of Elder and Paul (2010) and Papp *et al.* (2014) (*cf.* 2.5).

If a participant scored between 0 – 4, it was interpreted as a negative result, indicating an **unreflective, challenged thinker (Level 1)**. The researcher argued that this result could be an indication of thinking where the individual lacks the ability to assess and improve thinking, cannot identify the influence of personal assumptions on thinking, cannot make inferences and identify implications, and does not apply dispositions and standards for reasoning (Elder & Paul, 2010) (*cf.* 2.5.1, 2.5.2).

Scores between 5 to 8, were interpreted as a moderate score, linking with Elder and Paul's classification (2010) (*cf.* 2.5) of a **beginning thinker (Level 2)**, who is growing towards being possibly more aware of the role of assumptions in reasoning and the application of dispositions and standards for reasoning to become better at thinking (*cf.* 2.5.3).

If the participant scored between 9 to 12, it was interpreted as a positive score linking with Elder and Paul's (2010) (*cf.* 2.5) **practicing thinker (Level 3)**, who, according to the researcher would monitor and identify problems in thinking related to the influence of assumptions or a lack of adhering to thinking dispositions and standards for reasoning. Practicing thinkers are knowledgeable to make inferences and identify implications, can find faults in their thinking and improve their thinking, as well as monitor and check if their thinking adheres to dispositions and standards for reasoning (*cf.* 2.5.4).

Lastly, if the participant scored between 13 and 16, it was interpreted as an exemplary score linking with Elder and Paul's (2010) (*cf.* 2.5) **advanced thinker** moving towards **becoming a master thinker (Level 4)**. According to the researcher, this classification could imply a thinker who can make well-reasoned deductions, inferences and interpretations, is effective at evaluating information, can acknowledge biases and assumptions, revise thinking and apply good dispositions and standards for reasoning during thinking (*cf.* 2.5.5, 2.5.6)

In the absence of a guideline to interpret the W-GCTA raw scores, this guideline was necessary to enable the researcher to tentatively make conclusions about the nature of the development of the participants' critical thinking, and to establish which of the

elements of critical thinking probably required additional development. The researcher used the same categories to classify the total test score out of 80 for all five sub-tests as follows: A score of 0 – 20 would be considered as **unreflective** or **challenged thinking**, 21 – 40 would be considered **beginning thinking**, 41 – 60 would be considered **practicing thinking** and 61 – 80 would be **advanced thinking** moving towards becoming a master thinker.

The researcher acknowledges that the classification was applied to the test scores without practical evidence of the nature and characteristics of the participants' thinking that would explain how they obtained their answers. In this regard, the researcher argued that the observations of the participants' application of critical thinking during the intervention, would allow him to confirm whether the classification could be regarded as appropriate and valid (*cf.* 7.8).

As effective critical thinking also comprises, among others, the application of well-developed dispositions and standards for reasoning, these two elements were also included in the observations. However, it is important to note that these two aspects were not present in the W-GCTA. These dispositions included working systematically and persistence, and the standards for reasoning comprised accuracy, logic, clarity and relevancy (*cf.* 2.3.3) (*cf.* Appendix H).

The participants were expected to work with a specific problem solving model during the implementation of the intervention, known as GROW (*cf.* Table 1.1) to specifically nurture systematic working ways and persistence, as well as the standards for reasoning such as logic, during task completion. As this strategy provided a step by step plan, it would allow participants to work systematically, and approach problem solving in a logical manner. The participants were required to provide feedback constantly to the researcher while they played the game, stating what they were thinking when faced with the various challenges in the game, in order for the researcher to establish the relevance, logic and clarity of their reasoning.

The observation criteria used during the implementation of the intervention, were linked to the five skills that were tested in the W-GCTA, namely making deductions, recognising assumptions, drawing inferences, evaluating arguments and doing interpretations (*cf.*

Appendix H), as well as the dispositions (working systematically, persistence) and standards for reasoning (accuracy, logic, clarity, relevancy). In addition, the researcher's observations were accompanied by anecdotal records (*cf.* Appendix G).

The researcher identified four developmental levels suggested by Anderson (2012) and for classifying growth in relation to dispositions that guided the observations namely: **1 – Novice, 2 – Able, 3 – Skilled and 4 – Sophisticated** (*cf.* 2.5.7, *cf.* Appendix H), that guided the observations. In support of uniform observations, the four levels also guided the observations for the application of the critical thinking skills and the standards for reasoning.

The researcher aligned the developmental levels used during the observations to the categories identified for classifying the W-GCTA test results, namely novice (unreflective, challenged), able (beginning), skilled (practicing), and sophisticated (advanced/master) for the integrated interpretation of the W-GCTA test results and observations in relation to the participants' critical thinking skills (*cf.* 6.3.1 - 6.3.4).

Discrepancies between the observations of the researcher and co-observer during the final week of observations, were dealt with by making use of the video recordings to confirm and verify the observations made, and to come to a joint, final conclusion about the assessment of a participant.

The researcher used the following guide for the interpretations in relation to stagnation, growth and decay during the observations.

- **Stagnation:** Maintaining a certain score on the observation scale.
- **Growth:** A higher score in comparison to a previous score on the observation scale.
- **Decay:** A lower score in comparison to a previous score on the observation scale.

In summary, the researcher handled the data analysis for the participants in the experimental group as follows:

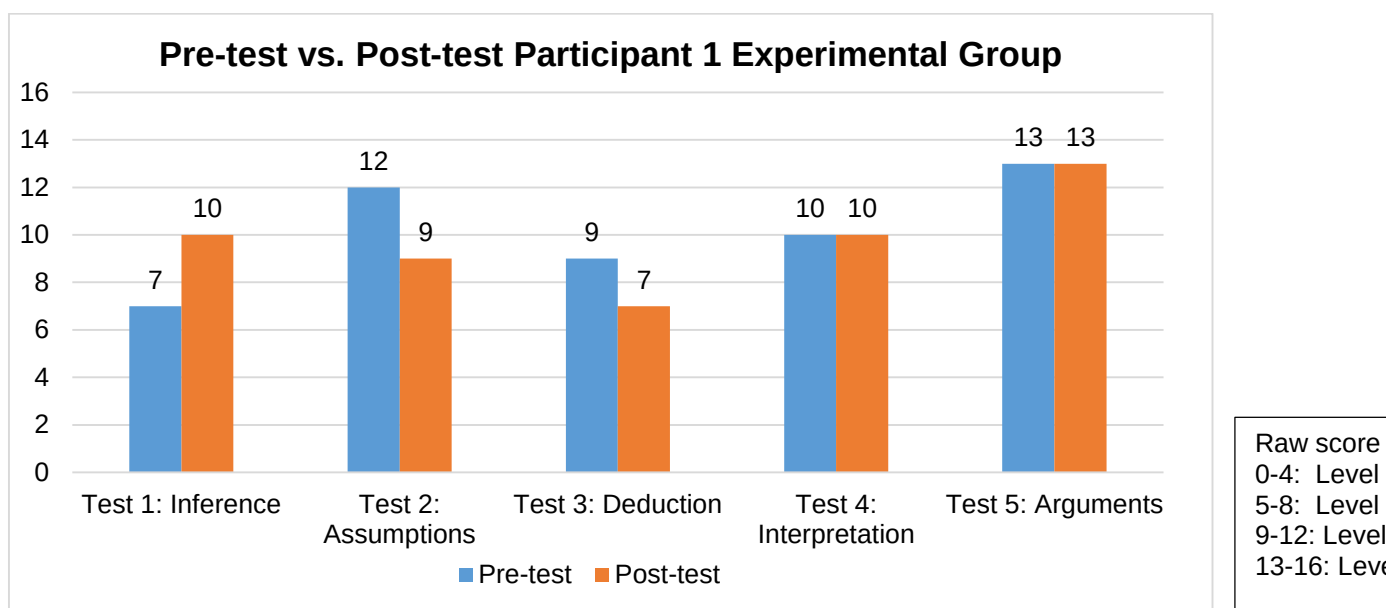
- Due to the bulkiness of the data, and based on a suggestion made by the Research and Innovation Committee at the NWU, Chapter 6 provides an integrated synthesis of the analysis of the test data, aligned to the weekly account of the observations for each of the critical thinking elements on which the study focused.

- Although the W-GCTA test data sometimes indicated an improvement in results, the results did not reflect a higher level of thinking according to the researcher's classification of results, and were therefore not regarded as growth.
- An extensive, descriptive, weekly account of the observations supported by the anecdotal records is included in Appendix L, and provides a true reflection of what happened during the intervention with each participant, with supporting evidence from the anecdotal records (*cf.* Appendix G), to motivate the observations made. Where trends in development were noted across weeks, the trends were clustered together, to avoid unnecessary repetition.
- The observation criteria clarified in section 4.5, are integrated in the synthesis of the data analysis.
- Although according to the embedded mixed method experimental research design interpretations only occur at the end of the study (*cf.* Figure 5.1), the bulkiness of the data convinced the researcher to provide some initial interpretations that emanated from the W-GCTA test and observation data, to ensure that a within-case and cross-case oversight of the development of critical thinking in relation to the participants is maintained (*cf.* 6.3.5), until the triangulation of all the data sets (*cf.* 6.7).

The following sections deal with the data analysis and interpretation for each of the four participants in the experimental group, starting with participant 1.

6.3.1 Data analysis: Participant 1

Participant 1 was selected from score category 1 of the TAG/TALL results, which ranged from 80% to 100%. Participant 1 scored 86% in the TAG/TALL test. The following Graph, Graph 6.1, illustrates the results obtained for each of the five sub-tests out of 16 for Participant 1 during the pre-and post-test.



Graph 6.1: Participant 1: W-GCTA sub-test scores

According to Graph 6.1, participant 1 demonstrated apparent growth in one critical thinking skill, namely making inferences. For two skills, namely recognising assumptions and making deductions, decay was noted and stagnation was noted for two skills, namely doing interpretations and evaluating arguments. Although the skill for recognising assumptions showed decay, the quality of the level of thinking, according the researcher's classification, remained the same, namely at practicing level. To the researcher, this finding is disappointing as it was hoped that all five skills would show growth over the 13-week intervention programme. Making inferences was the skill that appeared to be the weakest at the outset of the study, however during the post-test, skills to deduct information appeared to be the most difficult for this participant.

The subsequent sections summarise the data analysis for the observations in relation to the elements of critical thinking on which the research focused.

Table 6.1 below, summarises the findings obtained for participant 1 based on the W-GCTA test and observation data.

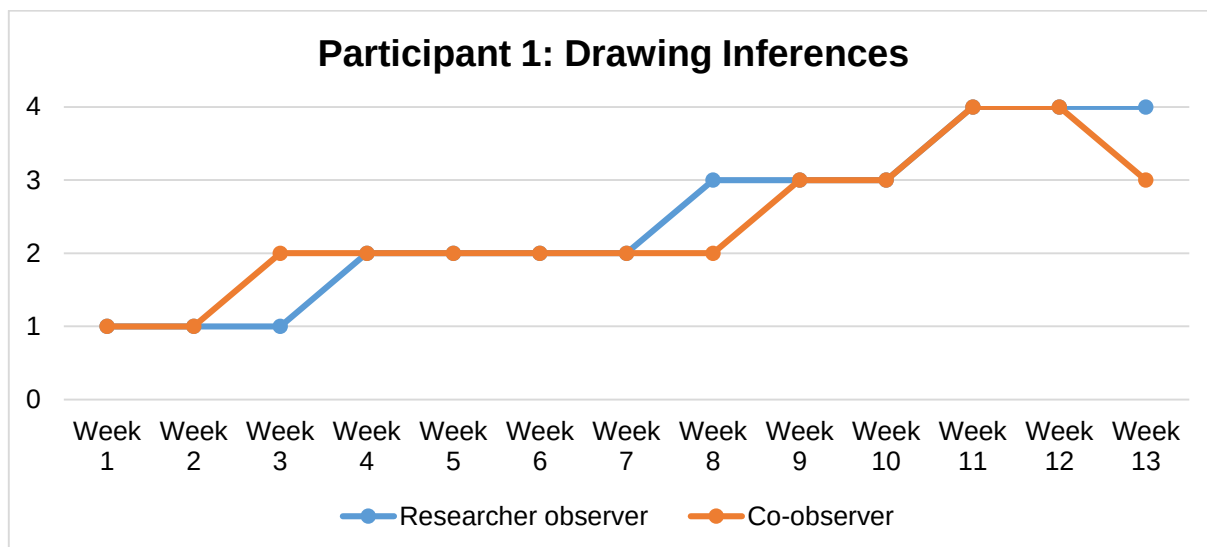
Table 6.1: Summary of initial findings: Participant 1

Critical thinking skills: W-GCTA	Growth	Decay	Stagnation
Inference	beginning to practicing		
Assumptions			practicing to practicing
Deduction		practicing to beginning	
Interpretation			practicing-practicing
Arguments			advanced/master-advanced/master
Observations: Showed growth for all skills: novice to sophisticated (inferences, assumptions, deductions, interpretations, evaluation of arguments).			
Dispositions: Observations	Growth	Decay	Stagnation
Systematic working ways	novice to sophisticated		
Persistence	novice to sophisticated		
Accuracy	novice to sophisticated		
Universal standards for reasoning: Observations	Growth	Decay	Stagnation
Logic	novice to sophisticated		
Clarity	able to skilled		
Relevancy	novice to sophisticated		

An extended discussion of the summary follows below.

Drawing inferences

Graph 6.2 below provides an overview of the growth and development in relation to making inferences, as revealed during the observations.



Graph 6.2: Observations: Drawing inferences – Participant 1

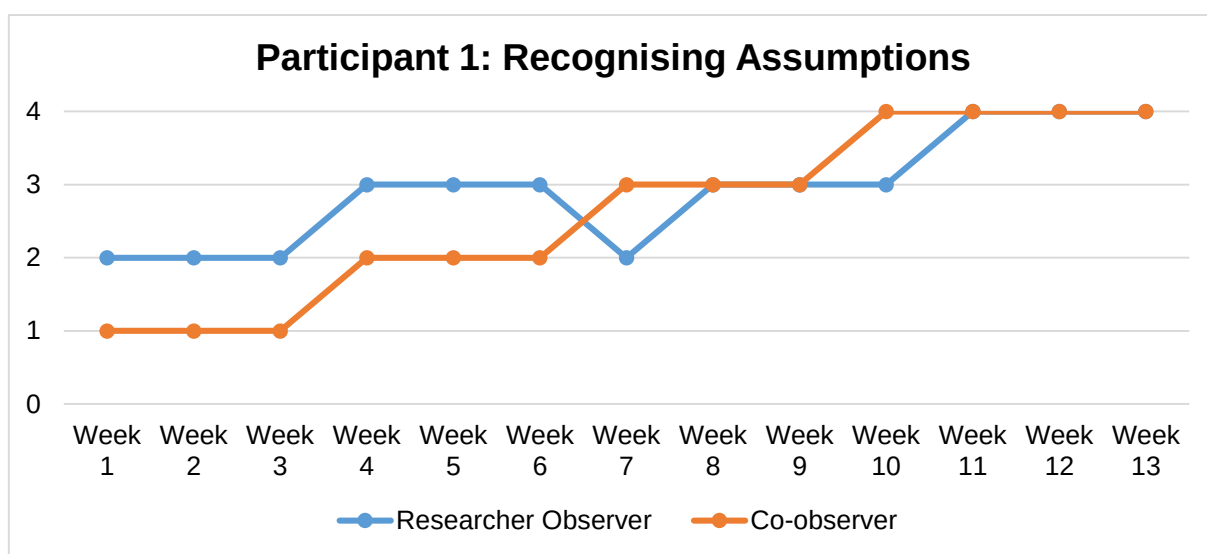
In summary, participant 1 set out as a *novice* (level 1) in relation to making inferences, thus being unable to draw conclusions regarding certain puzzle mechanics. From weeks 3 - 7 growth was noticed, as the participant appeared to become more adept (level 2) to draw conclusions regarding certain puzzle mechanics. The participant however remained at level 2 during these weeks, and only during weeks 8 - 10 more growth was observed towards becoming more *skilled* (level 3) in drawing conclusions about puzzle mechanics. Finally, during weeks 11 - 13, the participant demonstrated greater *sophistication* (level 4) in drawing conclusions about the mechanics of the game. It is encouraging that a growth trend was observed in the participant's ability to apply skills to make inferences. Supported by the video recordings, and in order to be cautious about the observations of the participant, the researcher and co-observer agreed to take the lower score, namely level 3 (*skilled*), as the final score.

The initial observations that indicated an inability (*novice* level) to draw conclusions regarding certain puzzle mechanics corresponded with the pre-test result reflecting a *beginning* thinker (level 2) in making inferences about the test scenarios, who steadily developed into becoming a *practicing thinker* during the post-test, able of improving thinking in well-thought out ways (Paul & Elder, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). The growth observed during the post test result, therefore concurred to some extent with what was observed, as the inferential ability according to the observations showed growth to *practicing* level (level 2), and the participant could identify problems and solve them in an

organised way (cf. 2.5.4). According to the observations, the participant seemed to be capable of drawing conclusions in terms of puzzle mechanisms based upon evidence and reasoning ability (cf. 4.5) for example, that portals can maintain momentum when jumped through them.

Recognising assumptions

Graph 6.3 below summarises the researcher's observations regarding the growth and development in terms of the recognition of assumptions during the intervention.



Graph 6.3: Observations: Recognition of assumptions – Participant 1

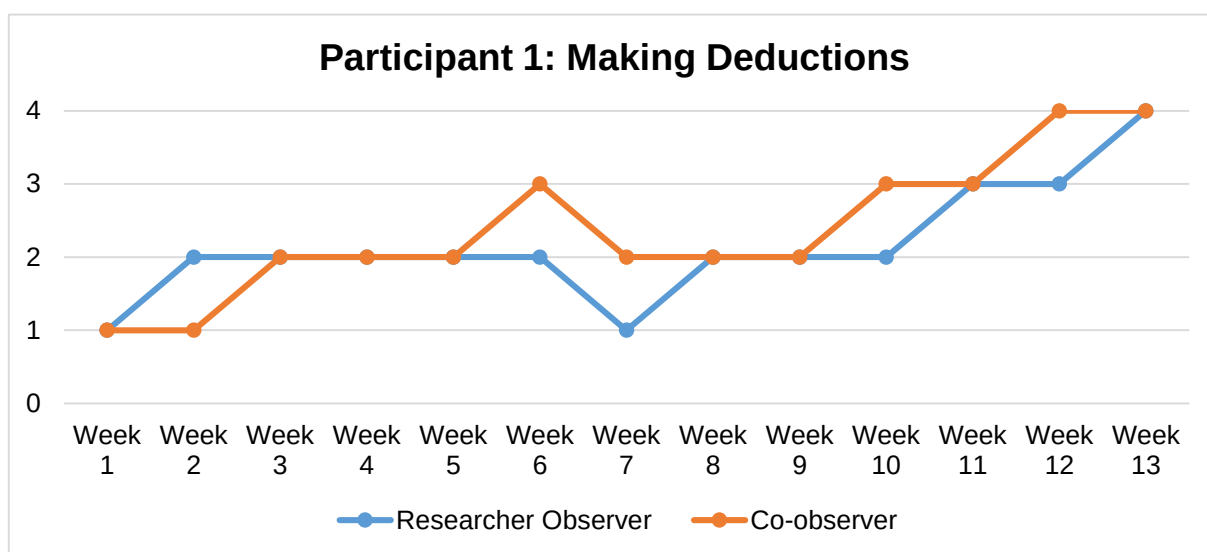
In summary, participant 1 set out as *novice/able* (level 1 - 2) in relation to recognising assumptions during weeks 1 - 3, thus not being good at distinguishing between past assumptions that existed in the context of the portal activity, such as knowing how the button and cube work together, as well as adapting when past assumptions no longer applied in new contexts within the portal test chambers. From weeks 4 - 10 growth was noticed, as the participant appeared to become more *skilled* (level 3) in distinguishing between past assumptions that existed in the context of the portal activity, as well as adapting when past assumptions no longer applied in new contexts within the portal test chambers. Some fluctuation to *able* level however occurred during week 7. During weeks 11 - 13 continued growth was observed towards becoming more *sophisticated* (level 4) in distinguishing between past assumptions that existed in the context of the portal activity. The participant was able to adapt when past assumptions no longer applied in

new contexts within the portal chambers (*cf.* 4.5). An example of this would be when the chambers no longer had boxes available and the puzzle required the use of portals to reach the next chamber.

The initial *novice/able* ability to distinguish between past assumptions that existed in the context of the portal activity did not correspond with the pre-test result reflecting a *practicing thinker* in recognising assumptions. This could be due to the inexperience of this participant playing a puzzle video game, which meant that the participant needed to first get accustomed to the game mechanics before assumptions were recognised correctly. Although the post-test result was lower than the pre-test result, the classification of the researcher indicated that the participant still appeared to be a *practicing thinker*, who experiences problems in monitoring thinking for the influence of assumptions (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). This finding does not align with the observations that noted growth towards *sophistication* (advanced/master thinker) in recognising assumptions, implying a strong ability to revise thinking and to acknowledge biases and assumptions (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.5, 2.5.6).

Making deductions

The growth and development observed for making deductions during the intervention, are displayed in Graph 6.4 below.



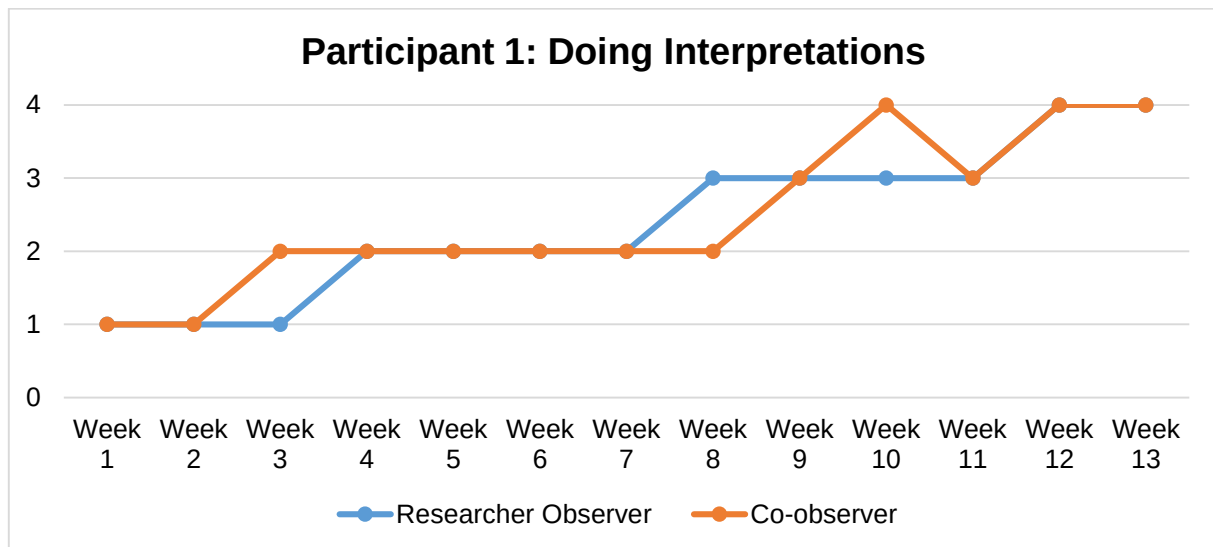
Graph 6.4: Observations: Making deductions – Participant 1

In sum, participant 1 started as a *novice* (level 1) in relation to making deductions, thus being unable to apply deductive reasoning during the game play of Portal, and was unable to scrutinise specific puzzle situations or to create hypotheses, such as how to open doors with the boxes by placing them on the buttons. During weeks 3 - 10 mostly able levels of development were noted, which fluctuated during weeks 6, 7 and 10 between able/skilled (level 2 – 3), and able/novice levels (level 2 – 1). Weeks 11 - 13 also witnessed fluctuating levels of growth towards becoming more *skilled* (level 3) and *sophisticated* (level 4) in applying abstract, deductive reasoning during the game play of Portal, and scrutinising specific puzzle situations or hypothesising solutions (*cf.* 4.5).

The initial *novice* (level 1) ability to apply deductive reasoning observed at the onset of the Portal game play, did not correspond with the pre-test result reflecting a *practicing thinker* (level 2) who can find faults in thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). Reasons for this may be that the participant was unsure of how the game mechanics worked and perhaps struggled with the controls of the game that consequently hampered the game play (*cf.* Appendix L). The post-test result revealed the participant only as a *beginning thinker* (level 1), who still misses solutions to problems (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3), thus not supporting the improvement to *sophisticated* level (level 4) noticed during the final observation. It seems as if the participant developed to become more capable of making well-reasoned deductions in the context of the puzzle game play than in relation to the W-GTA test scenarios.

Making interpretations

Graph 6.5 below indicates the growth and development for making interpretations during the intervention.



Graph 6.5: Observations: Doing interpretations – Participant 1

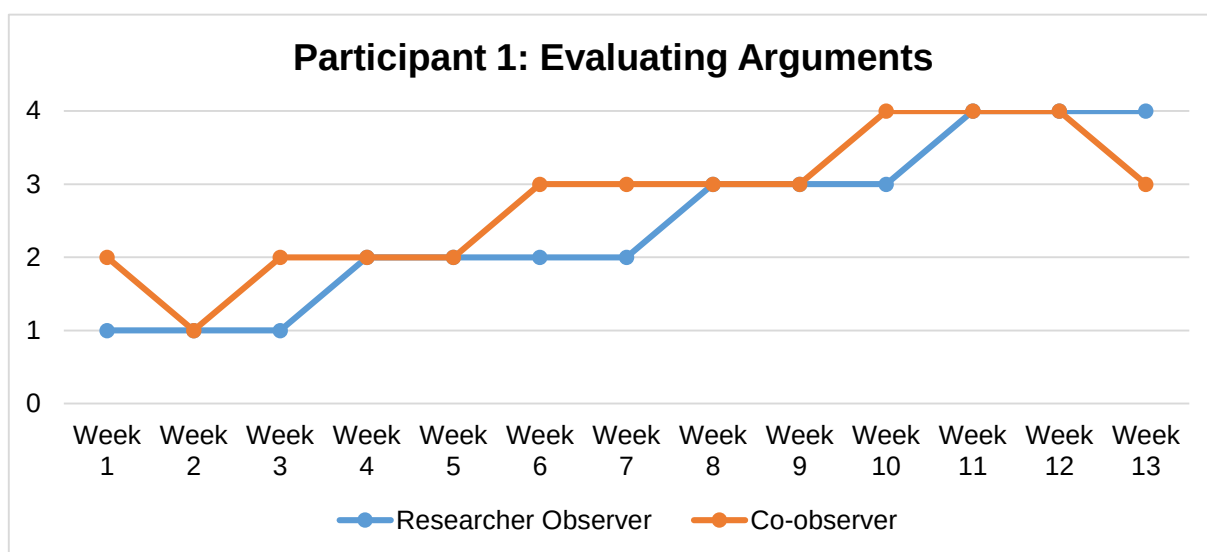
In brief, participant 1 started as a *novice* (level 1) in relation to doing interpretations, thus being unable to interpret the relationships between various mechanisms presented within the puzzle test chambers (*cf.* 4.5), such as being able to interpret how the portals only open on specific surfaces. From weeks 4 growth was noticed, that stagnated at the *able* level (level 2), until week 8, as the participant became better at interpreting the various mechanisms presented within the puzzle test chambers. During weeks 9 - 11 continued growth was observed towards becoming more *skilled* (level 3) and *sophisticated* (level 4) in doing interpretations during the game play of Portal, and interpreting the various mechanisms presented within the puzzle test chambers, such as being able to interpret how the portals only open on specific surfaces. Weeks 12 – 13 noted further growth towards becoming *sophisticated* (level 4) in terms of doing interpretations, and appearing to be effective at interpreting relationships between various mechanics that form part of the puzzle game play.

The initial *novice* (level 1) ability to do interpretations during the game play of Portal was not supported by the pre-test result reflecting a *practicing thinker* (level 3) who can identify problems and solve them in an organised way (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). The post-test score that remained similar to the pre-test score, indicated that the participant could be regarded as a *practicing thinker* (level 3). This result seems to be supportive of the growth noted during the observations towards *sophisticated* level (level

4). It is encouraging, that the intervention seemingly did not have any negative influence on the application of skills to do interpretations.

Evaluating arguments

The researcher reports the growth and development for becoming more effective at evaluating arguments, in Graph 6.6 below.



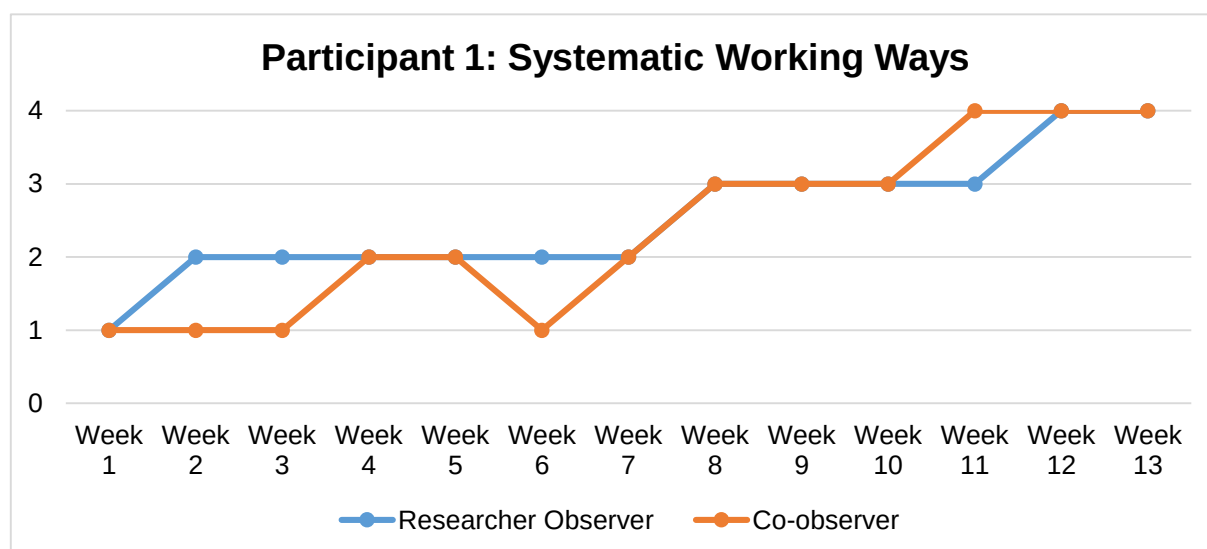
Graph 6.6: Observations: Evaluating arguments – Participant 1

In brief, participant 1 started as being *novice* (level 1) to *able* (level 2) in relation to evaluating arguments, thus not being able to provide reasons for each of the steps followed during the solving of a problem, and not reflecting on the steps chosen to solve a problem. Weeks 3 - 7 indicated growth, with the participant apparently becoming abler and skilled in providing reasons for each of the steps followed during the solving of a problem, which fluctuated between level 2 (*able*) and 3 (*skilled*) during these weeks. Some signs of growth towards becoming more *skilled* were observed at the start of week 6, which stagnated at level 3, until week 10. After week 10 growth was observed, that indicated a skilled thinker growing towards becoming more *sophisticated* (level 4) in terms of evaluating arguments, by providing reasons for steps followed during problem solving, and reflecting continuously whether the steps to solve problems were correct (*cf.* 4.5). The video recordings confirmed the researcher's observation at sophisticated level (*cf.* Appendix L).

The initial *novice* (level 1) ability to evaluate arguments that was observed during the game play of Portal, did not correspond with the pre-test result reflecting an *advanced/master* (level 4) thinker who could be regarded as effective in argument evaluation (Paul & Elder, 2010; Papp *et al.*, 2014) (*cf.* 2.5.5, 2.5.6). This discrepancy could be due to the participant's inexperience with puzzle video games, that might have obstructed effective problem solving within the various test chambers of the Portal game (*cf.* Appendix L). The final observation however, pointed to a thinker who was growing towards becoming more *sophisticated* (level 4) at evaluating arguments, thus supporting the post-test score of thinking at *advanced/master* level.

Systematic working ways

The following graph, Graph 6.7, highlights participant 1's performance regarding systematic working ways, over the 13-week intervention programme.



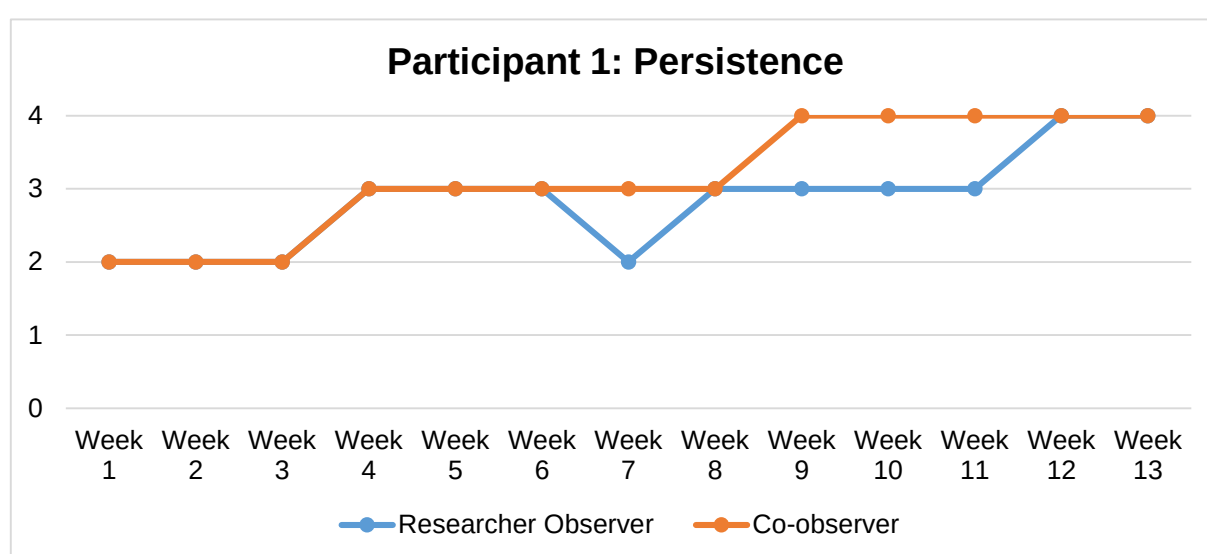
Graph 6.7: Observations: Systematic working ways – Participant 1

In a nutshell, participant 1 started as a *novice* (level 1) in relation to systematic working ways, thus being unable to apply a plan of action to solve problems during the game play of Portal. Weeks 2 - 7 noted fluctuating levels of development between novice and able in relation to working systematically. The participant managed to develop towards *skilled* level (level 3) during weeks 8-10, and ended the intervention at *sophisticated* level (level

4); working according to the GROW model, being able to apply previously used strategies, and being able to formulate own rules and strategies for solving problems. Although decay in the working systematically was noted during weeks 6 and 11, a growth trend was evident in the development of applying more systematic working ways, by working with the GROW model (*cf.* 4.5).

Persistence

The following graph, Graph 6.8, highlights participant 1's performance regarding persistence, over the 13-week intervention programme.

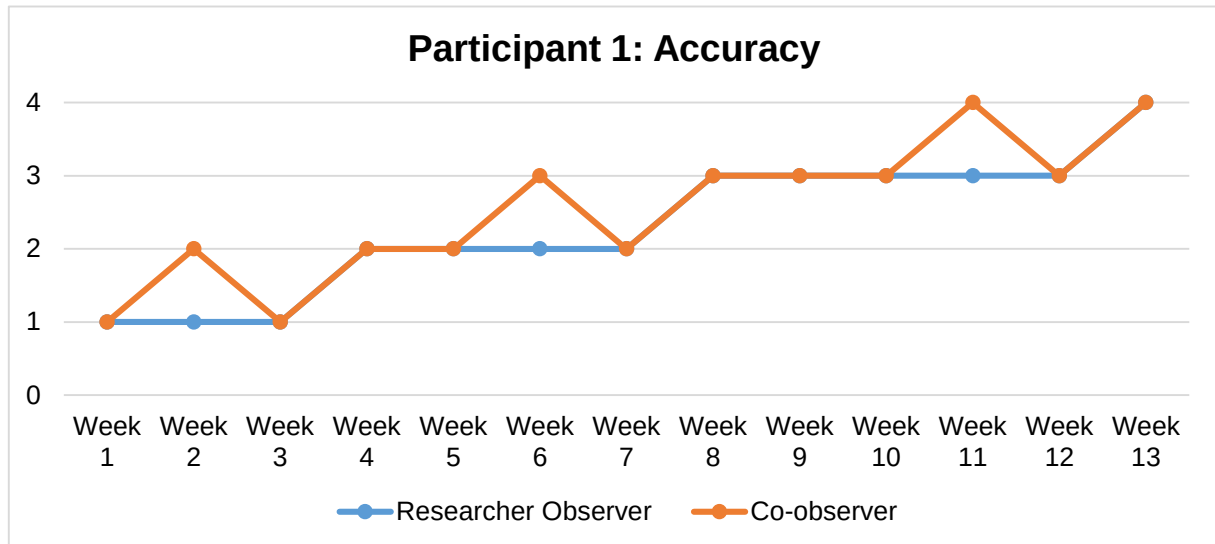


Graph 6.8: Observations: Persistence – Participant 1

In summary, the persistence levels of participant 1 saw growth throughout the 13-week intervention programme from being *able* (level 2) during weeks 1 – 3, with continued growth noted towards becoming more skilled during weeks 4 – 8, ultimately showing greater *sophistication* (level 4) from weeks 9 – 13. Although some decay was noted during week 7 the overall trend in relation to working more persistently, speaks of growth towards sophistication. The initial observation that the participant gave up and opted out before solving a problem was reversed, and the participant managed to work on a task without giving up and asking for assistance (*cf.* 4.5).

Accuracy

The following graph, Graph 6.9, highlights participant 1's performance in terms of accuracy, over the 13-week intervention programme.

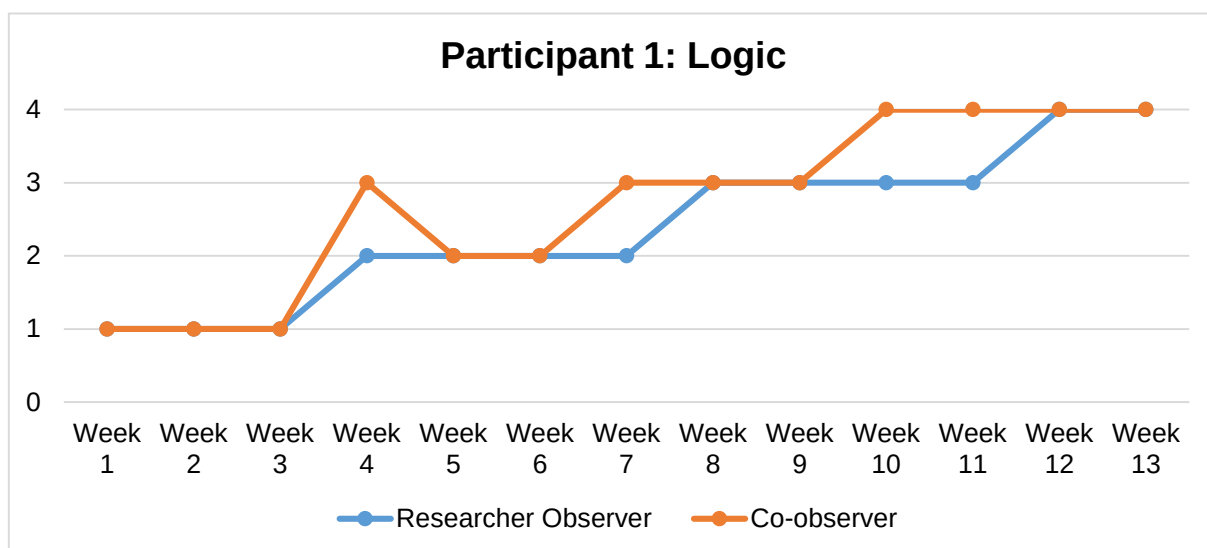


Graph 6.9: Observations: Accuracy – Participant 1

In brief, during weeks 1 – 3, participant 1 started as a *novice* (level 1) in relation to accuracy, and constantly made errors when trying to solve the puzzles in the various test chambers. From weeks 4 - 7 stagnation was noticed, as the participant seldom strove to work accurately, but still made errors when trying to solve the puzzles in the various test chambers. During weeks 8 - 12 growth was observed towards becoming more *skilled* (level 3) in accuracy during the game play of Portal, and the participant frequently ensured that he was doing the correct thing when trying to solve the puzzles in the various test chambers by referring to the GROW model, which would assist him by striving for accurate solutions. Week 13 saw even more growth in terms of *sophisticated* levels (level 4) of accuracy, as the participant continuously strove for accuracy, constantly ensuring that he was doing the correct thing when trying to solve the puzzles in the various test chambers. Although some fluctuation in relation to decay was noticed (Weeks 2, 6, 11), as well as stagnation for some time at level two (Weeks 4-7) and three (Weeks 8-12), the upward growth trend was remarkable and the researcher assumes that the participant acquired a need for ensuring that work is precise during the intervention (*cf.* 4.5).

Logic

The following graph, Graph 6.10, highlights participant 1's performance in relation to logic, over the 13-week intervention programme.

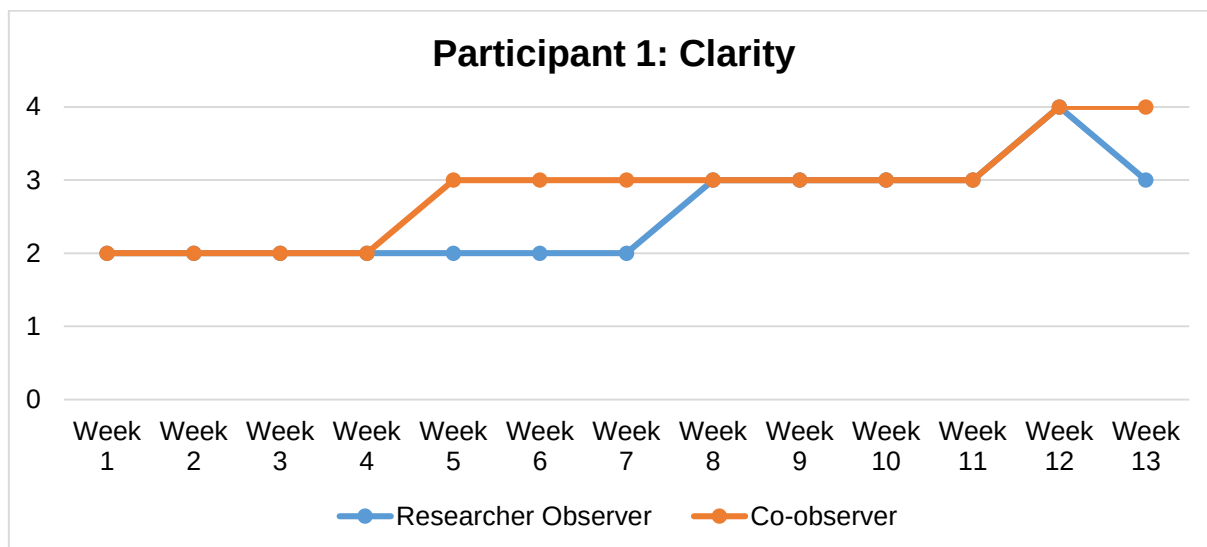


Graph 6.10: Observations: Logic – Participant 1

Overall, participant 1's performance for applying logic can be seen as a positive, as tremendous growth was witnessed when comparing week 1 to week 13; moving from level 1 (*novice*) to level 4 (*sophisticated*) (*cf.* Appendix L). Decay and stagnation were noted for the application of logic, however the growth evidenced during weeks 9 - 13 is encouraging. Evidence for the observed growth in terms of *sophisticated* levels (level 4) of logic, could be linked to the participant's ability to perform advanced logical steps when trying to solve a problem within the portal test chambers, for example where combinations of mechanisms needed to be overcome such as during momentum jumps. The participant appeared to be capable in sorting and combining information until it made sense (*cf.* 4.5).

Clarity

The following graph, Graph 6.11, highlights participant 1's performance for clarity, over the 13-week intervention programme.

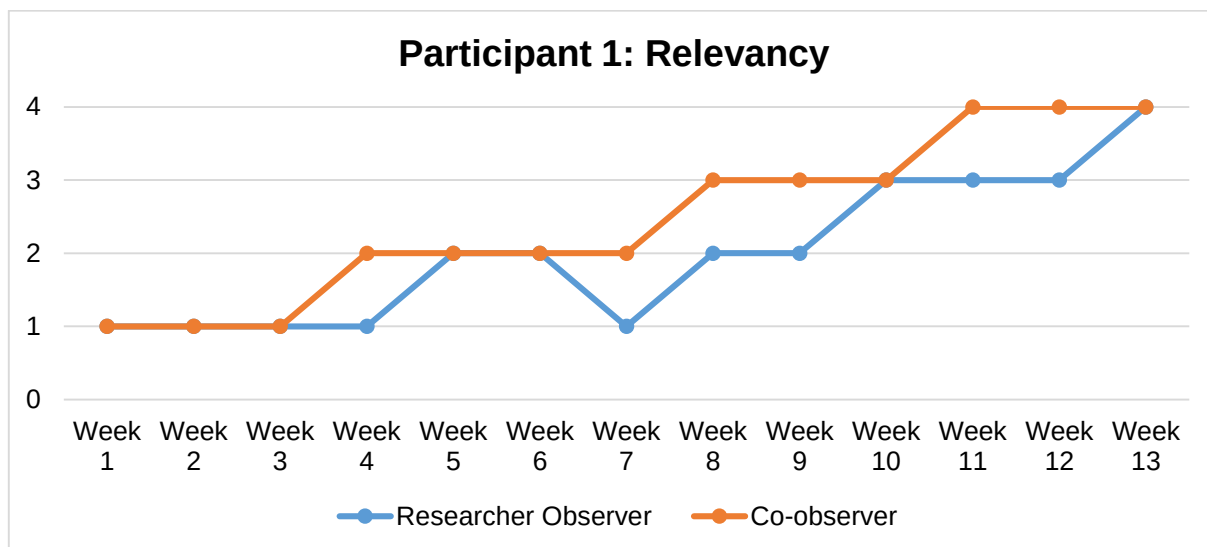


Graph 6.11: Observations: Clarity – Participant 1

In conclusion, the performance of the participant could be summed up as extremely positive when comparing week 1 to week 13. The observation levels rose from level 2 (*able*) to level 3 and 4 (*skilled, sophisticated*), implying growth. Initially, the participant was not very effective at reflecting and communicating his thoughts and actions during the game play (*cf.* 4.5). Although growth stagnated during weeks 5 – 11 at *skilled* level (with some decay noted during weeks 4 - 7 to *able* level), weeks 12 -13 indicated growth trends towards greater *skilled* and *sophisticated* application of communicating feedback about the game play and attempts to solve the puzzle problems with clarity (*cf.* 4.5). The video recordings supported the researcher's observation.

Relevancy

The following graph, Graph 6.12, highlights participant 1's performance for relevancy, over the 13-week intervention programme.



Graph 6.12: Observations: Relevancy – Participant 1

In summary, relevant reasoning developed from *novice* (level 1) to sophisticated levels during the 13-week intervention. Weeks 1 – 3 saw stagnation at level 1, with growth that stagnated towards becoming *abler*, during weeks 3 – 7. *Skilled* levels (level 3) of applying relevance were observed throughout weeks 8 – 10, growing further to *sophisticated* levels (level 4) during weeks 11- 13. Although some decay in the application of relevancy is noted (Weeks, 4, 7, 8, 9, 11, 12) the upwards growth trend is inspiring. Initially the participant’s communication of his thoughts and ideas whilst involved in the game play, did not relate well to the task at hand, which was reversed and replaced with to the point reflections and communication related to the task at hand (*cf.* 4.5) (*cf.* Appendix L).

In summary, Table 6.1 reveals that participant 1 started out with one critical thinking skill seemingly developed at practicing level (level 3), namely making deductions, of which the development over the course of the intervention decayed to beginning level (level 1) during the post-test. The development of one skill, namely inference, started at beginning level and ended at practicing level, which would imply some growth. During the post-test, three of the critical thinking skills, namely recognising assumptions, doing interpretations and evaluating arguments, apparently stagnated at the developmental level with which the participant entered the study. Recognising assumptions and doing interpretations started out at practicing level and remained at that level, and evaluation of arguments, started out at advanced level and remained at advanced level.

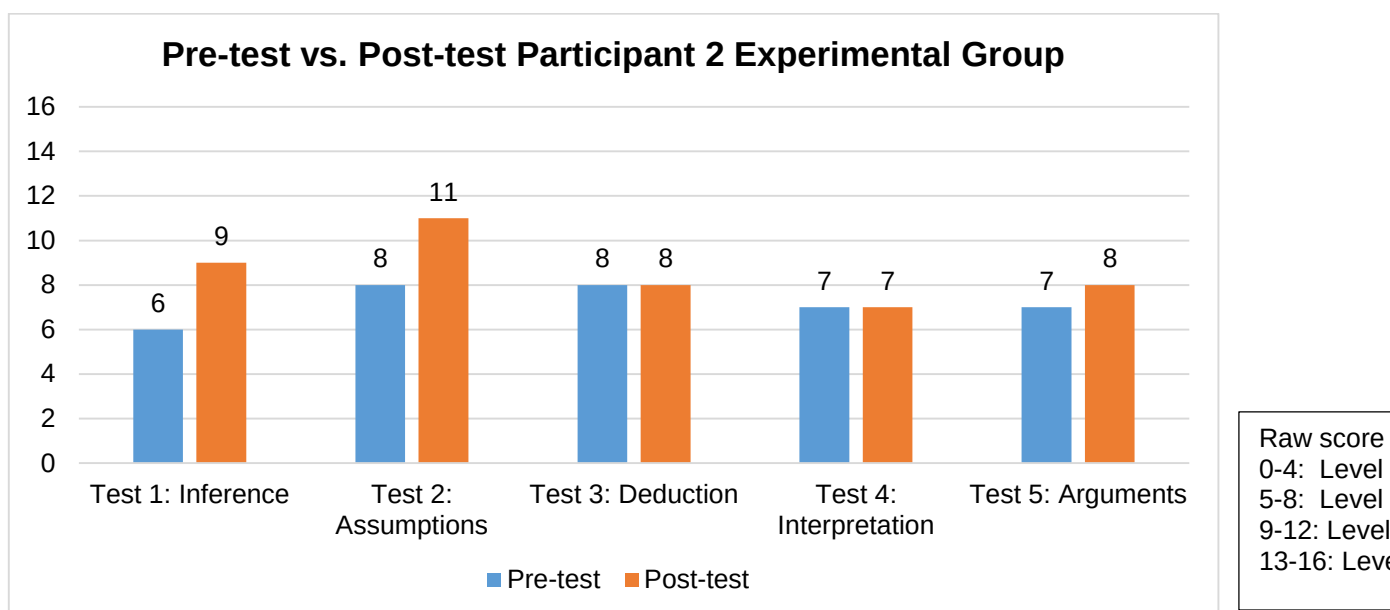
In terms of the critical thinking skills on which the study focused, it seemed that the intervention benefitted the development of the skill to make inferences the most, and that making deductions, benefitted the least, given the decay in development observed. Three of the skills, namely recognising assumptions, making interpretations and evaluating arguments, did not improve at all during the intervention, but also did not appear to decay in development either, according to the W-GCTA. Although the observations pointed to growth for all the critical thinking skills, the growth was not reflected in the post-test results, except for making inferences.

A noteworthy finding relates to all dispositions and standards for reasoning that started at novice or able level and improved to sophisticated level, implying that the intervention seemed to have been more successful in terms of growth in relation to the application of dispositions and standards for reasoning for this participant, than for the development of the critical thinking skills.

The following section presents the data analysis for participant 2.

6.3.2 Data analysis: Participant 2

Participant 2 was selected from category 2 of the TAG/TALL results, which ranged from 70% to 79%. She achieved 76% during the TAG/TALL test. The following graph, Graph 6.13, illustrates the results obtained for each of the five sub-tests out of 16 for participant 2.



Graph 6.13: Participant 2: W-GCTA sub-test scores

In relation to Graph 6.13 above, the raw scores indicated growth for three critical thinking skills, namely drawing inferences, recognising assumptions and evaluation of arguments, and showed stagnation in two skills, namely making deductions and doing interpretations. This is summed up as a modest finding, as the researcher hoped that all five skills would show growth. It was encouraging that the application of none of the skills showed any decay. The results for making inferences were the lowest at the outset of the study, but the participant showed improved performance during the post-test, making the test score for inferences the second best during the post-test occasion. At the end of the study, the participant appeared to experience difficulty with making interpretations and deductions, and the intervention seemingly did not benefit the development of these skills. Evaluation of arguments also appeared not to have greatly benefitted from the intervention, as the pre-test result which indicated a beginning level of thinking, remained at beginning level during the post-test, although the post-test result improved from 7 to 8.

Table 6.2 below summarises the initial research findings for participant 2.

Table 6.2: Summary of initial findings: Participant 2

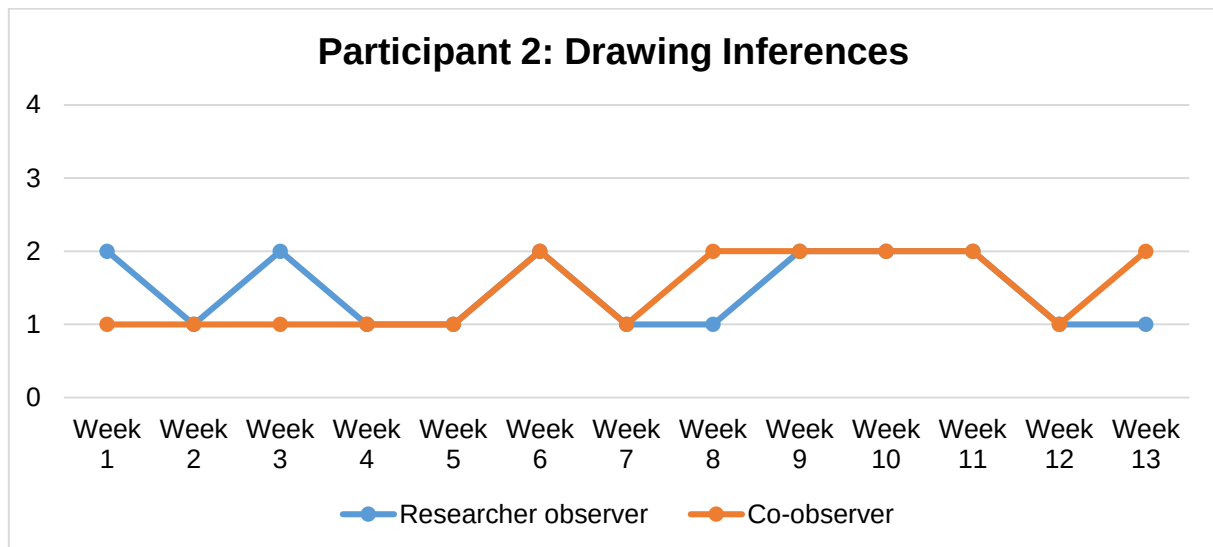
Critical thinking skills: W-GCTA	Growth	Decay	Stagnation
Inference	beginning to practicing		

Critical thinking skills: W-GCTA	Growth	Decay	Stagnation
Assumptions	beginning to practicing		
Deduction			beginning to beginning
Interpretation			beginning to beginning
Arguments			beginning to beginning
Observations: Showed no growth for any of the critical thinking skills.			
Dispositions: Observations	Growth	Decay	Stagnation
Systematic working ways			novice to novice
Persistence			novice to novice
Accuracy			novice to novice
Universal standards for reasoning: Observations	Growth	Decay	Stagnation
Logic			novice to novice
Clarity			novice to novice
Relevancy			novice to novice

The subsequent sections summarise the data analysis for the observations in relation to the elements of critical thinking on which the research focused.

Drawing inferences

Graph 6.14 below reports the observations for making inferences.



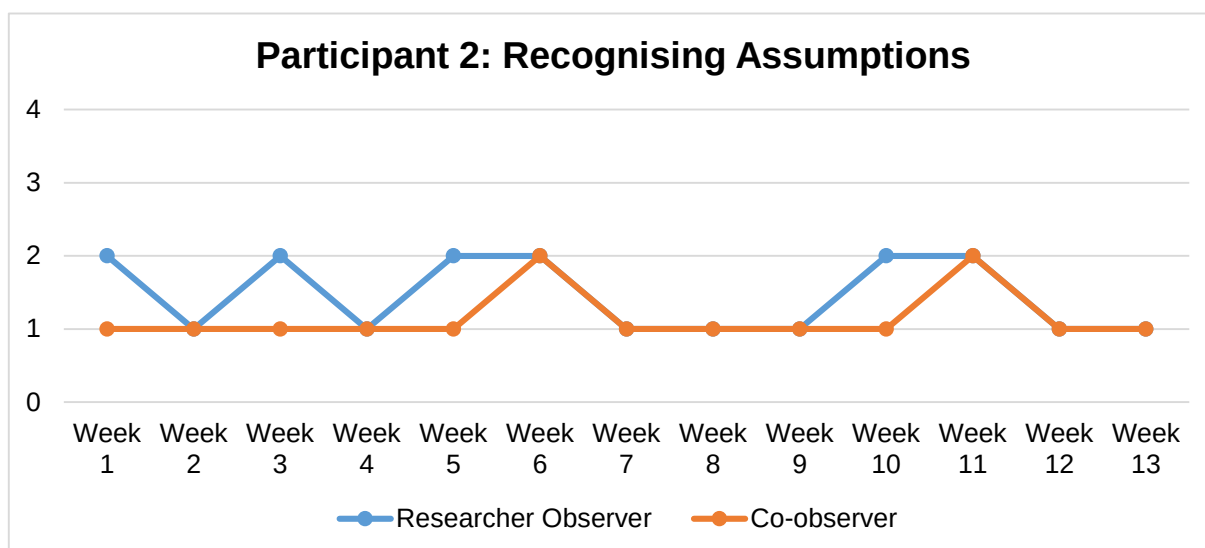
Graph 6.14: Observations: Drawing inferences – Participant 2

Overall, participant 2's performance regarding drawing inferences was poor, fluctuating between level 1 (*novice*) and 2 (*able*), and showing some stagnation during weeks 8 - 11, at *able* level. The observation scores remained at the lower end of the spectrum, implying that participant 2 apparently did not succeed in developing the skill to make inferences while playing the video game Portal. Based on the observations the participant did not succeed in being able to draw conclusions about certain puzzle mechanisms, and therefore could not solve the problems (*cf.* 4.5), and remained at novice level at the conclusion of the intervention. The final observation of the researcher was supported by the video recordings (*cf.* Appendix L).

The initial *novice/able* (level 1/2) ability to draw inferences during the game play of Portal corresponded with the poor pre-test result reflecting a *beginning thinker* in drawing inferences, who starts to recognise problems in thinking, but still misses solutions to problems (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). The post-test result however, showcased improvement in this particular skill to *practicing level*, which does not align entirely with the observations that only reflected a *novice* ability, implying an inability to make inferences. At practicing level, one is knowledgeable to monitor one's thinking for making proper inferences (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4).

Recognising assumptions

The following graph, Graph 6.15, highlights the observation data recorded for participant 2 regarding recognising assumptions.



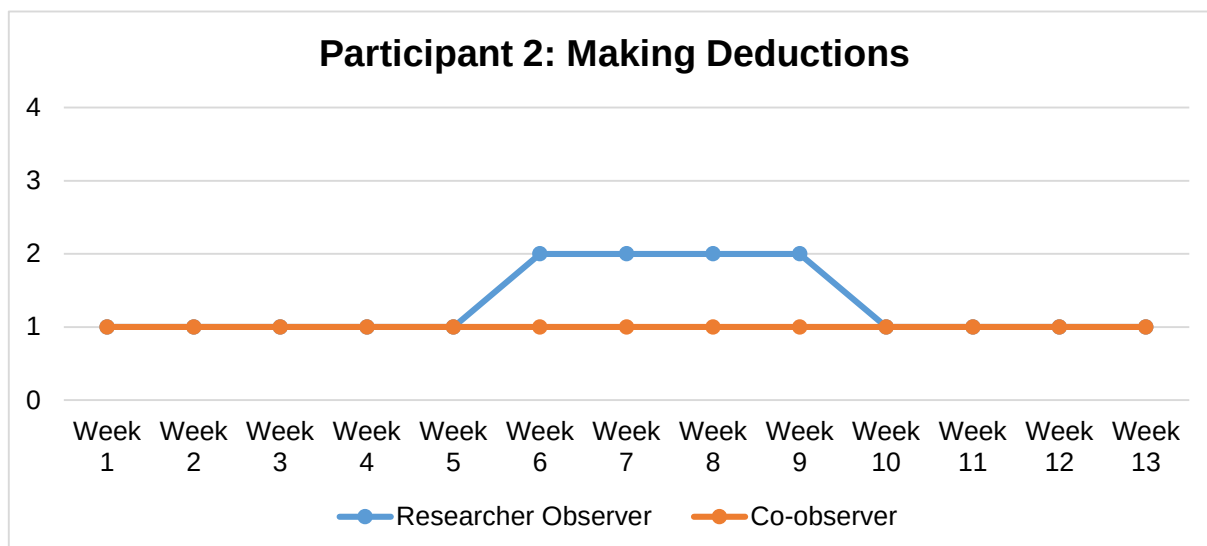
Graph 6.15: Observations: Recognition of assumptions – Participant 2

To sum up, the application of the skill to recognise assumptions fluctuated between *novice* (level 1) and *able* level (level 2) throughout the entire intervention. It is concluded that the participant could not adapt successfully to changes when past assumptions no longer applied for solving the puzzle problems in the game (*cf.* 4.5).

The *novice* (level 1) to *able* (level 2) ability to recognise assumptions during the game play of Portal at the outset of the study, did not quite correspond with the pre-test result reflecting a *beginning thinker*, and therefore somebody who is more aware of the role that assumptions play during thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). The improved post-test result in recognising assumptions that indicated levels of *practicing thinking* (level 3), also did not correspond with the observations at the end of the intervention, revealing that the participant only achieved a *novice* level for recognising assumptions. According to the post-test result, the participant appeared to be more successful in mastering thinking for the influence of assumptions (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4).

Making deductions

The following graph, Graph 6.16, highlights the observation data recorded for participant 2 regarding making deductions.



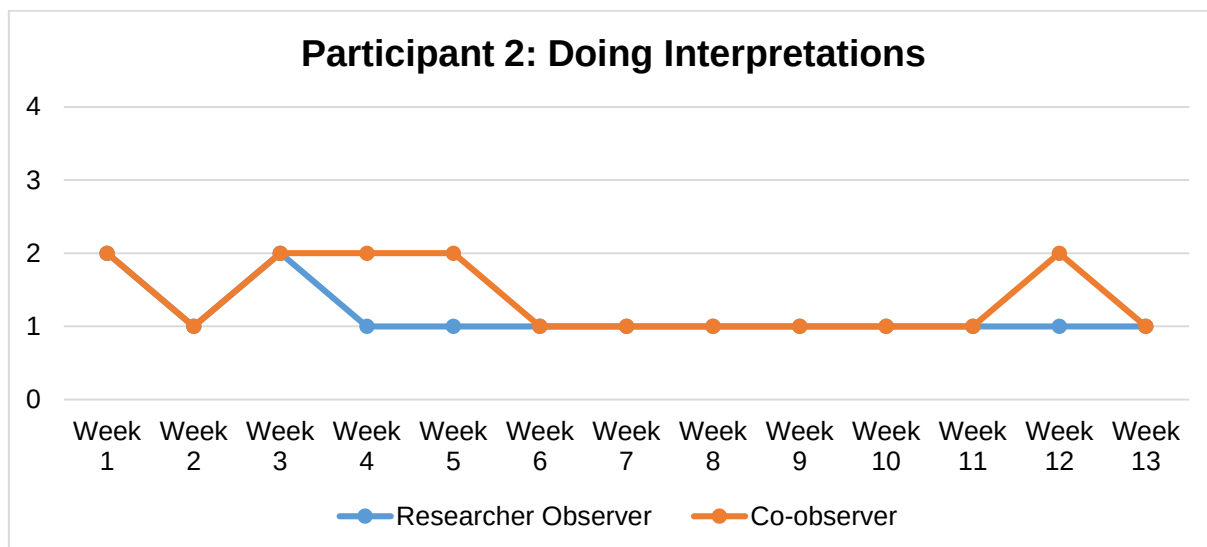
Graph 6.16: Observations: Making deductions – Participant 2

In summary, participant 2 started as a *novice*, and ended the intervention as a *novice* (level 1) in relation to making deductions, with slight growth noted in weeks 6 – 9 to able level (level 2). She could not scrutinise specific puzzle situations or create hypotheses in order to find solutions to the puzzles (*cf.* 4.5). The intervention seemingly did not contribute to the development of the skill to make deductions and hypothesise solutions.

The *novice* (level 1) ability to make deductions during the game play of Portal at the start of the study, is not a true reflection of the pre-test result, according to which the participant could be regarded as a *beginning thinker*; someone who is more alert to reflect on conclusions in relation to information (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). This result remained stable during the post-test, implying no growth in relation to making deductions, which corresponded with the final observation during week 13 that also indicated no growth.

Doing interpretations

The following graph, Graph 6.17, highlights the observation data recorded for participant 2 regarding doing interpretations.



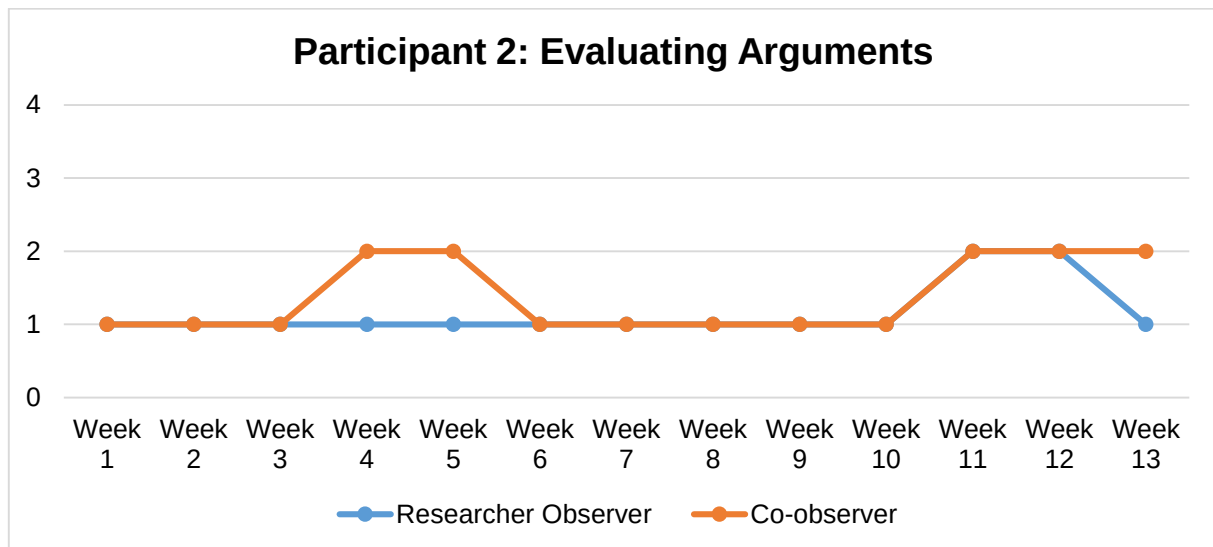
Graph 6.17: Observations: Doing interpretations – Participant 2

All around, the scores for this participant were very low for doing interpretations and fluctuated mainly between level 1 (*novice*) and 2 (*able*), with limited evidence of growth noted during weeks 4, 5 and 12. No noteworthy growth was evident.

Initially, the participant appeared able to do interpretations during the game play of Portal at *able* level (level 2), which corresponded with the pre-test result that reflected a *beginning thinker*; somebody who is more conscious of own viewpoints and reflects on thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). It however appears, as if the skill to do interpretations did not benefit at all from the participant's involvement in the intervention. Interpretations in the context of the game would involve interpreting the puzzle room itself and finding pathways to progress through the environment (*cf.* 4.5). The participant however got stuck frequently, meaning that wrong interpretations of the puzzle situation were made. The final observation that revealed a *novice* ability (level 1) to do interpretations therefore did not concur with the post-test result that pointed to a *beginning thinker*; someone who spots problems in thinking and makes attempts to improve the problems (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3).

Evaluating arguments

The following graph, Graph 6.18, highlights the observation data recorded for participant 2 regarding evaluating arguments.



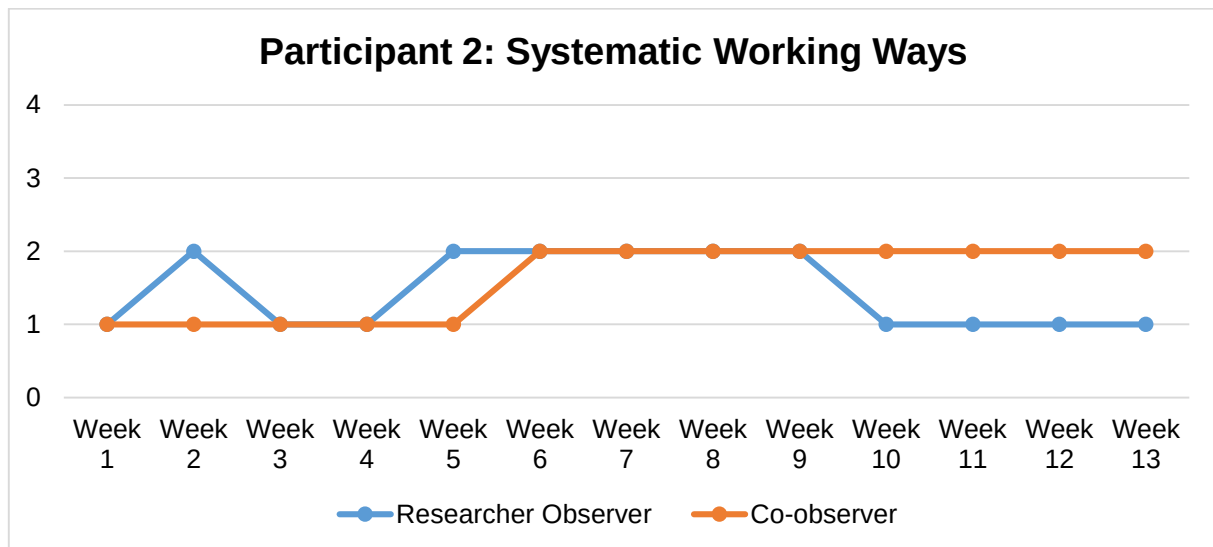
Graph 6.18: Observations: Evaluating arguments – Participant 2

To sum up, throughout the intervention, the researcher noted that the participant was unable to evaluate arguments related to the more complex puzzle mechanics, such as the mid-air portal placement, because the participant repetitively made mistakes when firing portals while upside down, and did not try to evaluate why she was making mistakes (*cf.* 4.5). Similar trends in growth that were observed for doing interpretations, were also noted for evaluating arguments. The observation scores fluctuated between level 1 (*novice*) and 2 (*able*), with no noteworthy growth evident. At the conclusion of the intervention, the video recordings confirmed the researcher's observation at *novice* level.

The initial *novice* (level 1) ability to evaluate arguments observed at the start and conclusion of the intervention, seemed to confirm the pre-test and post-test results, which were similar, and reflected a *beginning thinker*, who still misses solutions to problems (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). As with the previous skill, it could be argued that the development of skills to evaluate arguments, did not benefit much from taking part in the intervention, and the participant apparently remained ineffective at solving the puzzle problems, and the problems in the W-GCTA.

Systematic working ways

The following graph, Graph 6.19, highlights the observation data recorded for participant 2 regarding systematic working ways.

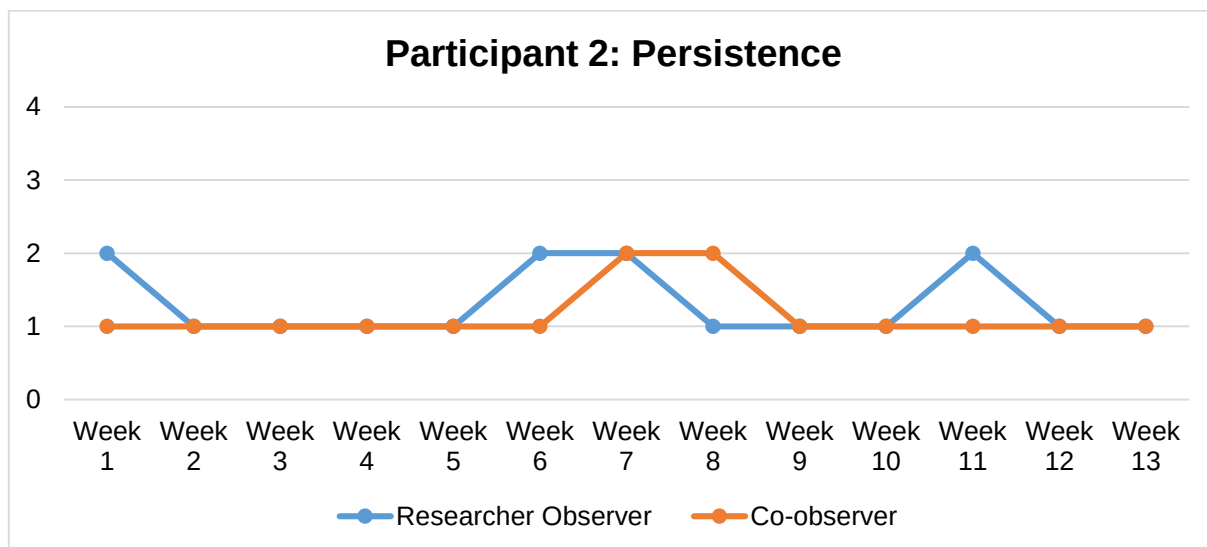


Graph 6.19: Observations: Systematic working ways - Participant 2

Overall, it can be interpreted that participant 2 did show slight improvement when it came to working systematically, but that it was not exceptional. Her performance could be assessed as *novice* (level 1) in nature initially, as it was characterised by an inability to work with a plan of action. Some growth to *able* level (level 2), was however observed, but in general her performance remained closer to novice level, as she was not able to utilise the GROW model effectively to assist her in systematically dealing with the solving of problems (*cf.* 4.5). She was also not able to apply own strategies and rules that would benefit systematic task completion (*cf.* Appendix L). During week 13, the researcher's observation at *novice* level (level 1), was confirmed by the video recordings, which was used as the final score.

Persistence

The following graph, Graph 6.20, highlights the observation data recorded for participant 2 regarding persistence.

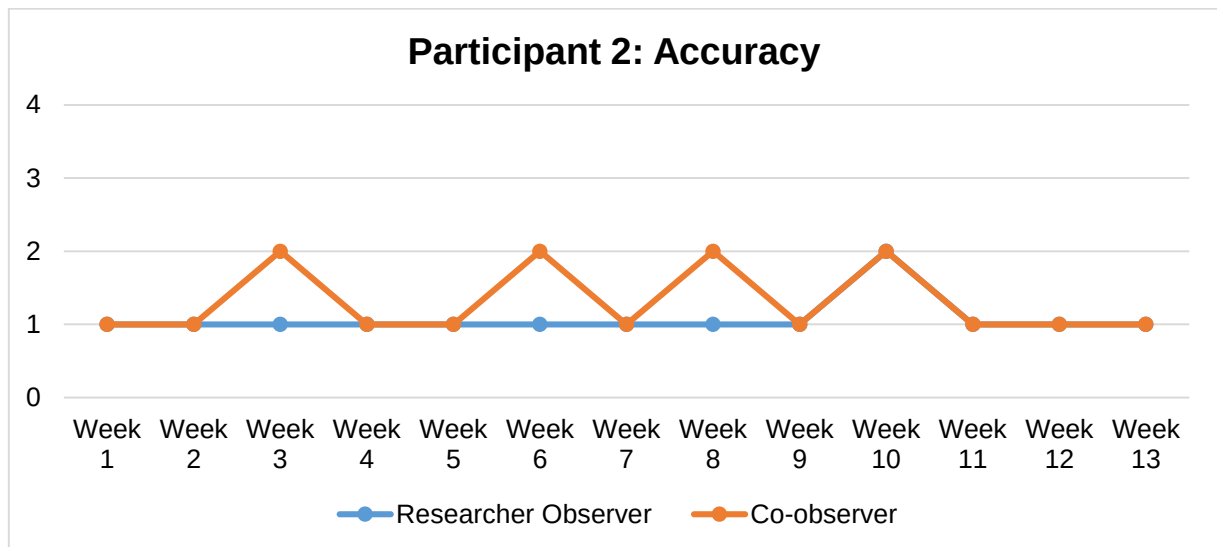


Graph 6.20: Observations: Persistence – Participant 2

To conclude, the participant's performance was characterised by an initial *novice* (level 1) to *able* (level 2) ability to carry on with tasks, as she opted out quite early when she could not solve the puzzle game problems, and required assistance (*cf.* 4.5). Some growth to *able* level, was observed during weeks 6 – 8, and 11, but in general her performance remained closer to novice level, as she was not able to utilise coping mechanisms, such as the GROW model, to complete tasks autonomously without giving up. Complete dependence on the researcher/mediator was required to complete tasks successfully.

Accuracy

The following graph, Graph 6.21, highlights the observation data recorded for participant 2 regarding accuracy.

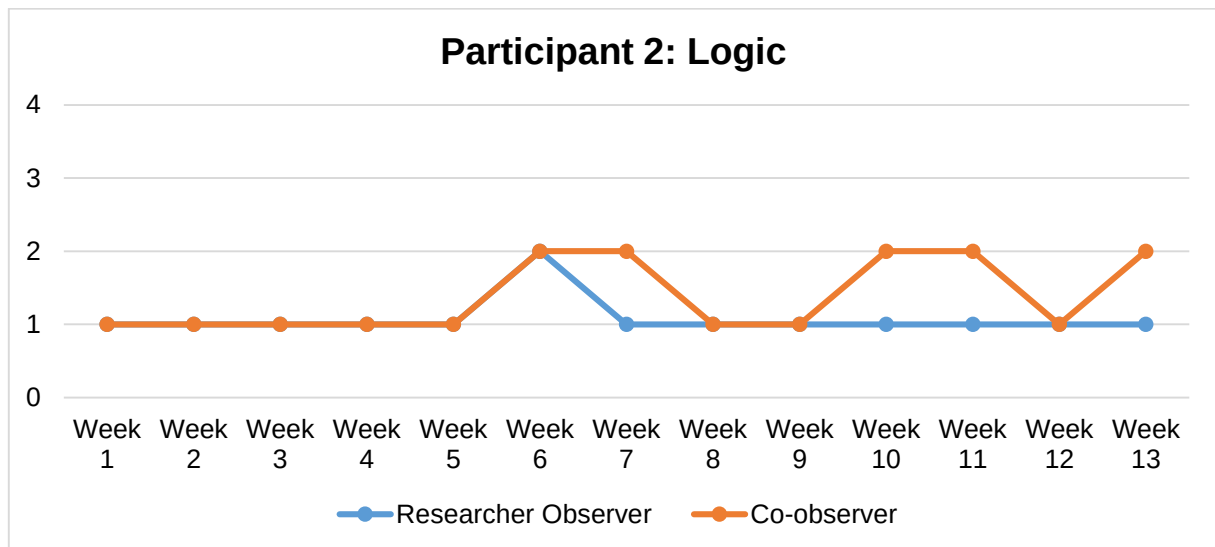


Graph 6.21: Observations: Accuracy – Participant 2

Participant 2 was observed as a *novice* (level 1) in relation to working accurately most of the time during the implementation of the intervention. The participant constantly made errors when trying to solve the puzzles in the various test chambers (*cf.* 4.5), like constantly opening portals on wrong surfaces, or constantly getting shot by turrets. Some growth to *able* level (level 2) was observed during weeks 3, 6, 8 and 10, but she mostly made mistakes when trying to solve the puzzles in the various test chambers (*cf.* Appendix L). The researcher therefore concluded that she did not acquire the disposition to work accurately during the implementation of the intervention, and remained a *novice*.

Logic

The following graph, Graph 6.22, highlights the observation data recorded for participant 2 regarding logic.

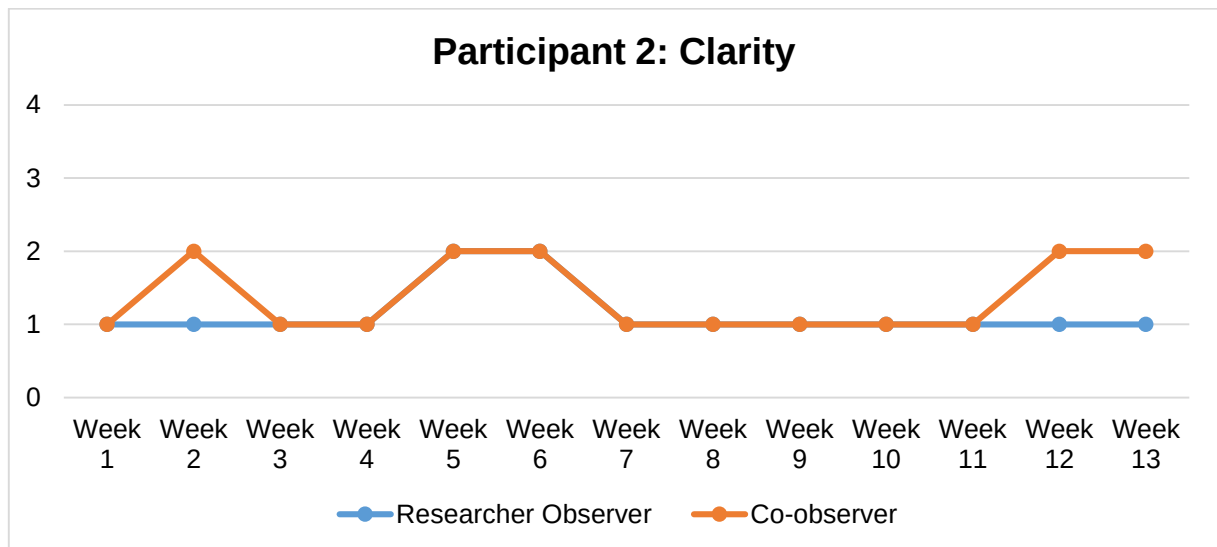


Graph 6.22: Observations: Logic – Participant 2

Overall, in terms of growth over the 13-week period, it is evident that only slight growth and improvement were witnessed when comparing week 1 to week 13. Participant 2 displayed the tenets of a *novice* (level 1) in relation to applying logic during weeks 1 – 5, and 7 – 13, with some signs of growth towards becoming abler (level 2), noticed during this time by the co-observer. The participant could not perform simple logical steps when trying to solve a problem, such as redirecting laser beams into receptacles. However, some growth was noticed, as the participant appeared to become abler, and could perform simple logical steps when trying to solve a puzzle, although still struggling with more advanced procedures, such as the mid-air portal placement while flinging (*cf.* Appendix L). The video recordings supported the final observation of the researcher at *novice* level (*cf.* Appendix L), which was used as the final score.

Clarity

The following graph, Graph 6.23, highlights the observation data recorded for participant 2 regarding clarity.

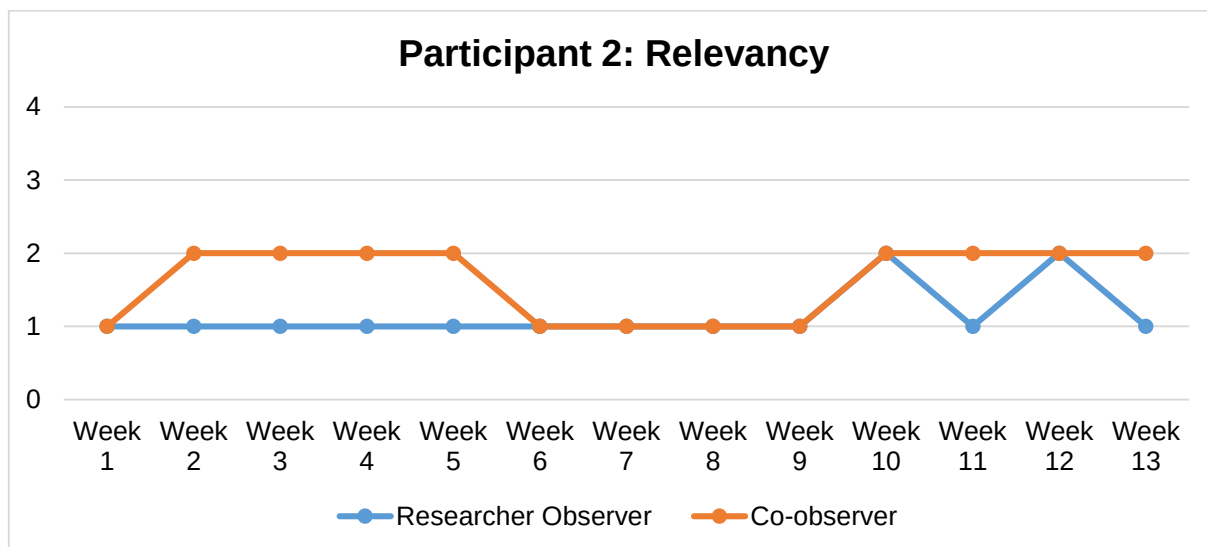


Graph 6.23: Observations: Clarity – Participant 2

In general, participant 2 started out as a *novice* (level 1) in relation to working with clarity during weeks 1 – 4 and 7 – 11. The participant was never transparent, very seldom articulating reflections and communicating actions and thoughts involved in solving the puzzles with precision (*cf.* Appendix L). During weeks 2, 5, 6, 12 and 13, some growth to *able* level (level 2) was noticed, as the participant sometimes articulated reflections about actions and thoughts during the solving of the puzzle games. Overall however, the researcher concludes that the performance of the participant reflected *novice* levels of not being transparent and not being able to articulate actions and thoughts in relation to the puzzle game, which was confirmed by the video recordings (*cf.* 4.5, Appendix L).

Relevancy

The following graph, Graph 6.24, highlights the observation data recorded for participant 2 regarding relevancy.



Graph 6.24: Observations: Relevancy – Participant 2

In sum, when looking at the performance of participant 2 over the 13-week period regarding relevancy, it is clear that no major improvement or growth is evident, with observations fluctuating between *novice* (level 1) and *able* levels (level 2) for reasoning with relevance, and concluding the intervention at *novice* level. The participant's thoughts and ideas that were verbalised made very little or no sense when compared to the actual task at hand, which was confirmed by the video recordings (*cf.* 4.5; Appendix L). Altogether, the observation data revealed that the participant seemingly did not manage to advance her ability to reason with relevance substantially during the intervention.

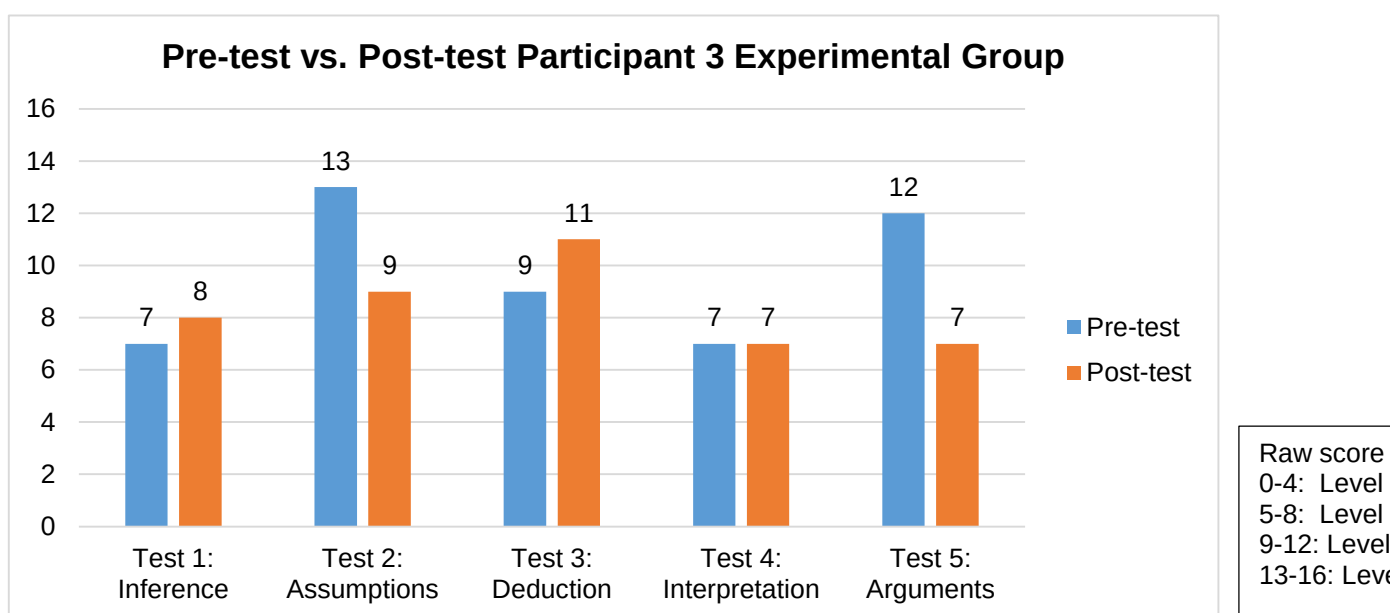
In summary, participant 2 started the study with low scores for all five skills, which can be considered beginning thinker levels (level 1) of performance (Elder & Paul, 2010) (*cf.* 2.5), with only making inferences and recognising assumptions improving to practicing thinker levels during the post-test. This improvement implied that the participant seemingly developed from not being able to recognise problems in her thinking, to being able to monitor her thinking and improve on her thinking in well-thought out ways (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3, 2.5.4). In terms of the observation data, the participant's performance in the application of the critical thinking skills did not reveal any growth.

It is disappointing to note that no growth was observed for the application of the dispositions and standards for reasoning, implying that the participant remained at novice level at the conclusion of the intervention.

The following section reports on the analysis of data for participant 3.

6.3.3 Data analysis: Participant 3

Participant 3 was selected from category 3 of the TAG/TALL results, which ranged from 60% to 69%. She obtained 64% in the TAG/TALL test. The following graph, Graph 6.25, illustrates the pre- and post-results obtained for each of the five sub-tests out of 16 for participant 3.



Graph 6.25: Participant 3: W-GCTA sub-test scores

In summary, Graph 6.25 indicates that the post-test results for two skills improved, namely for making inferences and deductions. Although the skill for making inferences and deductions showed improvement, the quality of the level of thinking for inferences according to the researcher's classification, remained the same, namely at beginning level. The thinking level for making deductions remained at practicing level during the pre- and post-tests. Stagnation at beginning level for one skill, namely doing interpretations, and decay in relation to two skills were noticed, namely for evaluation of arguments from

practicing to beginning level, and recognising assumptions from advanced/master level to practicing level.

Table 6.3 summarises the initial research findings for participant 3.

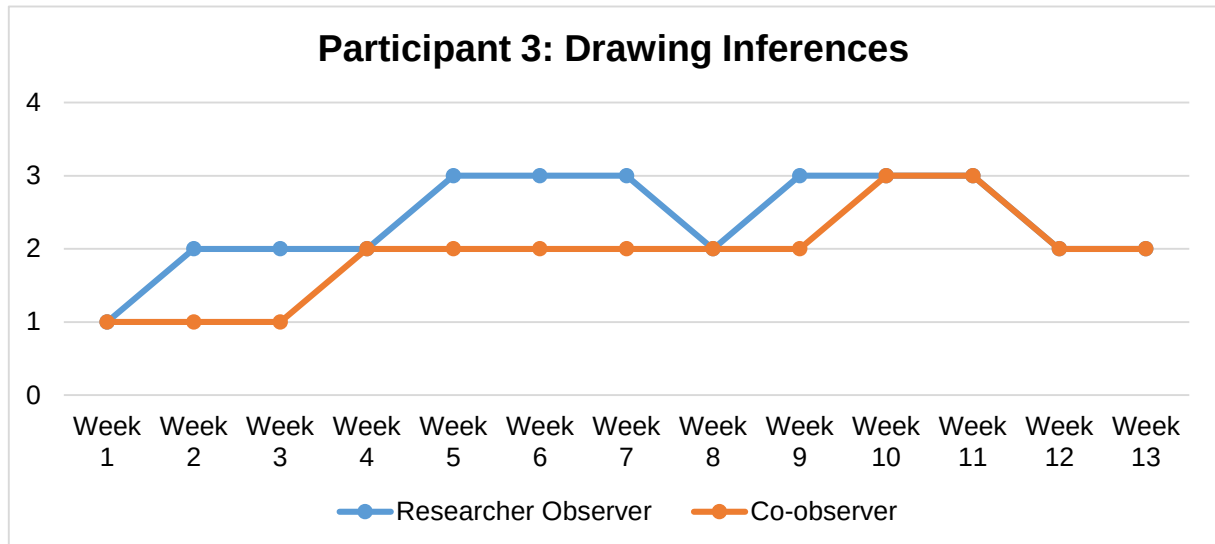
Table 6.3: Summary of initial findings: Participant 3

Critical thinking skills: W-GCTA	Growth	Decay	Stagnation
Inference			beginning to beginning
Assumptions		advanced/ master to practicing	
Deduction			practicing to practicing
Interpretation			beginning to beginning
Arguments		practicing to beginning	
Observations: Showed growth for all skills from novice to able (inferences) and novice to skilled (assumptions, deductions, interpretations, arguments)			
Dispositions: Observations	Growth	Decay	Stagnation
Systematic working ways	novice to skilled		
Persistence	novice to skilled		
Accuracy	novice to skilled		
Universal standards for reasoning: Observations	Growth	Decay	Stagnation
Logic	novice to skilled		
Clarity	novice to able		
Relevancy	novice to skilled		

The subsequent sections summarise the data analysis in relation to the elements of critical thinking on which the research focused.

Drawing inferences

The following graph, Graph 6.26, presents the observation data recorded for participant 3 regarding drawing inferences during the 13-week intervention.



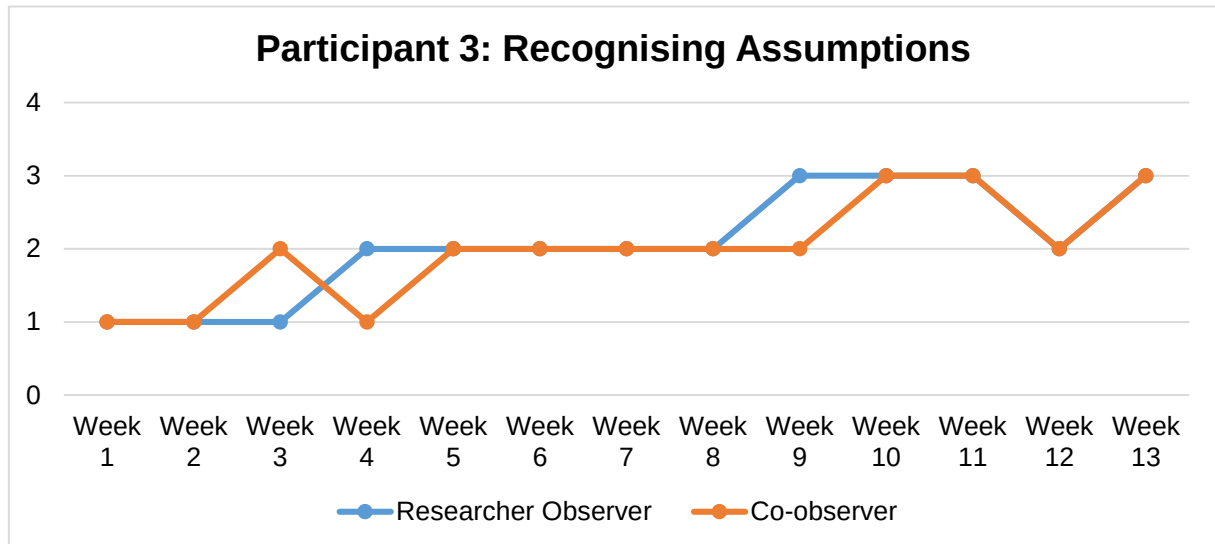
Graph 6.26: Observations: Drawing inferences: Participant 3

To sum up, the participant started the intervention at *novice* level (level 1) at the start of the intervention, who managed to achieve *able* (level 2) as well as *skilled* levels (level 3) of performance during the implementation of the intervention, however ending the intervention only at *able* level (level 2). The participant appeared to be unable to draw conclusions successfully, regarding certain puzzle mechanics, such as the button and box mechanic, as well as in relation to mid-air portal jumps during the play of the video game, and therefore could not solve the puzzle problems successfully (*cf.* 4.5).

The initial novice (level 1) ability to apply skills to make inferences during the game play of Portal, confirmed the pre-test and post-test results, which were similar, and reflected a *beginning thinker*, who tries to improve her thinking, but still does not succeed in finding solutions to problems (*cf.* Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). It could be argued that the development of skills to make inferences, did not benefit a great deal from taking part in the intervention.

Recognising assumptions

The following graph, Graph 6.27, highlights the observation data recorded for participant 3 regarding recognising assumptions.



Graph 6.27: Observations: Recognition of assumptions – Participant 3

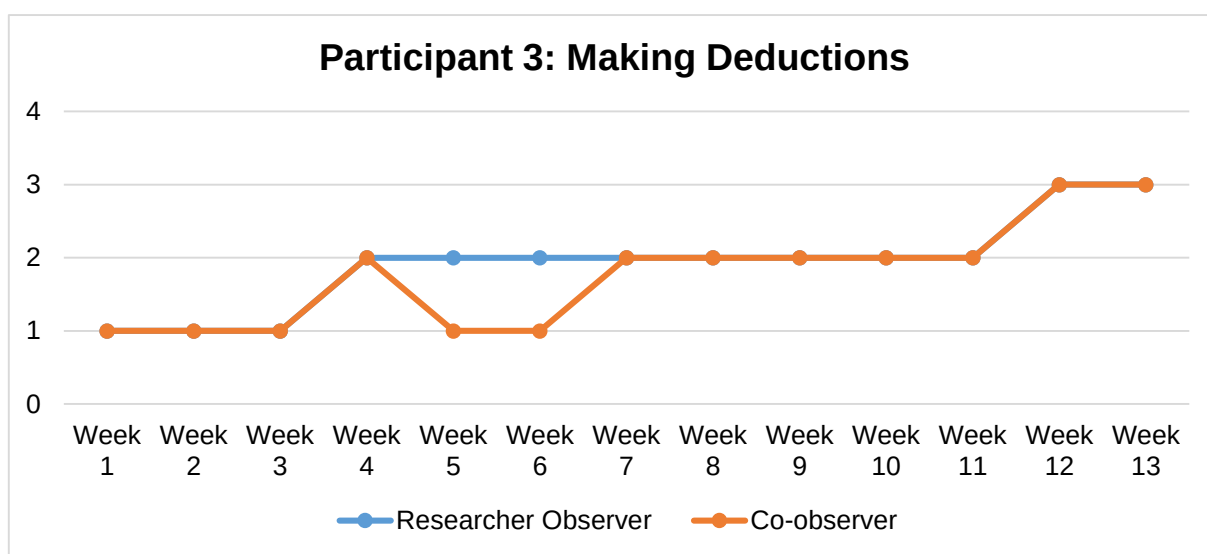
In sum, the participant's growth in relation to recognising assumptions varied between *novice* (level 1), *able* (level 2) and *skilled* level (level 3). Participant 3 set out as a *novice* (level 1) in relation to recognising assumptions, thus being unable to distinguish between past assumptions that existed in the context of the portal activity (*cf.* 4.5), for example knowing how the button and box work together, as well as making adaptations when past assumptions no longer applied in new contexts within the portal test chambers. Growth was noticed during the intervention, as the participant appeared to become *abler* (level 2) in distinguishing between past assumptions that existed in the context of the portal activity, as well as adapting when past assumptions no longer applied in new contexts within the portal test chambers. To the end of the intervention, during weeks 10, 11 and 13, growth was observed towards becoming more *skilled* (level 3) in distinguishing between past assumptions that existed in the context of the portal activity.

The initial novice ability to distinguish whether past assumptions remained applicable in the context of the portal activity, did not correspond with the pre-test result reflecting an *advanced thinker* in monitoring and recognising the influence of assumptions on thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.6) The skill to identify assumptions

however demonstrated decay during the post-test, reflecting the ability of a *practicing thinker*, one who tries to improve by eliminating the influence of assumptions on thinking (cf. Elder & Paul, 2010; Papp *et al.*, 2014) (cf. 2.5.4), which aligns better with the observation during week 13 at skilled level.

Making deductions

The following graph, Graph 6.28, highlights the observation data recorded for participant 3 regarding making deductions.



Graph 6.28: Observations: Making deductions – Participant 3

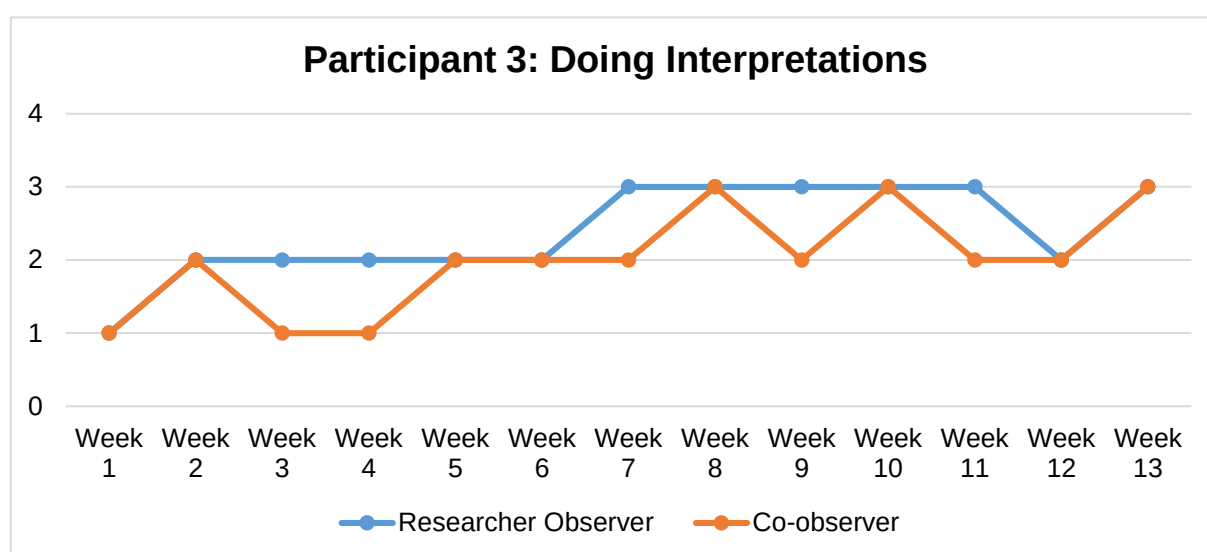
When interpreting the performance over the entire period, progressive growth is evident from *novice* (level 1) (Weeks 1-3, 5-6) to *able* (level 2) (Weeks 5-11) to *skilled* (level 3) (Weeks 12-13) level. Initially, she was unable to apply deductive reasoning, and to scrutinise specific puzzle situations during the game play of Portal, as well as to create hypotheses for solving problems (cf. 4.5, Appendix L). The skill to scrutinise specific puzzle situations and to create hypotheses, however showed growth and development to skilled level at conclusion of the intervention.

The initial observed *novice* (level 1) ability to apply deductive reasoning during the game play of Portal did not support the pre-test result that reflected a *practicing thinker* (level 3); someone who supposedly applies well-thought out ways to improve thinking, and is knowledgeable to infer conclusions (Elder & Paul, 2010; Papp *et al.*, 2014) (cf. 2.5.4). It

is encouraging to note, that the improvement noted during the observation to *skilled* level (level 3) was reflected in the post-test result, where the skill to make deductions, remained at *practicing* level (level 3), implying that the participant is knowledgeable about making conclusions and can monitor and try to improve her thinking (Elder & Paul, 2010; Papp et al., 2014) (cf. 2.5.4).

Doing interpretations

The following graph, Graph 6.29, highlights the observation data recorded for participant 3 regarding doing interpretations.



Graph 6.29: Observations: Doing interpretations – Participant 3

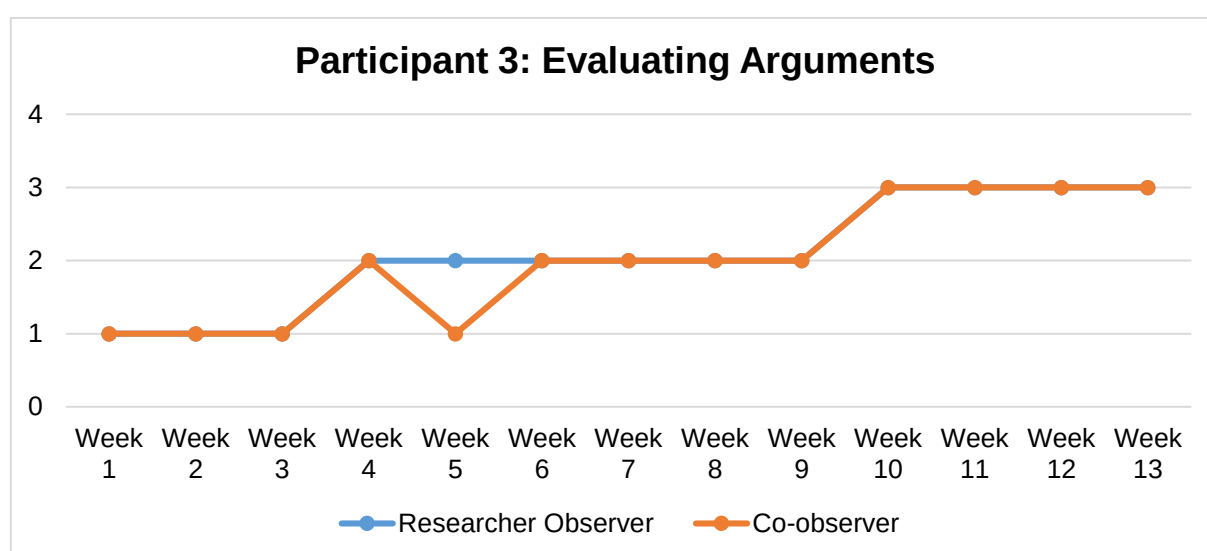
The ability of participant 3 to apply skills to do interpretations varied between *novice* (level 1), *able* (level 2) and *skilled* level (level 3), ultimately being observed as *skilled* at the end of the intervention. At the start of the intervention, the participant was completely unable to interpret the various mechanisms and their relationships (cf. 4.5) presented within the puzzle test chambers, such as how the portals only open on specific surfaces. She gradually became abler (level 2) and skilled (level 3) in interpreting the various mechanisms and their relationships presented within the puzzle test chambers, which assisted her in being more successful in solving the puzzle problems (cf. Appendix L).

The initial *novice* ability to do interpretations during the game play of Portal, did not align with the pre-test result reflecting a *beginning* thinker in doing interpretations; someone

who can recognise and persevere with problems, although still often missing the solutions to problems (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). The post-test result remained unchanged, classifying the participant as a *beginning* thinker, thus not aligned to the final observation that revealed the participant as *skilled*, and supposedly able to spot, and improve faulty thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). According to the post-test result that remained unchanged, the researcher concludes that the intervention possibly did not benefit the development of skills to do interpretations that could be transferred to the general test scenarios of the W-GCTA.

Evaluating arguments

The following graph, Graph 6.30, highlights the observation data recorded for participant 3 regarding evaluating arguments.



Graph 6.30: Observations: Evaluating arguments – Participant 3

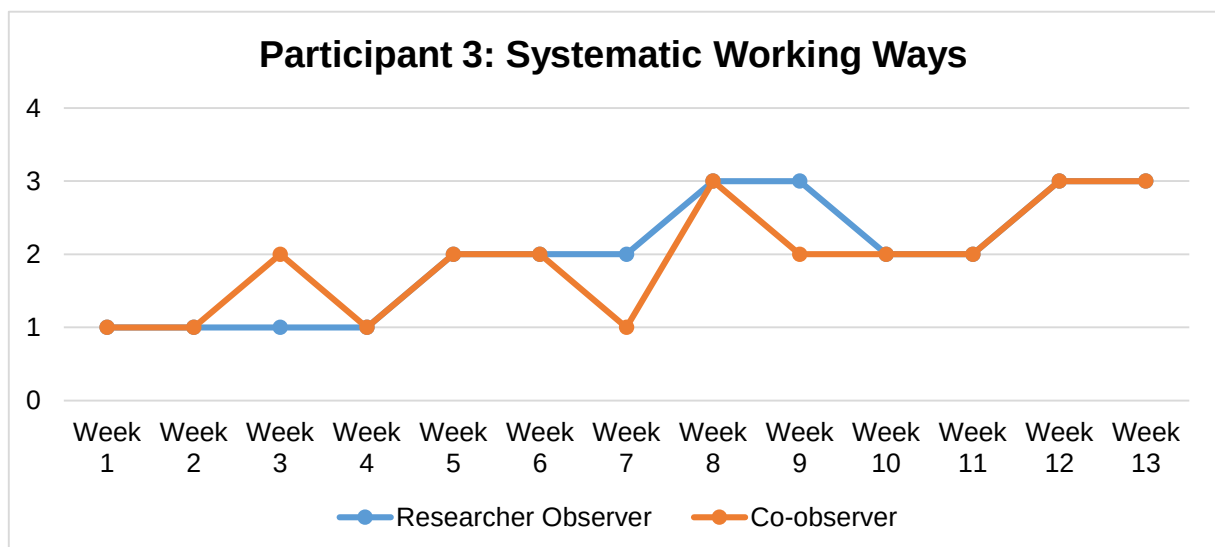
Participant 3 started as a *novice* (level 1) in relation to evaluating arguments, thus being unable to provide reasons for each of the steps followed during the solving of a problem (*cf.* 4.5), such as when faced with challenges with the laser redirection mechanic. As the intervention progressed, growth was noticed, and the participant appeared to become abler (level 2) to provide some reasons for each of the steps followed during the solving of a problem, for example, when dealing with the momentum jumps which require falling through one portal and flinging out the other. During weeks 10 - 13 more growth was

observed towards becoming more *skilled* (level 3) in providing solid reasons for each of the steps followed during the solving of a problem (*cf.* 4.5) (*cf.* Appendix L).

The pre-test result classified the participant as a *practicing thinker* in evaluating arguments, which contradicted the initial observed novice ability. Disappointingly, the pre-test results declined to that of a *beginning* thinker during the post-test, also not supporting the observed skilled ability at the end of the intervention, according to which the participant should be able to identify and improve faulty thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). The puzzle game possibly did not assist the participant in improving her skills to evaluate arguments. It could also be argued that the growth in the skill to evaluate arguments that seemingly took place during the intervention, was not successfully transferred to solving the general problems in the test scenarios.

Systematic working ways

The following graph, Graph 6.31, highlights the observation data recorded for participant 3 regarding systematic working ways.



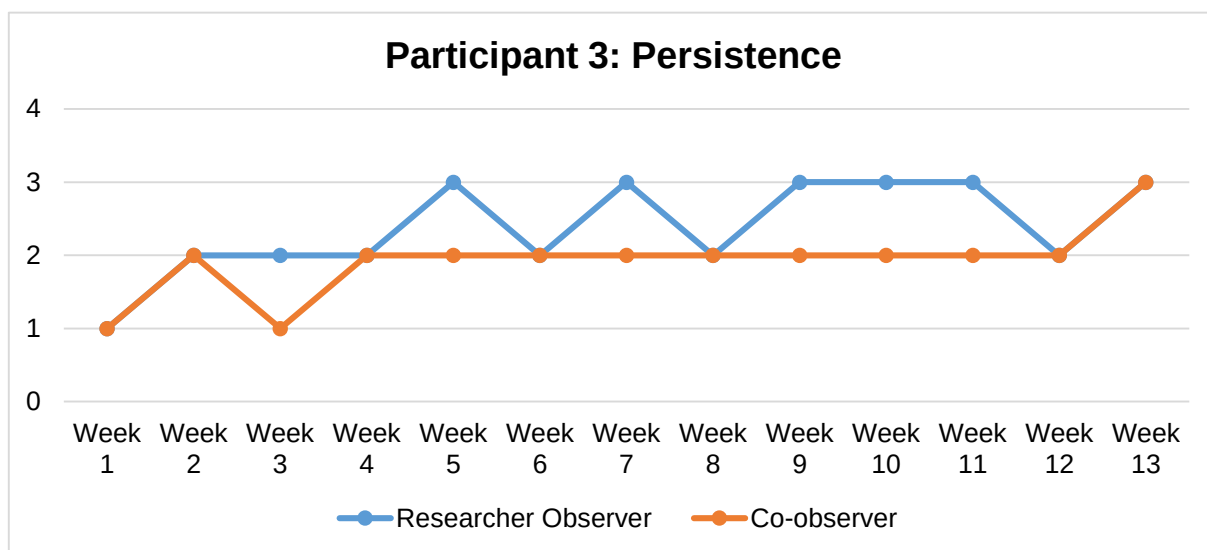
Graph 6.31: Observations: Systematic working ways – Participant 3

Overall, the performance of the participant over the 13 weeks could be summed up as positive when comparing week 1 to week 13. Although the application of the disposition to work systematically varied across the 13 weeks between *novice* (level 1), *able* (level 2) and *skilled* (level 3), the participant seemingly managed to understand the importance

of the GROW model to assist her in working more systematically (*cf.* 4.5; Appendix L), therefore concluding the intervention at *skilled* level.

Persistence

The following graph, Graph 6.32, highlights the observation data recorded for participant 3 regarding persistence.

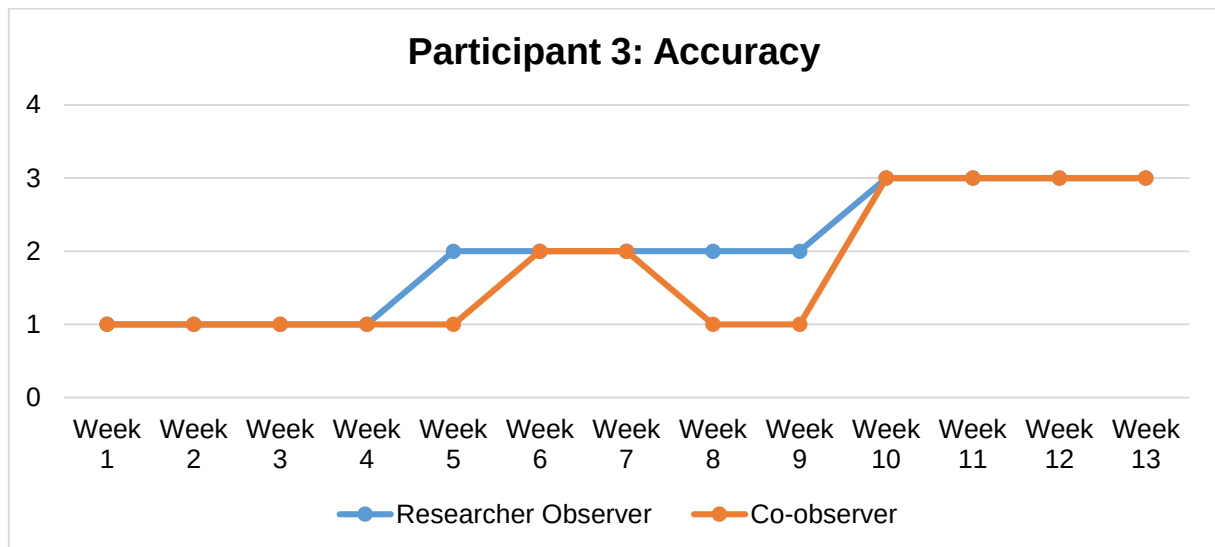


Graph 6.32: Observations: Persistence – Participant 3

Participant 3 entered the intervention at *novice* level (level 1) regarding the disposition to work with persistence. She could not complete tasks autonomously, wanted to opt out, and was dependent on the researcher to complete tasks (*cf.* 4.5, Appendix L). Fluctuating levels of development between able and skilled levels are observed across the implementation of the intervention. Ultimately, during week 13 growth was observed towards becoming more *skilled* (level 3) in persistence as the participant completed tasks autonomously without giving up (*cf.* 4.5)

Accuracy

The following graph, Graph 6.33, highlights the observation data recorded for participant 3 regarding accuracy.

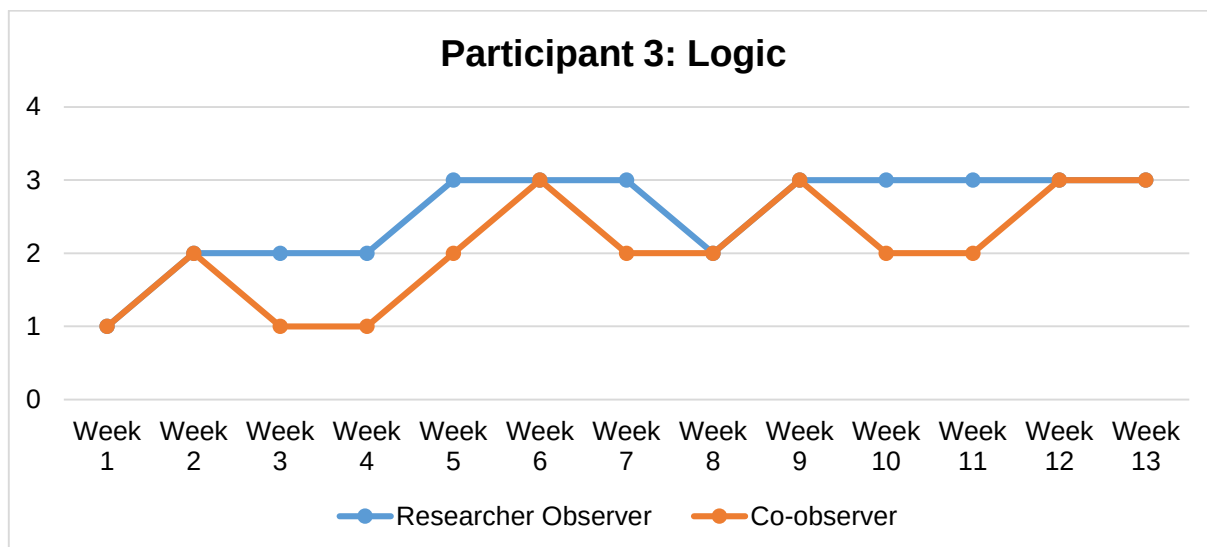


Graph 6.33: Observations: Accuracy – Participant 3

Overall, the performance measured over the entire period could be summed up as encouraging. When comparing week 1 to week 13, it is evident that the observation scores moved up from *novice* (level 1), to *able* (level 2), and *skilled* level (level 3), implying growth in this area. As the intervention progressed the participant put in effort to ensure that she was doing the correct thing when trying to solve the puzzles (*cf.* 4.5, Appendix L).

Logic

The following graph, Graph 6.34, highlights the observation data recorded for participant 3 regarding logic.

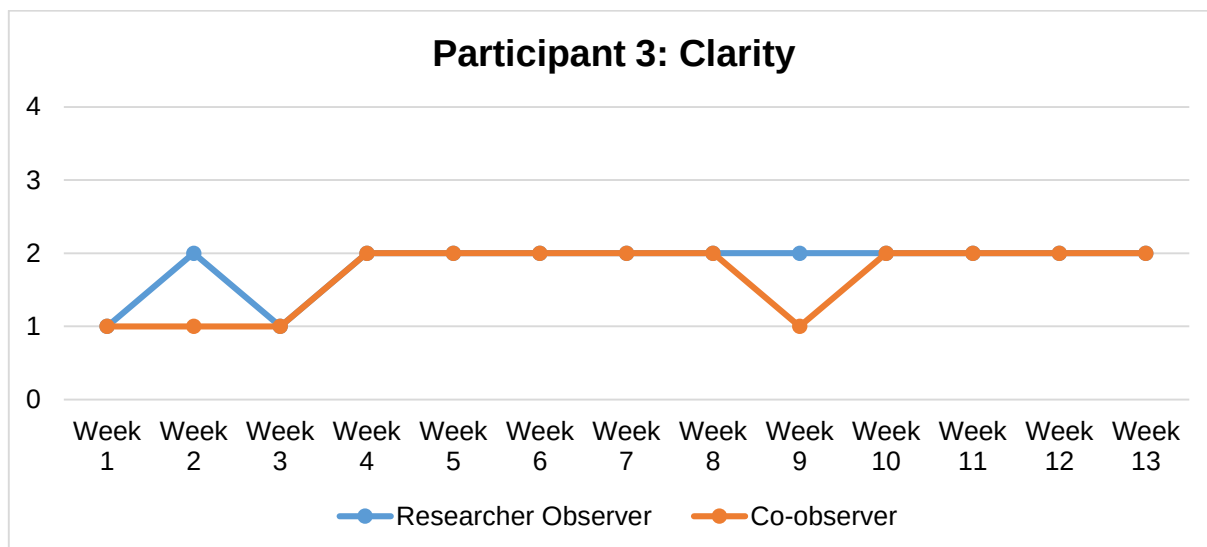


Graph 6.34: Observations: Logic – Participant 3

In sum, the participant was initially regarded as a *novice* (level 1) in relation to logic, thus not being able to apply simple logical steps when trying to solve a problem (*cf.* 4.5), such as redirecting laser beams into receptacles. According to the observations she managed to become abler, thus performing simple logical steps when trying to solve a puzzle, but still struggled with more advanced procedures, such as performing the multi-faceted momentum jumps (*cf.* Appendix L). Eventually, growth towards becoming more *skilled* (level 3) in logic was evidenced, and the participant could perform advanced logical steps when trying to solve a puzzle. The participant however still experienced some problems with complex procedures, especially with the laser redirection, in which logic is required to manipulate the laser through a portal at an angle placed on a wall (*cf.* Appendix L).

Clarity

The following graph, Graph 6.35, highlights the observation data recorded for participant 3 regarding clarity.

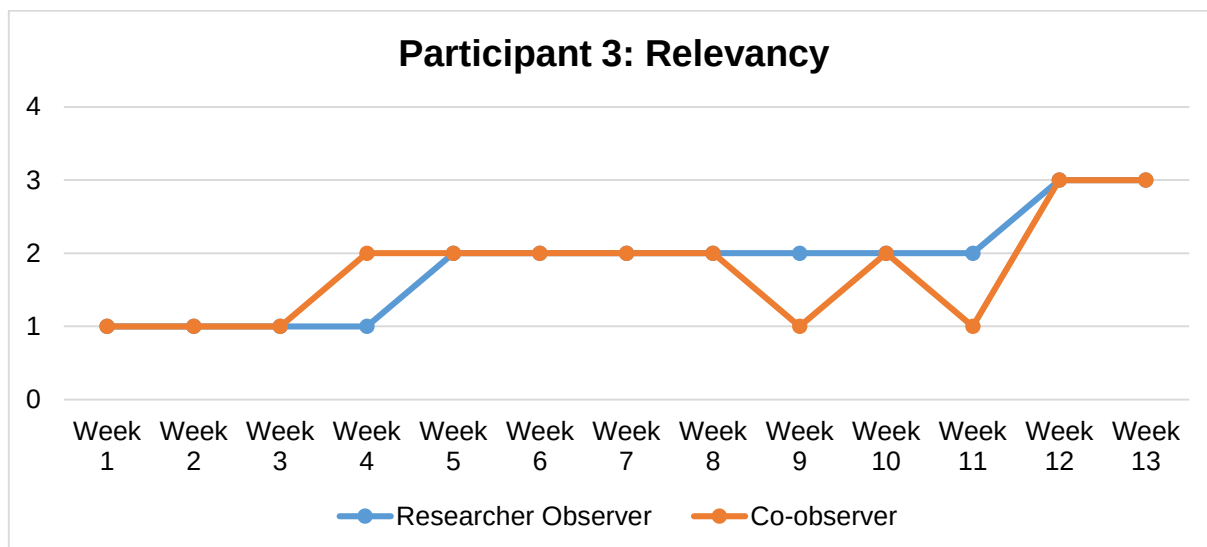


Graph 6.35: Observations: Clarity – Participant 3

In essence, the performance over the entire period could be summed up as mediocre, and not indicative of noteworthy growth, when comparing week 1 to week 13. It is evident that the observation scores only moved from level 1, *novice*, to level 2, *able*. The participant did not excel in being transparent about her actions and thoughts while playing the puzzle game (*cf.* 4.5, Appendix L).

Relevancy

The following graph, Graph 6.36, highlights the observation data recorded for participant 3 regarding relevancy.



Graph 6.36: Observations: Relevancy – Participant 3

The entire performance over the 13-week period can be summed up as promising, when comparing week 1 to week 13. Initial *novice* levels (level 1) of reasoning with relevancy; verbalising thoughts and actions about game play that did not link with the task at hand (*cf.* 4.5), developed to *able* level (level 2), and ultimately to *skilled* level (level 3) to the end of the intervention. The participant appeared to handle communication about her thoughts and actions during game play with greater relevancy in relation to what she was busy doing (*cf.* Appendix L).

In summary, participant 3 started with two skills at beginning level, namely making inferences and doing interpretations, which at the end of the intervention remained at beginning level, implying stagnation. In addition, making deductions that was measured at practicing level at the outset of the study, seemed to remain at practicing level at the end of the study. Recognising assumptions started at advanced/master level and ended at practicing level, thus showcasing decay in the application of the skill. Similarly, evaluation of arguments started out at practicing level and ended at beginning level, also showcasing a decay in the application of the skill. The observations indicated growth for all the skills, which is not supported by the post-test results, according to which none of the critical thinking skills showcased growth.

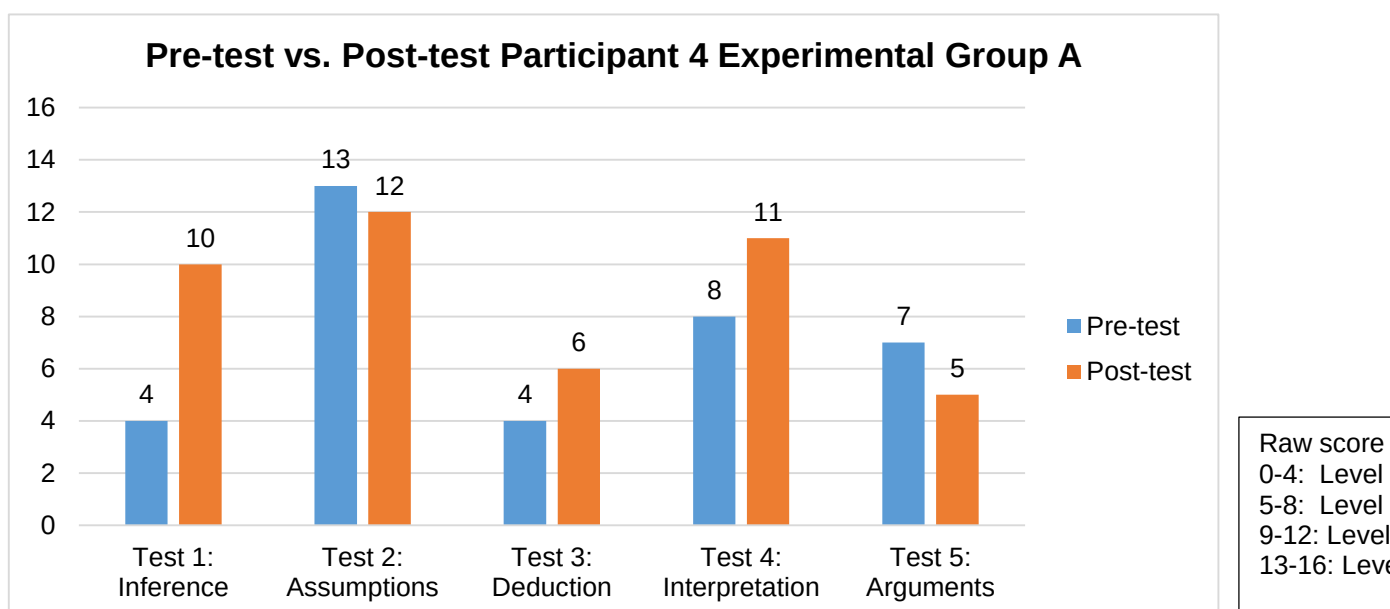
All the dispositions and standards for reasoning started out at novice level and developed to skilled level, except for reasoning with clarity, which developed from novice to able

level, implying that the intervention programme appeared to be beneficial for the development of the dispositions and standards for reasoning, but seemingly did not promote the development of the critical thinking skills on which the research focused.

The following section focuses on the data analysis for participant 4.

6.3.4 Data analysis: Participant 4

Participant 4 was selected from category 4 of the TAG/TALL results, which ranged from 50% - 59%. He scored 56% for the TAG/TALL test. The following graph, Graph 6.37, displays the results obtained for each of the 5 sub-tests out of 16 for participant 4.



Graph 6.37: Participant 4: W-GCTA sub-test scores

The post-test results demonstrated growth for participant 4 in relation to three critical thinking skills. Making inferences apparently developed from *unreflective* and *challenged* level (level 1/2) to *practicing* level (level 3) of thinking. Making deductions started out at *unreflective* and *challenged* level of thinking, and some improvement in the post-test result was noted, to *beginning* thinking level (level 1). Doing interpretations, for which improvement in the post-test results was noted started out at *beginning* level of thinking (level 1), which during the post-test seemed to have developed to *practicing* level (level 3) of thinking. Recognising assumptions showed decline in the post-test result from *advanced/master* level (level 4) of thinking to *practicing* level (level 3) of thinking, and

evaluating arguments seemingly remained at *beginning* level (level 1) of thinking throughout the study.

Table 6.4 below summarises the initial research findings for participant 4.

Table 6.4: Summary of initial findings: Participant 4

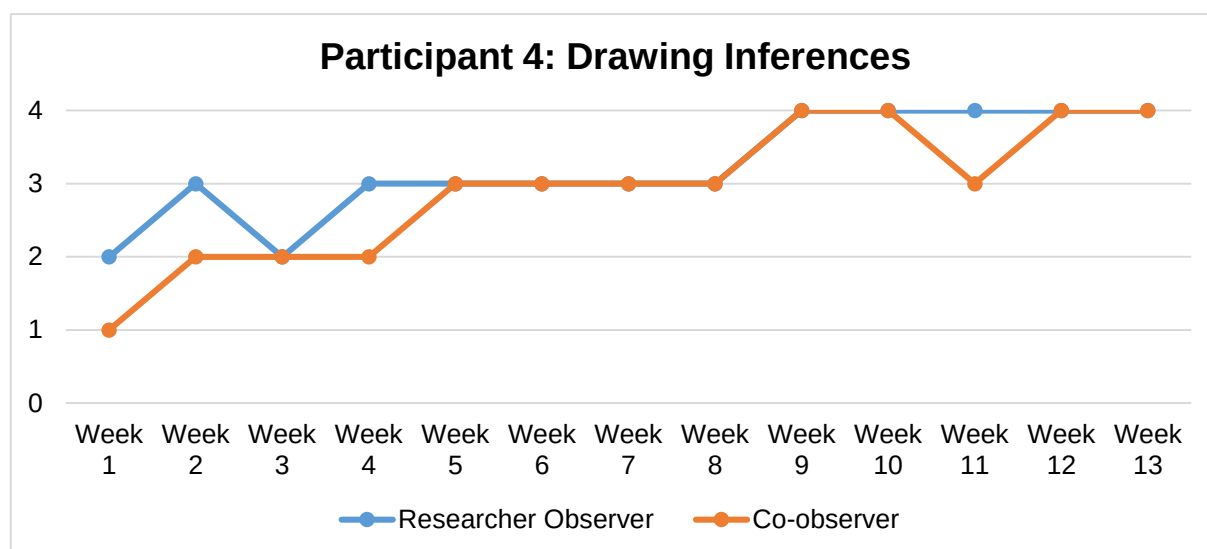
Critical thinking skills: W-GCTA	Growth	Decay	Stagnation
Inference	unreflective challenged to practicing		
Assumptions		advanced/master to practicing	
Deduction	unreflective challenged to beginning		
Interpretation	beginning to practicing		
Arguments			beginning to beginning
Observations: Showed growth from novice/able to sophisticated (inferences), able/skilled to sophisticated (recognising assumptions), able to sophisticated (deductions), skilled to sophisticated (interpretations), and able to skilled (evaluations)			
Dispositions: Observations	Growth	Decay	Stagnation
Systematic working ways	able to sophisticated		
Persistence	able to sophisticated		
Accuracy	able to sophisticated		
Universal standards for reasoning: Observations	Growth	Decay	Stagnation
Logic	able to sophisticated		
Clarity	able to sophisticated		

Critical thinking skills: W-GCTA	Growth	Decay	Stagnation
Relevancy	able/skilled to sophisticated		

The subsequent sections summarise the data analysis for the observations in relation to the elements of critical thinking on which the research focused.

Drawing inferences

The following graph, Graph 6.38, highlights the observation data recorded for participant 4 regarding drawing inferences.



Graph 6.38: Observations: Drawing inferences – Participant 4

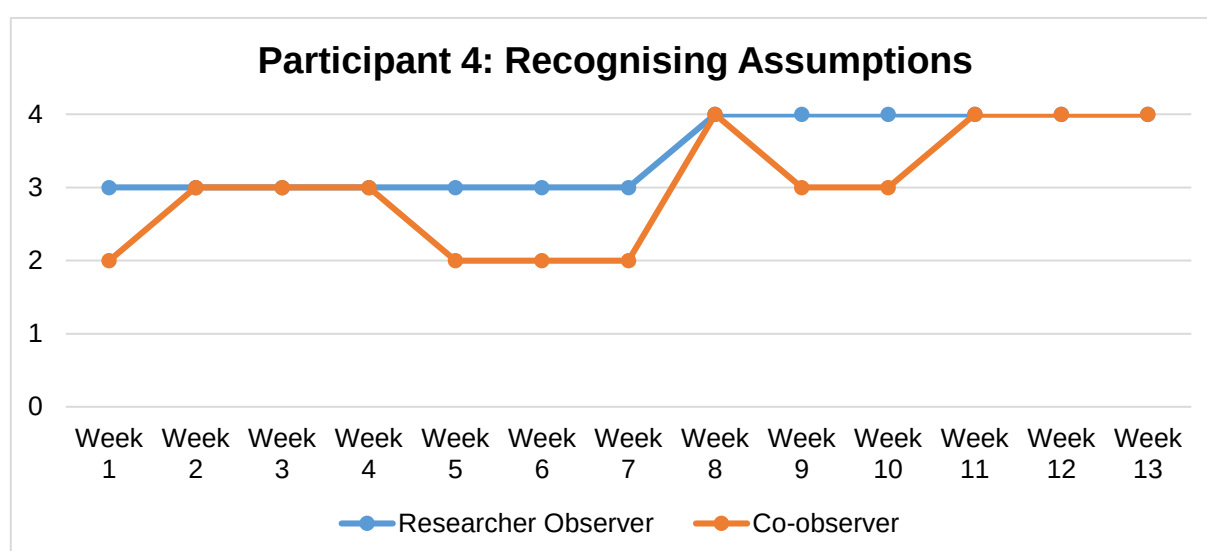
Overall, the performance of the participant could be summed up as inspiring, as the participant seemingly managed to improve the application of skills to make inferences from *novice/able* level (level 1/2) to *sophisticated* level (level 4) during the 13-week intervention. The participant quickly mastered the skill to reason effectively and draw correct conclusions regarding puzzle mechanisms (*cf.* 4.5).

The pre-test result of the participant in relation to making inferences, characterised the participant as a *challenged* and an *unreflective* thinker, who can neither assess and identify flaws in thinking, nor improve thinking (Elder & Paul, 2010, Papp *et al.*, 2014 (*cf.*

2.5.2, 2.5.2). The pre-test result corresponded with the initial novice to able ability to draw conclusions regarding certain puzzle mechanics that was observed at the outset of the intervention (*cf.* 4.5, Appendix L). In support of the observations that witnessed growth, the post-test result testifies to some growth too, characterising the participant as a *practicing* thinker. It could be argued that the intervention seemed to provide opportunities for the participant to become better at applying the skill to make inferences, thus enabling him to monitor and improve faulty thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4).

Recognising assumptions

The following graph, Graph 6.39, highlights the observation data recorded for participant 4 regarding recognising assumptions.



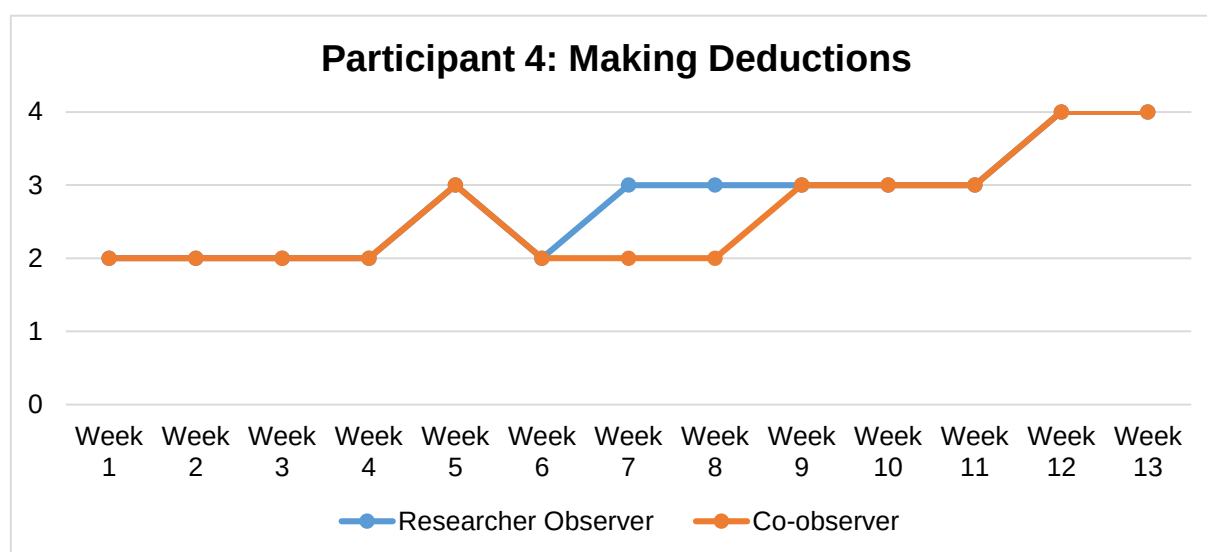
Graph 6.39: Observations: Recognition of assumptions – Participant 4

In a nutshell, the performance over the entire 13-week period could be summed up as powerful, as the participant seemingly managed to develop the application of the skill to identify assumptions from *able/skilled* level (level 2/3) to *sophisticated* level (level 4). From the outset, the participant appeared to be somewhat able to distinguish when assumptions did not apply in the context of the portal activity any more, and could effectively adapt his game play (*cf.* 4.5, Appendix L).

The initial observation that classified the participant as able to skilled to distinguish if past assumptions could be applied in the context of the portal activity, did not corresponded entirely with the pre-test result reflecting him as an *advanced/master thinker*. Being at advanced/master level implies that the participant acknowledges the influence of assumptions during thinking, and instinctively evaluates thinking for the influence of assumptions (Paul & Elder, 2010; Papp *et al.*, 2014) (*cf.* 2.5.5, 2.5.6). The post-test result declined with one level only, which moved the thinking performance of the participant to *practicing* level. Nevertheless, the slight decline could imply that the participant still remains close to advanced/master levels of thinking. The post-test result appears to be more aligned to the final observation, according to which the participant could be regarded as sophisticated in recognising the role of assumptions during thinking.

Making deductions

The following graph, Graph 6.40, highlights the observation data recorded for participant 4 regarding making deductions.



Graph 6.40: Observations: Making deductions – Participant 4

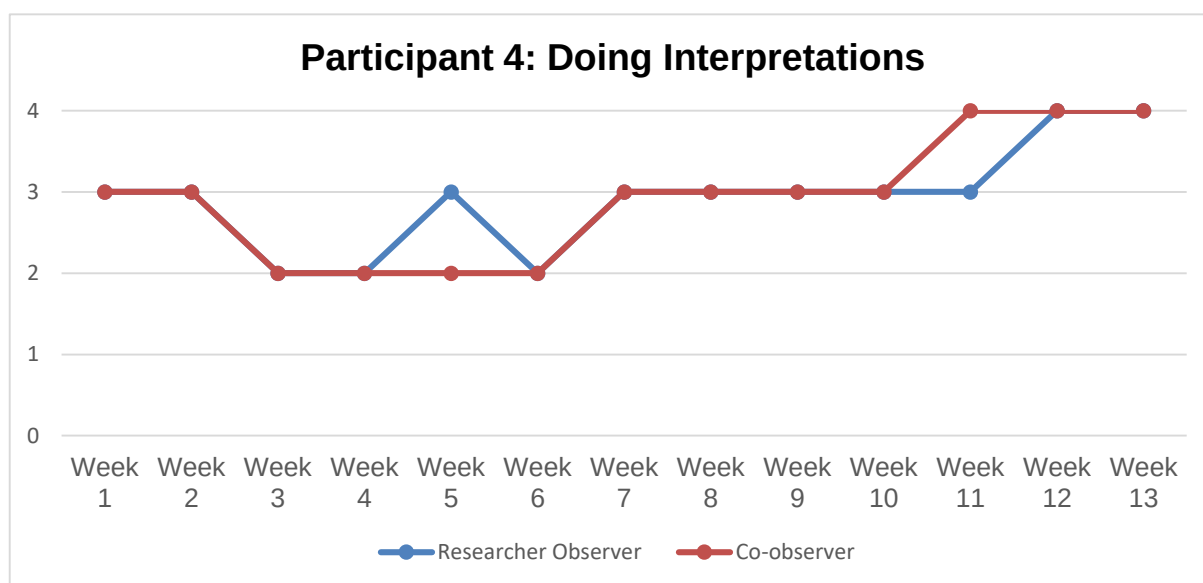
In sum, the performance over the entire period could be summed up as impressive, as the observation scores moved up from *able* level (level 2), to *sophisticated* level (level 4) for applying skills to make deductions. Taking part in the intervention appeared to have had benefits for the participant in relation to becoming more effective at scrutinising

puzzle situations and to hypothesise solutions for the puzzle problems (cf. 4.5, Appendix L).

The initial observed able ability to apply deductive reasoning during the game play of Portal, does not confirm the pre-test result reflecting an *unreflective and challenged thinker* (level 1) in making deductions within the test scenarios, who is not conscious of thinking and not able to identify problems and flaws in thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (cf. 2.5., 2.5.2). The final observation revealing sophistication at making deductions also does not support the post-test result that increased slightly, but still only reflected a *beginning thinker*, not capable of recognising problems in thinking, and missing solutions to problems (Elder & Paul, 2010; Papp *et al.*, 2014) (cf. 2.5.3).

Doing interpretations

The following graph, Graph 6.41, highlights the observation data recorded for participant 4 regarding doing interpretations.



Graph 6.41: Observations: Doing interpretations – Participant 4

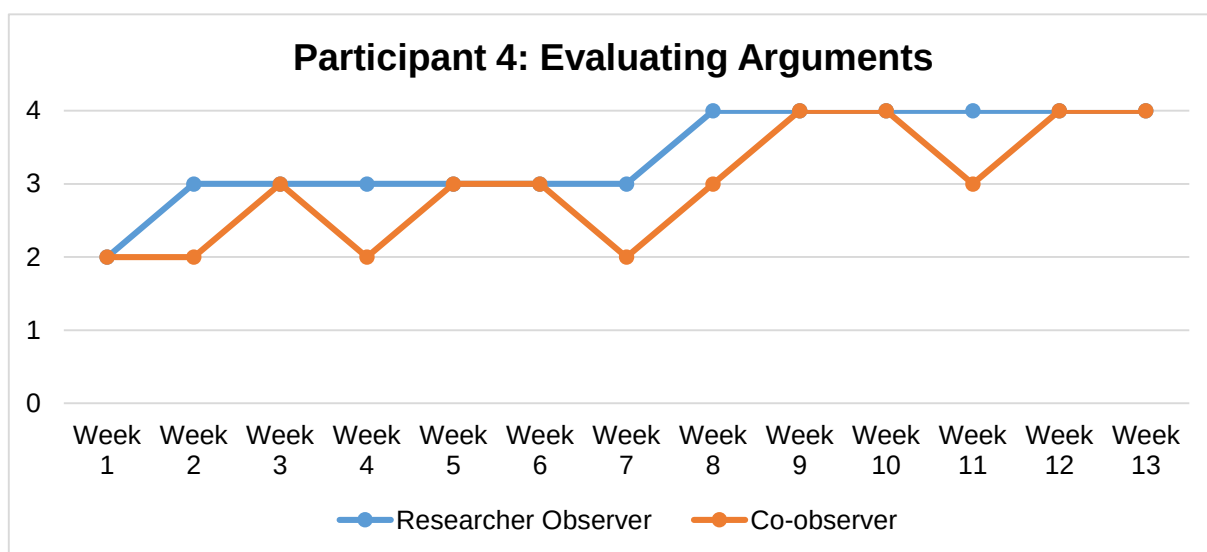
Overall, the performance of participant 4 regarding doing interpretations, witnessed growth. Initially, the participant appeared to be capable of doing interpretations, starting the intervention at *skilled* level (level 3). Although some decay was noted during the intervention to *able* level (level 2), the intervention was concluded at *sophisticated* level (level 4). This implied that the participant was fully able to interpret the various

mechanisms and their relationships presented in the puzzle test chambers (*cf.* 4.5, Appendix L).

The initial skilled ability to do interpretations during the game play of Portal did not correspond with the pre-test result reflecting the participant as a *beginning* thinker in doing interpretations, who starts to recognise problems in thinking and tries improve, although still missing solutions (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). Although the post-test result (*practicing thinker*) does not completely align with the observations that revealed the participant as sophisticated in doing interpretations, growth towards becoming a practicing thinker as indicated by the test results, signals that increased performance in becoming more effective at doing interpretations, was achieved.

Evaluating arguments

The following graph, Graph 6.42, highlights the observation data recorded for participant 4 regarding evaluating arguments.



Graph 6.42: Observations: Evaluating arguments – Participants 4

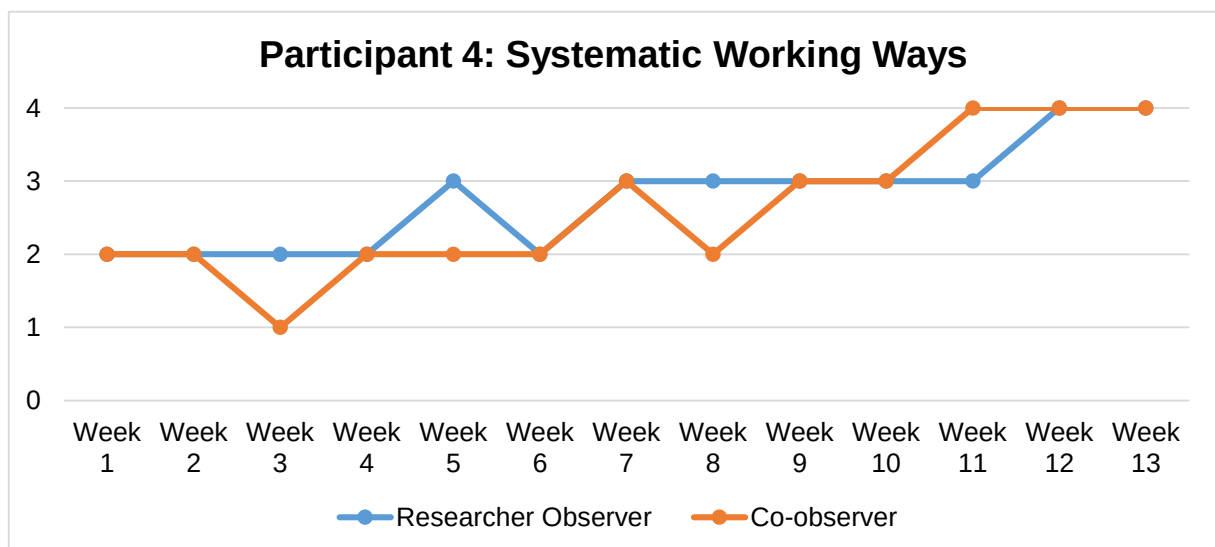
In conclusion, the performance over the entire period can be summed up as positive, when comparing week 1 to week 13. It is clear that the observation scores moved up from *able* (level 2) to *sophisticated* level (level 4), implying growth in the application of skills to evaluate arguments. The participant progressively became more effective at

reflecting continuously whether the steps he took to solve a problem were correct, and explaining the reasons for the steps he took to solve problems (cf. 4.5, Appendix L).

The initial observation that classified the participant as able to evaluate arguments during the game play of Portal could be regarded as confirming the pre-test result that reflected a *beginning thinker* in argument evaluation, someone who is starting to recognise and improve problems in thinking, although sometimes missing solutions to problems (Elder & Paul, 2010; Papp *et al.*, 2014) (cf. 2.5.3). However, the observed growth towards becoming skilled in evaluating arguments, thus implying that the participant can adjust faulty thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (cf. 2.5.4), is not supported by the post-test result that indicated a two-level decrease, and remaining at *beginning* thinking level.

Systematic working ways

The following graph, Graph 6.43, highlights the observation data recorded for participant 4 regarding systematic working ways.



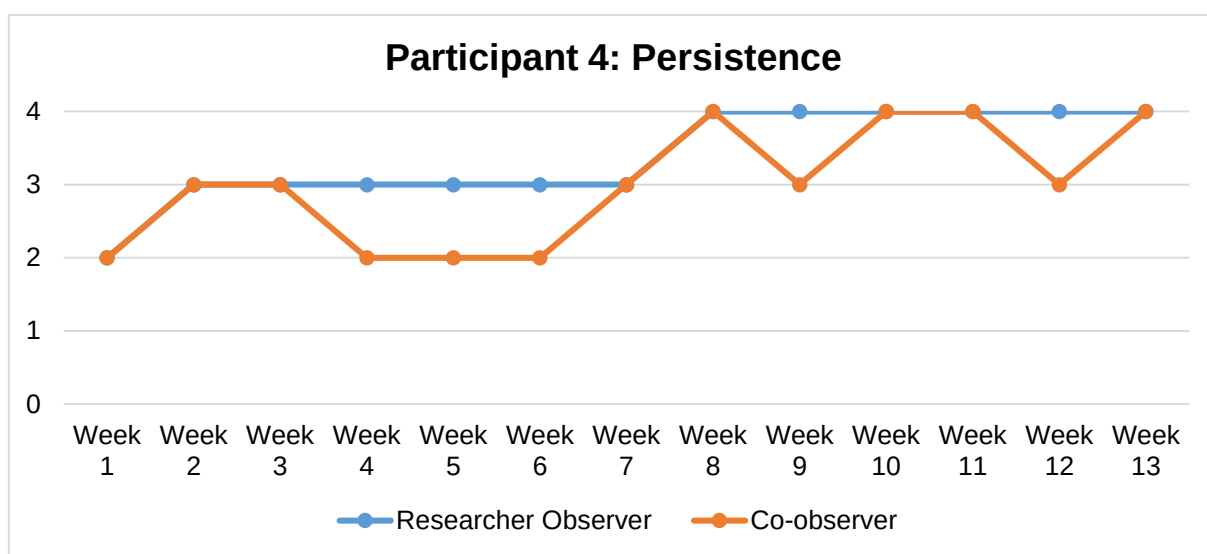
Graph 6.43: Observations: Systematic working ways – Participant 4

In brief, the participant who started out at *able* (beginning thinker) level (level 2), seemingly improved the disposition to work accurately at *sophisticated level* (level 4) at the conclusion of the intervention. Although fluctuations in the participant's level of performance between novice, able and skilled level occurred during the implementation,

which mainly related to the effective and continuous use of the GROW model during problem solving, it seems as if the value of the GROW model for systematic task completion became part of the participant's repertoire of tools to support systematicity as critical thinking disposition (*cf.* 4.5, Appendix L).

Persistence

The following graph, Graph 6.44, highlights the observation data recorded for participant 4 regarding persistence.

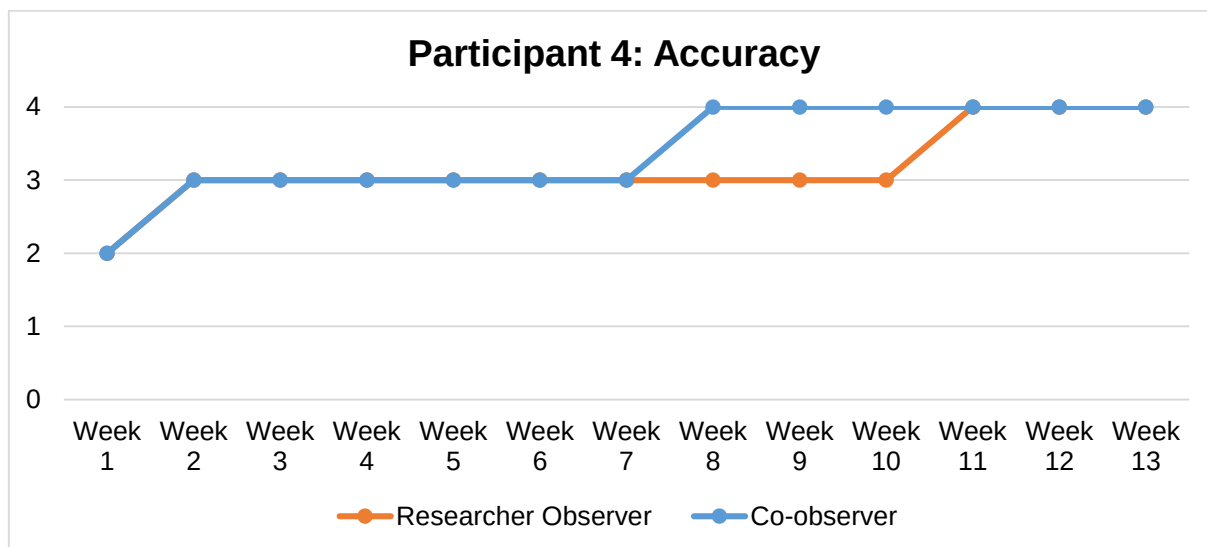


Graph 6:44: Observations: Persistence – Participant 4

Overall, the performance of the participant across the intervention, testify to growth from *able* (level 2) to *sophisticated* level (level 4). At *able* level, the participant tried to complete tasks, but eventually gave up. This was according to the co-observer. However, this tendency was reversed during the intervention and the participant became more skilled in working according to the GROW model during the solving of problems, which he eventually completed autonomously, without giving up (*cf.* 4.5, Appendix L).

Accuracy

The following graph, Graph 6.45, highlights the observation data recorded for participant 4 regarding accuracy.

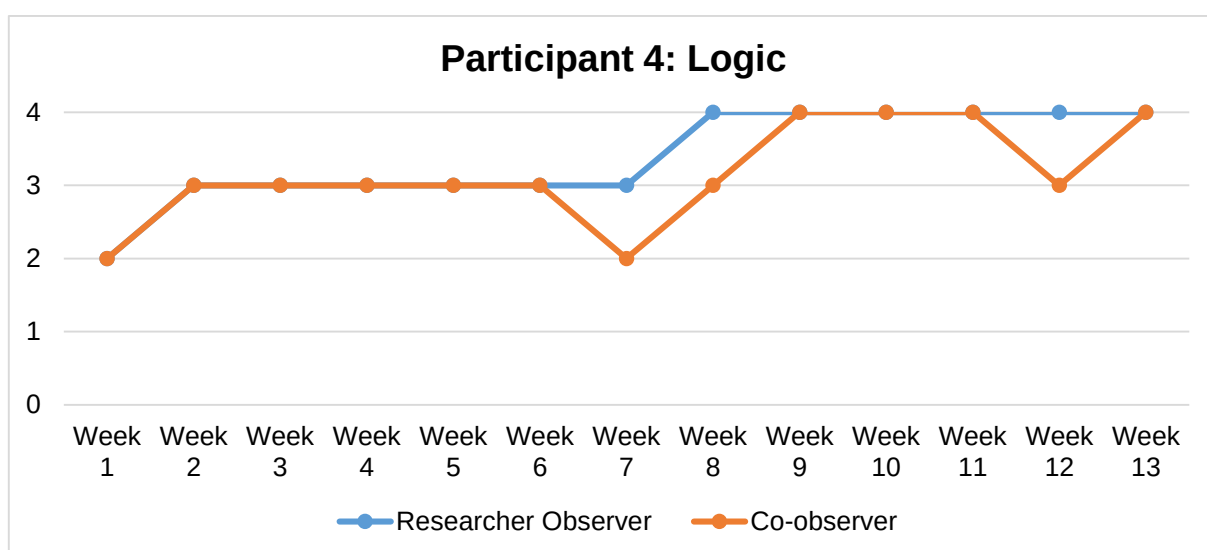


Graph 6.45: Observations: Accuracy – Participant 4

The researcher views the entire performance of the participant across the 13-week period as promising. Growth is noted from *able* (level 2) to *sophisticated* level (level 4), implying that the participant progressively managed to minimise the making of errors when solving problems (*cf.* 4.5, Appendix L).

Logic

The following graph, Graph 6.46, highlights the observation data recorded for participant 4 regarding logic.

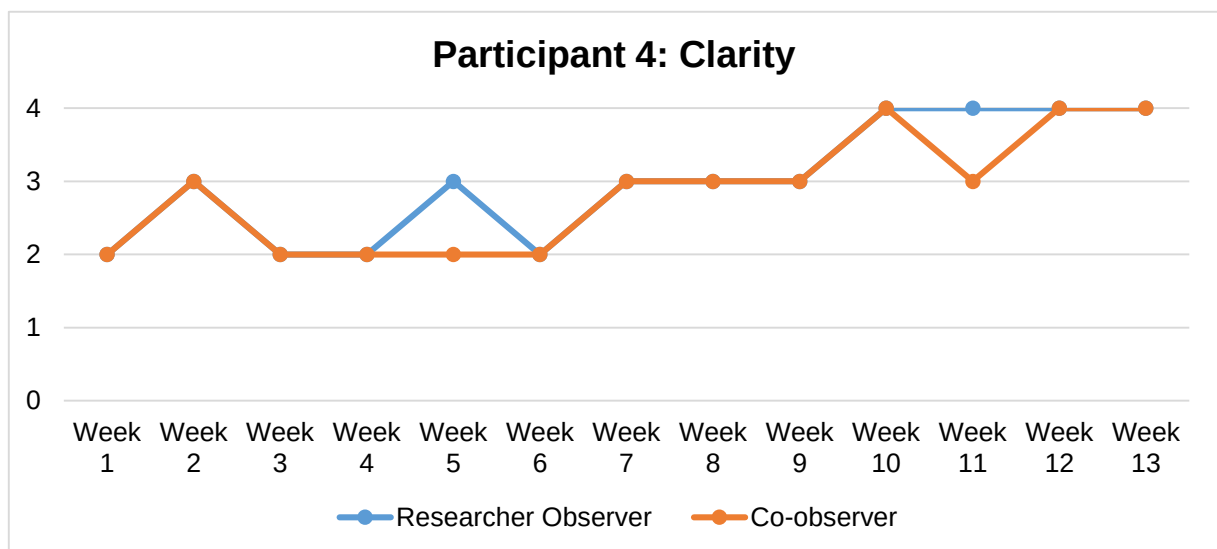


Graph 6.46: Observations: Logic – Participant 4

Participant 4 started week 1 as *able* (level 2) in relation to logic thinking, thus could perform some simple logical steps when trying to solve a problem (*cf.* 4.5), such as redirecting laser beams into receptacles. Growth to *skilled* level (level 3) was observed as the participant was able to perform advanced logical steps, like redirecting a laser through 2 linked portals into a door receptacle, when trying to solve a puzzle. The participant however still struggled with some advanced procedures, such as timed platforms closing and doing momentum jumps with portals. Closer to the end of the intervention, the participant demonstrated greater *sophistication* (level 4) in applying in logic during the game play of Portal. The participant could perform advanced logical steps when trying to solve a puzzle, and could handle complex procedures, such as momentum jumps through multiple portals, opening new portals in mid-air while falling down (*cf.* Appendix L).

Clarity

The following graph, Graph 6.47, highlights the observation data recorded for participant 4 regarding clarity.



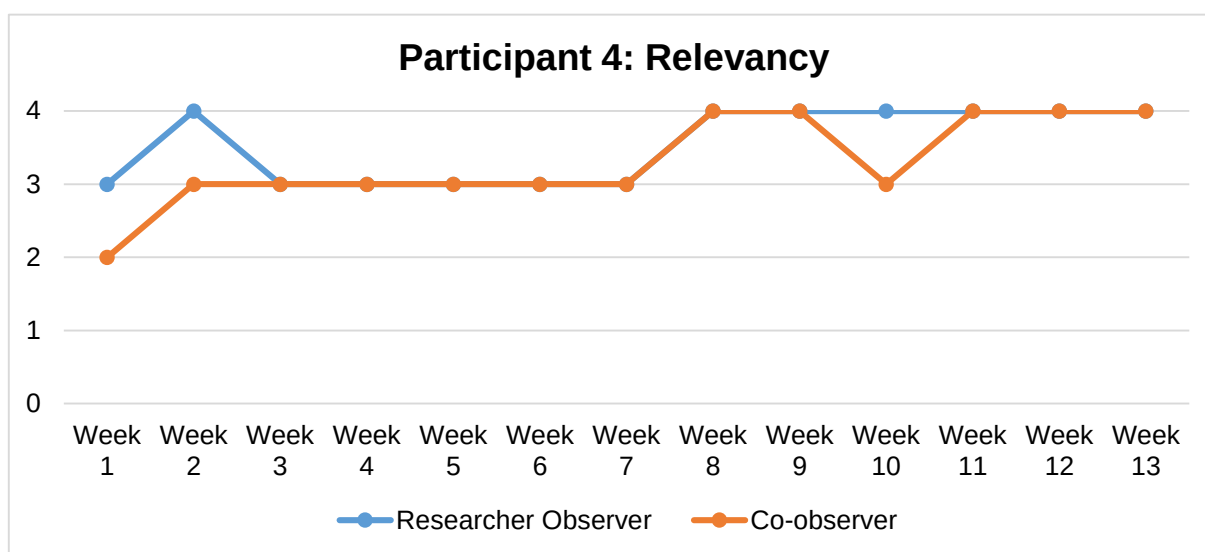
Graph 6.47: Observations: Clarity – Participant 4

Overall, when comparing the first week's performance to the performance of the last week, it is clear that growth in reasoning with clarity took place; developing from *able* (level 2) to *sophisticated* level (level 4). The participant managed to develop from not being able to provide transparent feedback about this thoughts and actions related to the

game, to being sophisticated. This implied that the participant provided clear feedback about his game involvement at all times (*cf.* 4.5, Appendix L).

Relevancy

The following graph, Graph 6.48, highlights the observation data recorded for participant 4 regarding relevancy.



Graph 6.48: Observations: Relevancy – Participant 4

Positive growth is noted for participant 4 in relation to reasoning with relevancy, as initial *able* (level 2) to *skilled* levels (level 3) improved to *sophisticated* levels (level 4) of performance. The participant succeeded in verbalising his thoughts and ideas completely in relation to the task that he was busy performing (*cf.* 4.5, Appendix L).

In brief, participant 4 started the study with very low pre-test scores for making inferences and deductions, which could be considered as challenged and unreflective levels of thinking (*cf.* 2.5.1, 2.5.2). During the post-test however, it appeared that making inferences showed growth towards practicing level of thinking (*cf.* 2.5.4), and making deductions achieved limited growth towards beginning level of thinking (*cf.* 2.5.3).

The pre-test scores for doing interpretations and evaluating arguments aligned with thinking at beginning levels of thinking, implying an awareness of the role of arguments, and points of view in thinking, and that standards for reasoning are recognised and slowly applied during thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). Doing

interpretations apparently developed further to practicing levels of thinking at the end of the intervention, whereas evaluation of arguments stagnated at beginning level of thinking. Participant 4 scored the highest at the start and of the study for recognising assumptions (advanced/master level of thinking) (Elder & Paul, 2010) (*cf.* 2.5.5, 2.5.6). The intervention programme apparently did not influence additional growth in the development of skills to identify assumptions, as the post-test indicated a slight decline to practicing levels of thinking (*cf.* 2.5.4). In terms of the observation data, growth was observed for all of the critical thinking skills, except for making assumptions.

An encouraging finding from the results of participant 4, is that no significant decline in the post-test results was noticed for the application of the critical thinking skills. Another inspiring finding is that all the dispositions and standards for reasoning seemingly developed to sophisticated level, again showcasing growth.

As part of the cross-case analysis, Tables 6.5 and 6.6 below, provides a collective summary of the **growth** noticed in relation to the five critical thinking skills and the dispositions and standards for reasoning on which the research focused for all four participants in the experimental group.

Table 6.5: Growth in critical thinking skills: Experimental group

Participant	Inference	Assumptions	Deduction	Interpretation	Arguments
1	beginning to practicing				
The observations showed growth for all skills – novice to sophisticated (inference, assumptions, deductions, interpretations, evaluation of arguments)					
2	beginning to practicing	beginning to practicing			
Observations showed no growth for any of the critical thinking skills					
3					
Observations showed growth for all skills from novice to able (inferences) and novice to skilled (assumptions, deductions, interpretations, arguments)					
4	unreflective/ challenged to practicing		unreflective/ challenged to beginning	beginning to practicing	
Observations showed growth for all skills from novice/able to sophisticated (inferences), able/skilled to sophisticated (recognising assumptions), able to sophisticated (deductions), skilled to sophisticated (interpretations), and able to skilled (evaluations)					

Table 6.6 below summarises the growth trends noted for the dispositions and standards for reasoning for the participants in the experimental group.

Table 6.6: Improvement in dispositions and standards for reasoning: Experimental group

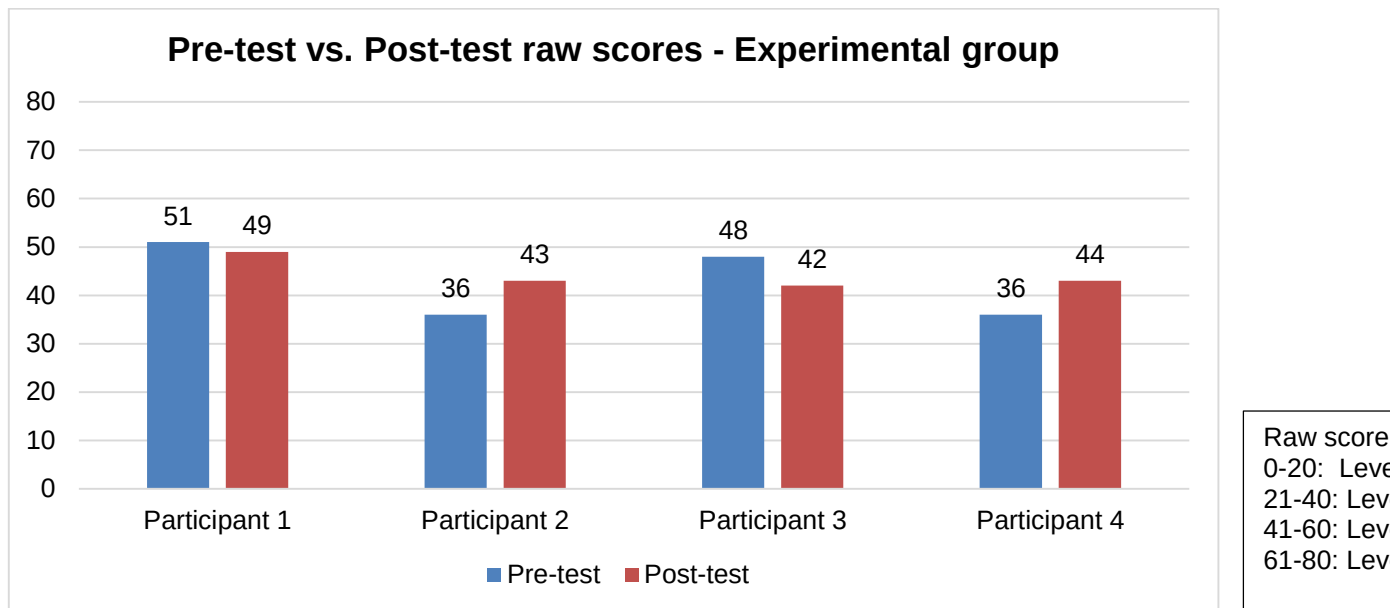
	Dispositions			Standards for reasoning		
Participant	Systematic working ways	Persistence	Accuracy	Logic	Clarity	Relevancy
1	novice-sophisticated	able-sophisticated	novice-sophisticated	novice-sophisticated	able-skilled	novice-sophisticated
2	N/A	N/A	N/A	N/A	N/A	N/A
3	novice-skilled	novice-skilled	novice-skilled	novice-skilled	novice-able	novice-skilled
4	able-sophisticated	able-sophisticated	able-sophisticated	able-sophisticated	able-sophisticated	able/skilled-sophisticated

According to Tables 6.5 and 6.6, it is noted that the intervention seemed to have had a differential influence on the development of the critical thinking skills and the dispositions and standards for reasoning of the participants.

The researcher also considered the overall improvement in the application of the critical thinking skills on which the research focused, by descriptively comparing the pre-and post-test raw score totals for each of the participants in the experimental group.

6.3.5 Pre- and post-test scores: Experimental group

Graph 6.49 below, compares the pre- and post-test raw score totals out of 80 for each of the participants in the experimental group.



Graph 6:49: Pre- and post-test raw score test totals: Experimental group

Graph 6.49, reveals the combined pre- and post-test scores for all five sub-tests for each of the participants who took part in the intervention.

Although according to the research design used in the study, the interpretation of data only follows on conclusion of the data analysis procedure, the following section presents an initial interpretation of the test and observation data for the experimental group, to enable the reader to maintain an oversight of the bulky test and observation data.

As part of cross-case analysis, the researcher identifies similarities and differences among the participants in relation to the developmental levels of thinking (*cf.* 2.5.1 – 2.5.6) observed for the application of critical thinking in action (*cf.* 2.4). Critical thinking in action comprises elements of logical, critical, creative, and big picture thinking modes (Beyer, 1983; Olivier, 2012) (*cf.* 2.4), involving the application of all the skills that the study focused on. Thinking modes are used to analyse and evaluate information, determine consistencies and inconsistencies, identify patterns in information, make deductions and inferences, determine cause and effect, make predictions, and formulate conclusions (Grosser & Olivier, 2017) (*cf.* 2.4).

The pre-test score of **participant 1** declined from 51 to 49 out of 80 during the post-test, and do not suggest exceptional growth, implying that the intervention seemingly did not contribute meaningfully to overall growth for participant 1. Participant 1 seemingly started the research at *practicing* level (level 3) of thinking, which remained constant during the post-test, which could possibly be linked to the fact that growth was only noted for making inferences (*cf.* Table 6.5). Practical thinkers are able to find faults in their thinking, are knowledgeable to apply critical thinking skills, and have internalised the dispositions and standards of reasoning that contribute to enhancing the effectiveness of thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). The aforementioned description seems to apply to participant 1, in particular for the growth observed in relation to the dispositions and standards for reasoning (*cf.* Table 6.1).

In terms of his logical thinking it is clear that his ability to apply the logical thinking mode apparently developed well, from novice to sophisticated level during the intervention. The observations indicated growth for the application of all the critical thinking skills, which was not reflected in the post-test results, that testified to stagnation for three skills and decay in one skill (*cf.* Table 6.1). Nevertheless, the creative, critical and big picture modes may have developed to a limited extent. These thinking modes enable one to move away from foreseeable thinking, and emphasises the creation of new meaning or structure and seeing things from a different perspective that involve the skills of making inferences, conclusions, analysis, synthesis and evaluation (Beyer, 1983; Wechsler *et al.*, 2018) (*cf.* 2.4.3). In support of the aforementioned, the participant seemed to be able to create new meaning by making inferences, which testifies to the improvement during the post-test from beginning to practicing levels (*cf.* Table 6.1).

The raw score obtained for **participant 2** increased from 36 to 43 out of 80, indicating some improvement. The results point out that overall, critical thinking skills appear to be fragile and that further development is required. The impact of the intervention programme could be considered helpful as the scores did improve, but only slightly. Participant 2 started out as an apparent *beginning* thinker who achieved limited growth towards *practicing* level of thinking. The growth suggests that participant 2 progressed from trying to rectify and improve her thinking to applying well-thought out ways to improve her thinking. The growth mentioned, could be supported by her becoming abler

to monitor the influence of assumptions on thinking, and making inferences (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). Although the observations did not demonstrate any growth in the application of the critical thinking skills (*cf.* Table 6.2), the growth noted in the post-test results for making inferences and recognising assumptions, probably suggest some growth in relation to the creative, critical and big picture thinking modes for which, among others, the skills to make inferences and identify assumptions are important. Her logical reasoning however remained at novice levels of performance, and needs substantial further growth. Participant 2 could not be regarded as a practicing thinker regarding the application of the dispositions and standards for reasoning, as no growth was observed for the mentioned elements of critical thinking, and she apparently did not internalise the dispositions and standards for reasoning (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4).

The test results of **participant 3** declined from 48 to 42 out of 80 during the post-test. The post-test results for participant 3 indicates that the intervention programme was seemingly not effective in developing any of the critical thinking skills of participant 3. Similar to participant 1, participant 3 could be considered a *practicing* thinker at the outset of the study, and according to the post-test result remained a *practicing* thinker. In terms of her logic levels showing growth from novice to skilled level, it is evident that participant 3 improved in applying logic to her reasoning. It however appears that the other modes of thinking did not benefit from the intervention, as no growth was noted during the post-test for any of the critical thinking skills, in spite of the fact that the observations noted growth for the application of all the critical thinking skills (*cf.* Table 6.3). The observations do not align well with the classification of the participant as a practicing thinker, who supposedly can monitor thinking for the influence of assumptions, can make inferences and identify implications (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). Contrary to the aforementioned, she could possibly be regarded as a practicing thinker because it appeared that she became effective at checking for the application of dispositions and standards for reasoning (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4), for which growth was noted during the observations.

Participant 4 obtained 36 out of 80, and 43 out of 80 for the pre- and post-tests, respectively. The intervention programme seemed to have benefitted participant 4 and

possibly had some impact on the development of the critical thinking skills on which the research focused. Similar to participant 2, participant 4 apparently started the intervention at *beginning* level of thinking, showing very limited signs of growth towards becoming a *practicing* thinker based on the post-test results, for which improvement in three critical thinking skills were noted (inference, deduction, interpretation). The growth to practicing level is supported by the growth noted from able to sophisticated level regarding reasoning with logic. It also appears that the creative, critical thinking and big picture thinking modes benefitted to some extent, as growth was observed for the application of critical thinking skills to make inferences and deductions, as well as doing interpretations (*cf.* Table 6.4). The researcher argues that the growth noted for all the dispositions and standards for reasoning during the observations, contributes to participant 4 being regarded as a practicing thinker, as he seemed to become capable of monitoring and checking his thinking for the application of dispositions and standards for reasoning (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4).

Based on the aforementioned descriptive account for the test and observation data the researcher provides a synthesis of what transpired from the test and observation data analysis:

- Of the five skills tested in the pre- and post-tests, making inferences apparently benefitted the most from the intervention in terms of growth, as three of the four participants managed to improve their post-test results. The improvement in making inferences was also supported by the growth noted in the observations of the three participants.
- Participant 1 demonstrated improved growth in the application of inferential thinking during the post-test, which is supported by the observation data. In addition, growth was observed for the application of all the dispositions and standards for reasoning.
- Participant 2 achieved growth in the application of making inferences and recognising assumptions, according to the post-test results. No growth in relation to any of the critical thinking skills, dispositions and standards for reasoning was however observed.

- Based on the post-test results, participant 3 seemingly did not benefit from the intervention in relation to growth for the application of any of the critical thinking skills, although the observation data revealed growth for all the skills. Nevertheless, growth was indicated during the observations for all the dispositions and standards for reasoning.
- Of all the participants, participant 4 apparently benefitted the most from the intervention, as the application of three of the critical thinking skills, namely making inferences and deductions, and doing interpretations, testify to growth during the post-test. The noted growth is also supported by the observations. Besides, growth was showcased for all the dispositions and standards for reasoning.
- Participants 2 and 3 probably benefitted the least from the intervention. Participant 2 achieved no growth for the dispositions and standards for reasoning, whereas participant 3 did not achieve any growth for the critical thinking skills in the post-test.
- One of the skills, namely evaluation of arguments revealed no growth among any of the participants during the post-test, and decay for one of the participants, namely participant 3. It could be argued that its application therefore possibly benefitted the least from the intervention.
- Only participants 2 and 4 managed to achieve higher post-test scores, whereas the post-test scores for participants 1 and 3 indicated decline. The argument of the researcher is supported by the summary in Table 6.5, that reveals that participants 2 and 4 seemingly achieved the most growth in relation to the critical thinking skills during the intervention.
- Overall, two participants, participant 1 and 3 started the intervention at practicing level of thinking in relation to the critical thinking skills, and seemed to remain at practicing level at the conclusion of the study.
- Based on the post-test results, participants 2 and 4 appeared to be at beginning level of thinking for the application of the critical thinking skills at the outset of the study, and achieved some growth to practicing level of thinking at the conclusion of the study.

- Overall, the researcher concludes, that all the participants appear to be beginning thinkers regarding the application of the critical thinking skills, as none of them achieved growth in relation to all of the skills during the post-test, and still seem to miss solutions to problems in their thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). In contrast to the critical thinking skills, the application of the dispositions and standards for reasoning for all the participants, with the exception of participant 2, likely benefitted more in terms of growth, according to which the participants could be seen as practicing thinkers who have internalised the dispositions and standards for reasoning and can monitor and check their application during thinking (Paul & Elder, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4).
- The growth noted for the application of the critical thinking skills during the observations was not always supported by an increase in the post-test results. This discrepancy possibly indicates that the skills for which growth was observed were possibly not retained and/or transferred successfully to the W-GCTA context.

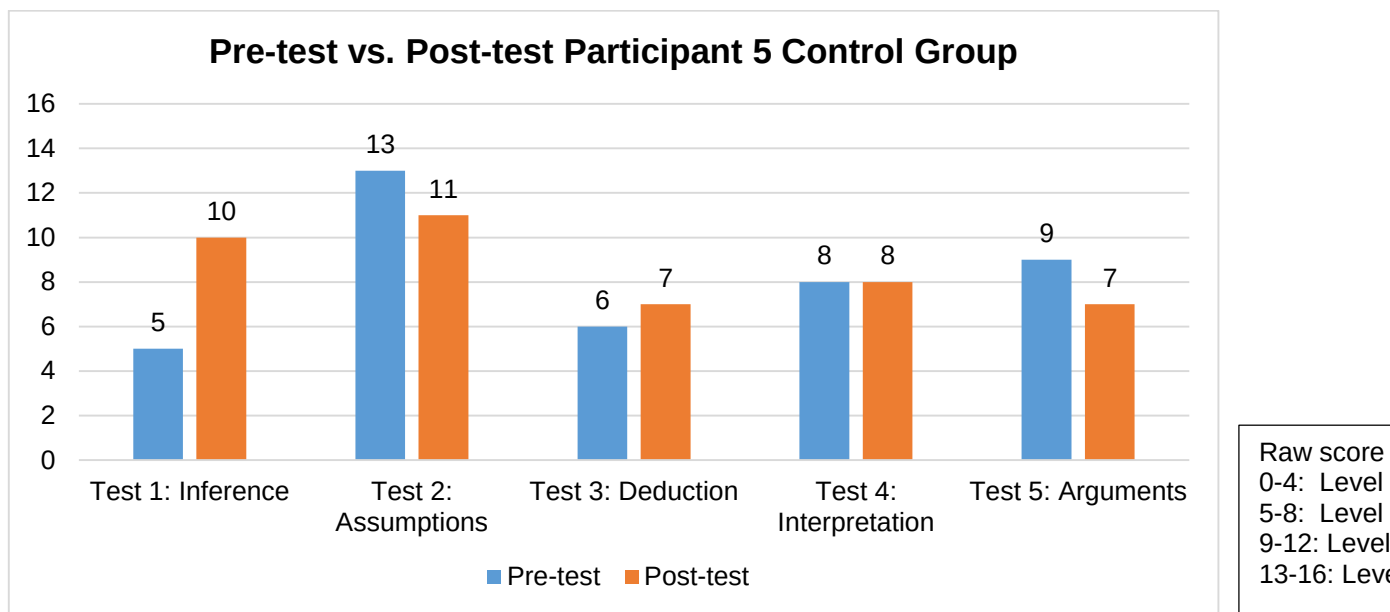
The following section focuses on the analysis and interpretation of the sub-test data for the pre- and post-tests in relation to the individual participants in the control group.

6.4 DATA ANALYSIS AND INTERPRETATION: TEST DATA – CONTROL GROUP

In this section, the researcher emphasises the growth among the participants of the control group, in relation to the critical thinking skills on which the study focused. Although the graphs might indicate slight improvement in post-test results, the improvement does not necessarily imply an improved level of performance in relation to critical thinking, according to the classification categories that the researcher used during the study for interpreting the W-GCTA test scores.

6.4.1 Participant 5

The following graph, Graph 6.50, illustrates the results obtained for each of the 5 sub-tests out of 16 for Participant 5.

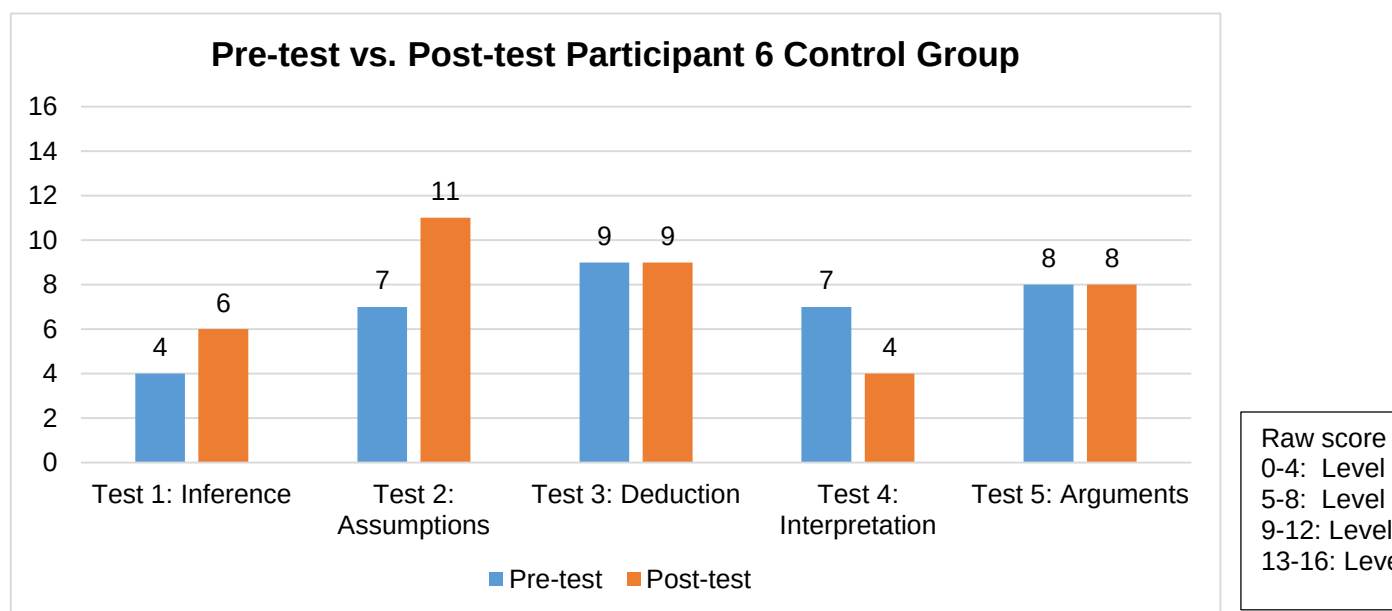


Graph 6.50: Participant 5: Sub-test results

Participant 5 belonged to category 1 of students whose TAG/TALL results ranged between 80% and 100%. This participant scored 82%. Graph 6.50 indicates that participant 5 seemingly demonstrated growth in one skill only, namely making inferences. This growth was noteworthy in terms of moving from one thinking level to a higher one. Inference started in the pre-test on a beginning thinker level, improving to practicing thinker levels (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3, 2.5.4). However, stagnation was evident for two skills, namely deduction and interpretation. Deduction and interpretation both started in the pre-test on beginning thinker levels, stagnating in the post-test at beginning thinker levels (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). Decay is noted in the application of two skills, namely recognising assumptions and evaluating arguments. Recognising assumptions started in the pre-test at advanced/master levels, declining to practicing thinker levels (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4) in the post-test. Evaluating arguments started at practicing thinker levels in the pre-test, ultimately declining to beginning thinker levels in the post-test (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). Making inferences received the lowest score during the pre-test, but the post-test result indicated noteworthy improvement. At the end of the study, deduction and evaluating arguments appeared to be the skills, that the participant found the most difficult to apply.

6.4.2 Participant 6

The following graph, Graph 6.51, illustrates the results obtained for each of the 5 sub-tests out of 16 for Participant 6.



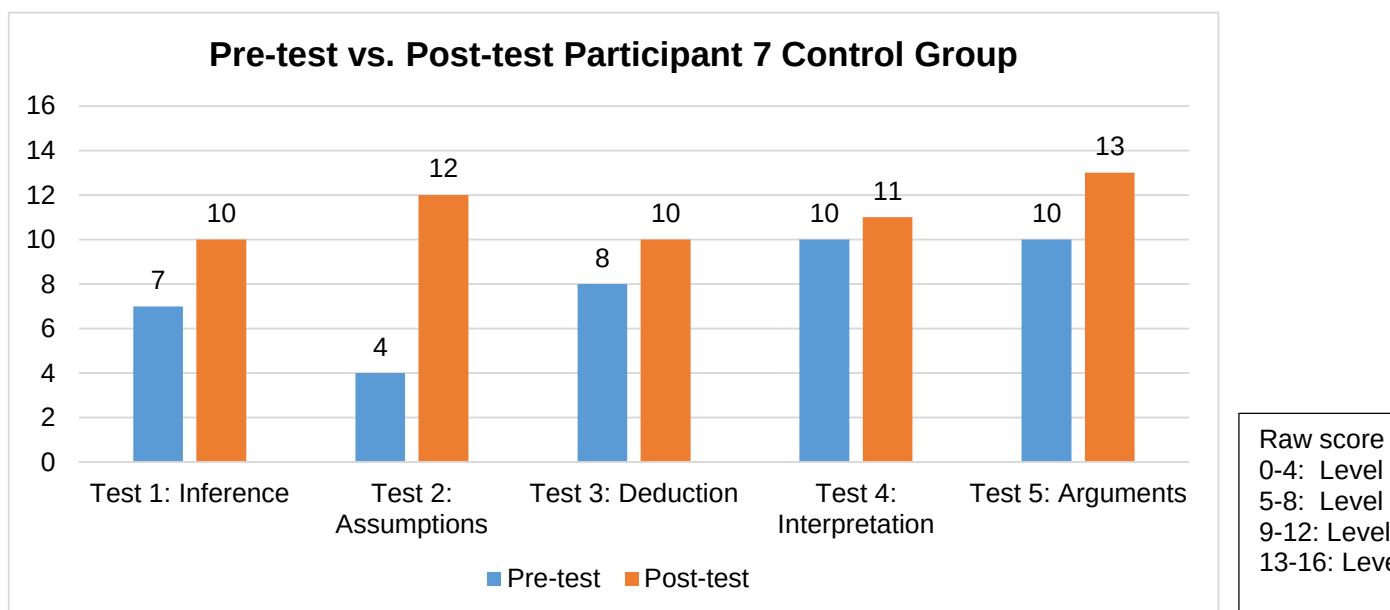
Graph 6.51: Participant 6: Sub-test results

Participant 6 belonged to category 2 of students whose TAG/TALL results ranged between 70% and 79%. This participant scored 78%. In summary, Graph 6.51 indicates that participant 6 apparently demonstrated growth for two skills, namely making inferences and recognition of assumptions. Making inferences started out at an unreflective and a challenged thinker level (*cf.* 2.5.1, 2.5.2) in the pre-test, and improved towards a beginning thinker in the post-test (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). Recognition of assumptions began at beginning thinker levels in the pre-test and improved towards practicing levels in the post-test (Elder & Paul, 2010; Papp *et al.*, 2014:716) (*cf.* 2.5.4). Two skills apparently did not improve, namely making deductions and the evaluation of arguments. Making deductions started at practicing thinker levels (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4) and remained at the same level in the post-test. Evaluation of arguments started at beginning thinker levels (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3) in the pre-test, and remained the same for the post-test. For one skill, decay in performance was noted, namely doing interpretations. The skill to do interpretations started at beginning thinker levels in the pre-test and decayed to

unreflective/challenged thinking levels in the post-test (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.1, 2.5.2).

6.4.3 Participant 7

The following graph, Graph 6.52, illustrates the results obtained for each of the 5 sub-tests out of 16 for Participant 7.



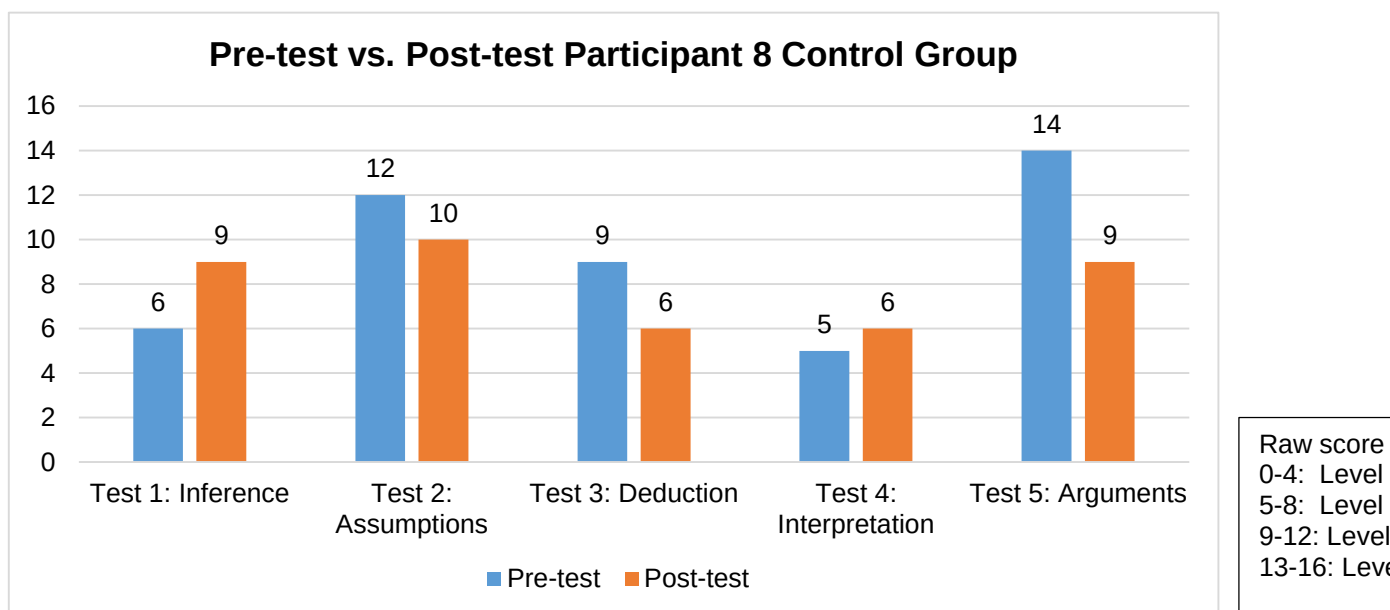
Graph 6.52: Participant 7: Sub-test results

This participant was chosen from category 3, with percentages ranging from 60% - 69% in the TAG/TALL test. This participant scored 65%. According to Graph 6.52, participant 7 seemingly started as an unreflective and a challenged thinker (*cf.* 2.5.1, 2.5.2) for the recognition of assumptions during the pre-test, who grew to become a practicing thinker according to the post-test result (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). Participant 7 also started as a beginning thinker in the pre-test for 2 skills, namely making inferences and deductions, whereupon growth was noted in the post-test towards becoming a practicing thinker (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3, 2.5.4). Regarding the evaluation of arguments, participant 7 started as a practicing thinker in the pre-test, and growth was seen towards becoming an advanced/master thinker (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.5, 2.5.6) in the post-test. Some stagnation was noted, as the participant started as a practicing thinker (Elder & Paul, 2010; Papp *et al.*,

2014) (*cf.* 2.5.4) for doing interpretations in the pre-test, and seemingly ended on the same level during the post-test.

6.4.4 Participant 8

The following graph, Graph 6.53, illustrates the results obtained for each of the 5 sub-tests out of 16 for Participant 8.



Graph 6.53 Participant 8: Sub-test results

This participant was chosen from category 4, with the TAG/TALL results ranging between 50% - 59%. This participant scored 56%. According to Graph 6.55, participant 8 started as a beginning thinker in the pre-test for making inferences, who showed growth towards becoming a practicing thinker (Elder & Paul 2010, Papp *et al.*, 2014) (*cf.* 2.5.3, 2.5.4) in the post-test. For recognising assumptions, participant 8 started as a practicing thinker (Elder & Paul, 2010; Papp *et al.*, 2014:716) (*cf.* 2.5.4) whose post-test result remained at the same level, although the post-test result revealed two points improvement. For making deductions, participant 8 started in the pre-test as a practicing thinker (*cf.* 2.5.4), but the post-test result showed some decline towards being a beginning thinker (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3) in the post-test. Regarding making interpretations, participant 8 started as a beginning thinker (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3), whose results stagnated at the same level during the post-test. Participant 8 started as an advanced/master thinker in the application of skills to evaluate

arguments during the pre-test. However, the application of the skill seemingly decayed to practicing thinking levels during the post-test (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.5, 2.5.4),

In summary, the researcher provides an overview in Table 6.7 below, of the improvement noted in the application of the critical thinking skills on which the intervention focused, among the participants of the control group.

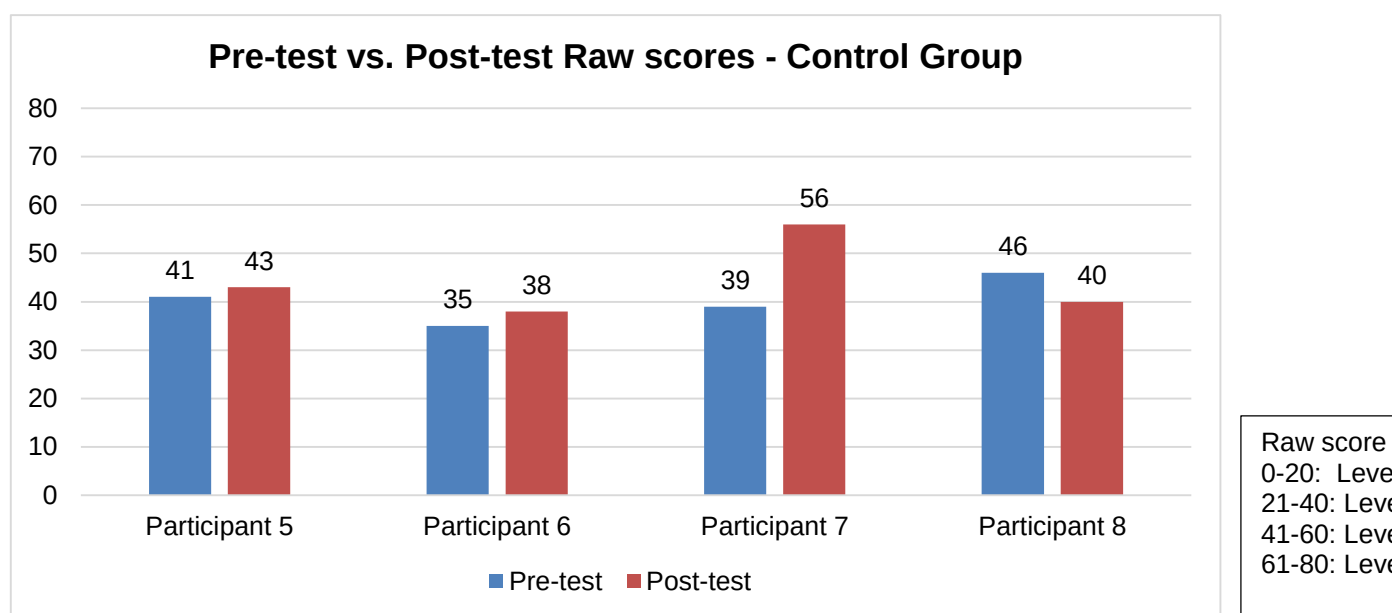
Table 6.7: Improvement in critical thinking: Control group

Participant	Inference	Assumptions	Deduction	Interpretation	Arguments
5	beginning to practicing				
6	unreflective/ challenged to beginning	beginning to practicing			
7	beginning to practicing	unreflective/ challenged to practicing	beginning to practicing		practicing to advanced master
8	beginning to practicing				

According to Table 6.7, and similar to the experimental group (*cf.* Table 6.5), it appeared that doing inferences was the skill for which the most growth was observed. All four participants in the control group managed to obtain higher scores for making inferences during the post-test. Among all the participants in the control group, participant 7 appeared to be the participant who achieved the best scores in the post-test, with improvement noted for four of the critical thinking skills. The improvement in the post-test results revealed in Table 6.7, could imply that the participants' normal academic programme provided opportunity for developing and practicing some of the critical thinking skills on which the research focused, which enabled them to cope better with the application of the skills once the post-test was written.

Unfortunately, data in relation to the development of dispositions and standards for reasoning could not be established for the control group, as they did not take part in the PVG-CEP intervention.

The researcher also made a descriptive comparison of the pre- and post-test raw score totals out of 80 for the participants in the control group, as reflected in Graph 6.54.



Graph 6.54: Pre- and post-test raw score totals: Control group

According to Graph 6.54, participant 5 started out as a practicing thinker and remained at practicing thinking level (*cf.* 2.5.4). Participant 6, who obtained the lowest pre- and post-test scores in the control group, started out as a beginning thinker, and remained at beginning thinking level (*cf.* 2.5.3) during the post-test. Participant 7 scored the highest out of the four students in the control group, for the post-test. The participant started at beginning level of thinking (*cf.* 2.5.3), but ended at practicing levels (*cf.* 2.5.4) of thinking. The application of critical thinking skills showed a decay for participant 8, who started at practicing level (*cf.* 2.5.4), but ended at beginning level (*cf.* 2.5.3).

In comparison to the experimental group where two participants managed to achieve better results during the post-test, only one participant, namely participant 7, apparently managed to achieve better results during the post-test. Of all the participants in the experimental and control group, participant 7 appears to be the participant who likely achieved the most growth in relation to the application of the critical thinking skills.

In the following section, the researcher compares the data obtained for the experimental and control groups.

6.5 DATA ANALYSIS AND INTERPRETATION –TEST DATA: COMPARISON – EXPERIMENTAL AND CONTROL GROUP

Although it was not the aim of the researcher to compare the data obtained for the experimental and control groups in order to accept or reject hypotheses, the researcher was encouraged by the independent statistician who assisted with the data analysis and interpretation to do the comparisons that could guide the formulation of tentative hypotheses for future, rigorous, true experimental studies (*cf.* 6.8).

In order to compare the results obtained for the pre- and post-tests, the researcher made use of **descriptive statistics** as well as **non-parametrical inferential statistics** (Ivankova *et al.*, 2007; Pietersen & Maree, 2007a). The researcher utilised the data obtained from the tests to calculate frequencies, percentages, means, standard deviations and medians for the various test measurements (Babbie & Mouton, 2001). In the context of the data analysis by means of inferential statistics, it was important to consider whether parametric or nonparametric statistical procedures should be utilised. In this study where a small sample was utilised (less than 30), it could not be assumed that the study variable was normally distributed, therefore non-parametric statistical procedures were applied (McMillan & Schumacher, 2006). This decision was supported by the independent statistician who assisted the researcher with the capturing and analysis of the data.

The **Mann-Whitney U test** was used to compare the pre-test and post-test results of the two independent groups of participants in the experimental and control groups (Pietersen & Maree, 2007b). This test uses the ranks of the study variable and not the actual values, in order to avoid that extreme values, influence the outcome of the analysis (Swanepoel *et al.*, 2006; Steyn, 2005).

The **Wilcoxon signed-rank test** was utilised to compare the differences between the pre-test and post-test results within each of the groups. The differences between two scores are ordered, and ranks are assigned to them. The actual values of the differences are not used during the analysis of data (Pietersen & Maree 2007b).

The effect size estimate, r , was used to interpret statistical significant differences between results (*cf.* 5.9.1).

The following section reports on the comparison of pre- and post-test data obtained for the experimental group.

6.5.1 Comparison: Test totals – Experimental group participants

Table 6.8 below presents that data to illustrate the statistical differences between the pre- and post-test results for the experimental group.

Table 6.8: Comparison of differences between pre- and post-test totals: Experimental group

	Group A	N	Mean	Median	Mean rank			Mean rank		Sum of ranks		Z	Significance (p)	r	Effect
					Negative	Positive	Ties	Negative	Positive	Negative	Positive				
Inference (16)	Post-test	4	9.3	9.5	0	4	0	0.00	2.50	0.00	10.00	-1.841	0.066	-	-
	Pre-test	4	6	6.5											
Assumptions (16)	Post-test	4	10.3	10	3	1	0	2.50	2.50	7.50	2.50	-0.921	0.357	-	-
	Pre-test	4	11.5	12.5											
Deduction (16)	Post-test	4	8.0	7.5	1	2	1	2.00	2.00	2.00	4.00	-0.577	0.564	-	-
	Pre-test	4	7.5	8.5											
Interpretation (16)	Post-test	4	8.8	8.5	0	1	3	0.00	1.00	0.00	1.00	-1.000	0.317	-	-
	Pre-test	4	8	7.5											
Arguments (16)	Post-test	4	8.3	7.5	2	1	1	2.50	1.00	5.00	1.00	-1.069	0.285	-	-
	Pre-test	4	9.75	9.5											
Test total (80)	Total Post	4	44.7	43.5	0	4	0	0.00	2.50	0.00	10.00	-1.826	0.068	-	-
	Total Pre	4	42.75	42											

Significance: * $p < 0.05$

According to Table 6.8, no statistical significant differences occurred within the experimental group between the pre- and post-tests for any of the five skills on which the W-GCTA focused. Although higher means were obtained in the post-test for *inference*, *deduction* and the *test total*, the differences were not statistically significant, as $p > 0.05$ in all instances. The researcher can therefore not conclude with certainty that the intervention contributed to the improvement noticed in the post-test results.

The following section, section 6.5.2, compares the test data for the participants in the control group.

6.5.2 Comparison: Test totals – Control group participants

Table 6.9 below presents that data to illustrate the statistical significant differences between the pre- and post-test results for the control group.

Table 6.9: Comparison of differences between pre- and post-test totals: Control group

	Group A	N	Mean	Median	Mean rank			Mean rank		Sum of ranks		Z	Significance (p)	r	Effect
					Negative	Positive	Ties	Negative	Positive	Negative	Positive				
Inference (16)	Post-test	4	8.75	9.5	0	4	0	0.00	2.50	0.00	10.00	-1.841	0.066	-	-
	Pre-test	4	5.5	5.5											
Assumptions (16)	Post-test	4	11	11	2	2	0	1.50	3.50	3.00	7.00	-0.736	0.461	-	-
	Pre-test	4	9	9.5											
Deduction (16)	Post-test	4	8	8	1	2	1	3.00	1.50	3.00	3.00	0.000	1.000	-	-
	Pre-test	4	8	8.5											
Interpretation (16)	Post-test	4	7.25	7	1	2	1	3.00	1.50	3.00	3.00	0.000	1.000	-	-
	Pre-test	4	7.5	7.5											
Arguments (16)	Post-test	4	9.25	8.5	2	1	1	2.00	2.00	4.00	2.00	-0.535	0.593	-	-
	Pre-test	4	10.25	9.5											
Test total (80)	Total Post	4	44.25	41.5	0	4	0	0.00	2.50	0.00	10.00	-1.826	0.068	-	-
	Total Pre	4	40.25	40											

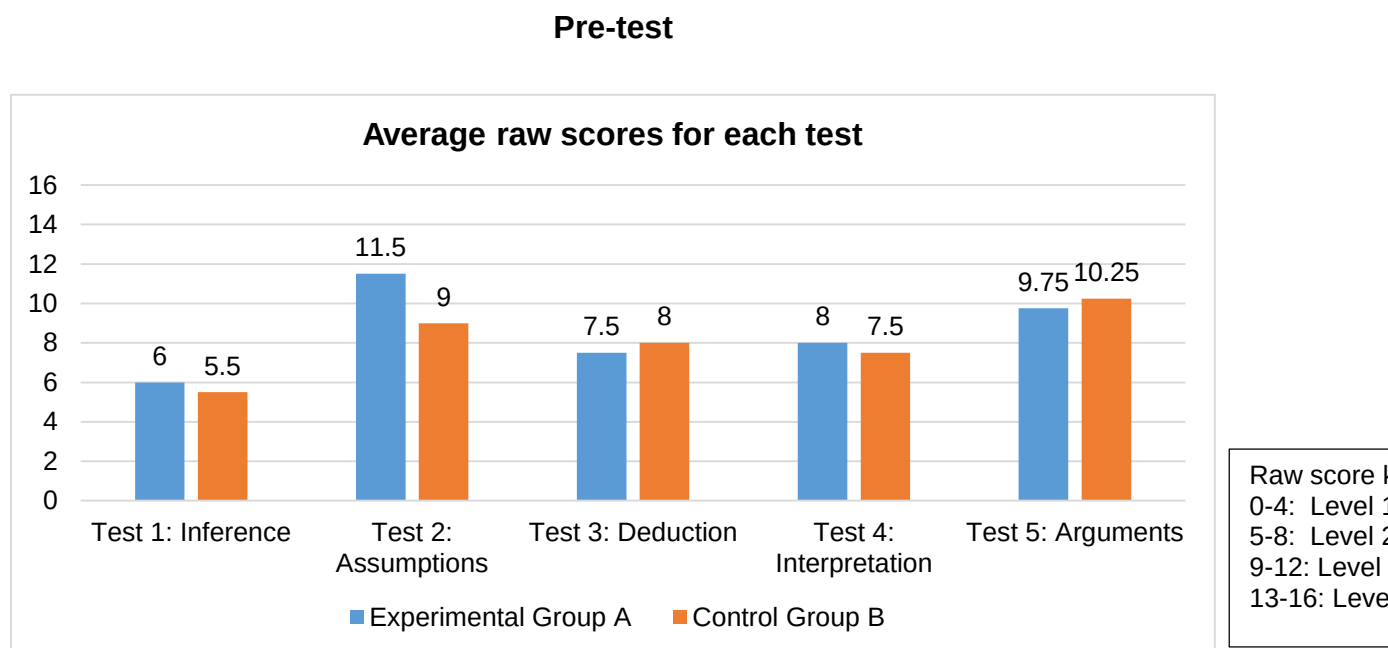
Significance: * $p < 0.05$

According to Table 6.9, no statistical significant differences occurred within the control group between the pre- and post-tests for any of the five skills on which the W-GCTA focused. Although higher means were obtained in the post-test in relation to making *inferences, recognising assumptions* as well as for the *test total*, the differences were not statistically significant, as $p > 0.05$ in all instances. It could be assumed that the normal academic programme to which the participants were exposed, possibly contributed to the improvement noted in the post-test results. These improvements were however not statistically significant.

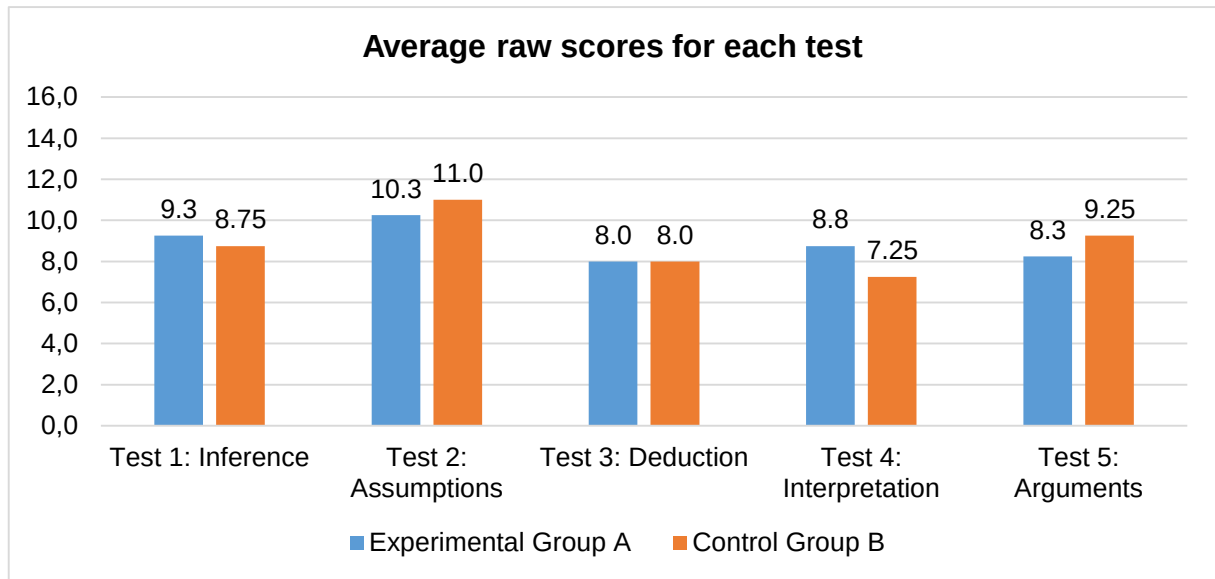
The following section pays attention to a comparison of the individual sub-test data obtained during the pre-test for the experimental and control groups.

6.5.3 Comparison: Sub-tests – Experimental and control group

The following graph, Graph 6.55, illustrates the comparison of the average scores for the pre-and post-test obtained for each of the critical thinking sub-tests between the experimental and control group.



Post-test



Graph 6.55: Comparison of the average sub-test data between experimental group and control group – pre-test and post-test

Table 6.10 compares the mean ranks between the different pre-tests of the experimental and control group to determine whether the differences noted between the two groups were statistically significant. A statistical significant difference occurs when $p < 0.05$.

Table 6.10: Comparison: Pre-test results - experimental and control group

Test	Group	N	Mean	Median	Mean rank	Sum of ranks	Mann-Whitney U	Z	Significance (p)	r	Effect
Inference (16)	Pre-test Experimental	4	6	6.5	5.00	20.00	6.000	-.599	0.549	-	-
	Pre-test Control	4	5.5	5.5	4.00	16.00					
Assumptions (16)	Pre-test Experimental	4	11.5	12.5	5.38	21.50	4.500	-1.042	0.297	-	-
	Pre-test Control	4	9	9.5	3.63	14.50					
Deduction (16)	Pre-test Experimental	4	7.5	8.5	4.38	17.50	7.500	-.155	0.877	-	-
	Pre-test Control	4	8	8.5	4.63	18.50					
Interpretation (16)	Pre-test Experimental	4	8	7.5	4.75	19.00	7.000	-.300	0.765	-	-
	Pre-test Control	4	7.5	7.5	4.25	17.00					
Arguments (16)	Pre-test Experimental	4	9.75	9.5	4.00	16.00	6.000	-.581	0.561	-	-
	Pre-test Control	4	10.25	9.5	5.00	20.00					
Test total (80)	Total Experimental	4	42.75	42	4.75	19.00	7.000	-.289	0.773	-	-
	Total Control	4	40.25	40	4.25	17.00					

Significance: * $p < 0.05$

Table 6.10 reveals no statistical significant differences, $p < 0.05$, between the pre-test results for experimental and control group in relation to the five sub-tests on which the W-GCTA focused. It could therefore be concluded that both groups were more or less similar in terms of the development of their critical thinking skills at the outset of the research.

Table 6.11 compares the mean ranks between the different post-tests of the experimental and control group to determine whether the differences noted between the two groups were statistically significant.

Table 6.11: Comparison: Post-test results - experimental and control group

Test	Groups	N	Mean	Median	Mean rank	Sum of ranks	Mann-Whitney U	Z	Significance (p)	<i>r</i>	Effect
Inference (16)	Post-test Experimental	4	9.3	9.5	4.63	18.50	7.500	-.155	.877	-	-
	Post-test Control	4	8.75	9.5	4.38	17.50					
Assumptions (16)	Post-test Experimental	4	10.3	10.5	3.88	15.50	5.500	-.749	.454	-	-
	Post-test Control	4	11.0	11	5.13	20.50					
Deduction (16)	Post-test Experimental	4	8.0	7.5	4.50	18.00	8.000	.000	1.000	-	-
	Post-test Control	4	8.0	8	4.50	18.00					
Interpretation (16)	Post-test Experimental	4	8.8	8.5	5.13	20.50	5.500	-.730	.465	-	-
	Post-test Control	4	7.25	7	3.88	15.50					
Arguments (16)	Post-test Experimental	4	8.3	7.5	3.88	15.50	5.500	-.735	.462	-	-
	Post-test Control	4	9.25	8.5	5.13	20.50					
Test total (80)	Total Experimental	4	44.7	43.5	5.13	20.50	5.500	-.726	.468	-	-
	Total Control	4	44.25	41.5	3.88	15.50					

Significance: * $p < 0.05$

Table 6.11 reveals that no statistical significant differences occurred between the post-test results for the experimental and control groups in relation to the five critical thinking skills on which the W-GCTA appraisal focused. In respect of all comparisons between the post-tests, it was noted that $p > 0.05$.

In the following section, the researcher analyses and interprets the data obtained for the interviews that were conducted with the participants of the experimental group.

6.6 DATA ANALYSIS AND INTERPRETATION: INTERVIEW DATA

Interviews were conducted with the four selected student participants at the end of the intervention, in order to understand their perspectives, experiences and thoughts about their involvement in the Portal video game. The interview data were used to support the quantitative data and qualitative data collected with the W-GCTA and the observations.

In this section, the main themes that were identified from the verbatim transcripts of the interview data will be highlighted. The discussion below is structured according to the questions in the interview protocol (*cf.* Appendix I).

In each of the following sections, direct quotations revealing the exact words of the participants are provided to support the themes that were extracted from the data. The row number as found in the verbatim transcripts (*cf.* Appendix J) is cross-referenced, to substantiate the interpretation made by the researcher, for example (*cf.* Appendix J 1.2), where 1 indicates the participant, and 2, the row number in the verbatim transcript.

The following section will look at the particular question that was asked to the interview participants, and the major themes that were identified (*cf.* Appendix J) will be discussed.

6.6.1 Question 1

Do you play video games frequently at home? / Have you ever played a puzzle video game before? What makes them enjoyable for you?

The participants were asked this question because the researcher assumed that experience, or rather the lack thereof with playing video games, could impact negatively

on the development of critical thinking that was envisaged while playing the puzzle video game. If the participants were struggling to play the game due to inexperience with video games, it could hamper their ability to actually play the game, or to understand its mechanics properly. The question relating to enjoyment was asked in order to gauge if the participants found playing games fun or not, because the researcher assumed that if the participants did not enjoy playing games the intention to develop their critical thinking skills might not be achieved through the use of a puzzle video game.

The following themes were identified from the responses to question 1.

6.6.1.1 Experience versus inexperience playing games

Three of the four participants had some experience playing video games, as seen in the responses of participant 1 who said “*Ja, I do a lot*” (cf. Appendix J 1.5), participant 3 who said “*Yes, sometimes*” (cf. Appendix J 3.5) and participant 4 who said “*Sometimes I do*” (cf. Appendix J 4.5). Participant 2 had never even played a video game before, as evidenced in the statement “*Honestly, no*” (cf. Appendix J 2.7).

All four of the participants had no experience playing puzzle video games. This is evident in their statements such as participant 1 who said “*No, I’ve never heard of such games before*” (cf. Appendix J 1.8), participant 2 who said “*It was my first time actually playing a game*” (cf. Appendix J 2.11), participant 3 who simply said “*No*” (cf. Appendix H 3.9) and participant 4 who stated “*No. It was my first time*” (cf. Appendix J 4.12).

The literature points out that video games require certain hardware, like controllers and monitors, in order to play them (Lowood, 2009) (cf. 3.5.3). Inexperience with such devices might lead to frustration on the part of the player, seeing as they need to learn how to play the game. The researcher was of the opinion that inexperience in playing puzzle video games would hamper participants’ performance in terms of developing skills to solve the puzzles themselves, and their needing more assistance from the researcher in terms of how to play the game, apply logic and tackle conceptual challenges. All four participants played puzzle video games for the first time, despite three of them having previous experience in playing video games in general. Participant 2 was regarded as an inexperienced game player. Despite this perceived setback, the post-test results of participant 2 showcased slight improvement in two critical thinking skills (cf. Table 6.2).

Participants 4 also managed to achieve growth in three critical thinking skills as well as in relation to the dispositions and standards for reasoning (cf. Table 6.4). This could possibly indicate that inexperience with playing video games might not necessarily have led to hampering the development of critical thinking in the context of the study.

6.6.1.2 Games are enjoyable, exciting, challenging, and test your mind

The four participants all agreed that playing video games are enjoyable and fun, as evidenced by the statements of participant 1, who stated *“I play games for fun and they relax me; you are always looking forward to doing more; I’m looking forward to this, I must crack it”* (cf. Appendix J 1.14 – 1.20). Participant 2 stated that she enjoys it *“too much”* (cf. Appendix J 2.15), whereas participant 3 said *“You have to understand what the game is about and you have to prove something; you have to achieve something”* (cf. Appendix J 3.12 - 3.15). Participant 4 also stated that *“It is so challenging; it makes you think harder”* (cf. Appendix J 4.16 – 4.17).

Video games help in relieving stress and relaxing players (Olson, 2010) (cf. 3.5.4), and can increase cognition and problem solving skills (Johnson & Schelsinger, 2007) (cf. 3.5.4). The responses of the participants confirmed the literature, and the researcher assumes that while playing the game Portal, the participants were having fun, enjoying themselves and were not bored. This could have impacted on the slight benefits in relation to growth that were achieved by taking part in the intervention programme. In particular, the growth observed among the participants in relation to the dispositions and standards for reasoning benefitted the most from their being involved in tangential learning (Armstrong, 2004) (cf. 3.2.3.8), as well as making inferences.

6.6.2 Question 2

Please describe in your own words what the puzzle video game Portal (which was played during the intervention programme) is all about.

The researcher wished to understand whether the participants comprehended that the game was about more than just fun and enjoyment.

The following themes were identified from the responses to question 2.

6.6.2.1 Cognitive stimulation

All four participants stated that the game Portal was about the stimulation of the mind and to reinforce thinking. This is evidenced in statements from participant 1 who said “*The game is all about developing how you think, your problem solving skills*” (cf. Appendix J 1.26 – 1.27), as well as participant 2 who said “*It helped you to think more; the game just needs you to think*” (cf. Appendix J 2.21 – 2.24). Participant 3 went on to say “*I was using my mind, thinking what I should do*” (cf. Appendix J 3.33 – 3.34), and participant 4 stated that the game is about “*Testing your intelligence, the level of your thinking*” (cf. Appendix J 4.23).

Literature states that the video game Portal consists of challenging puzzle elements (Mittell, 2012) (cf. 3.5.5) which require that the player must solve them utilising problem solving and critical thinking skills (Reynolds, 2011) (cf. 2.3.2). Therefore, the participants seemingly understood that the purpose of the game was ultimately to enhance their thinking skills, and give them the opportunity to practice and apply thinking skills.

6.6.2.2 Exploration and navigation

Of the four participants, three mentioned that the game was about exploration and navigation. Participant 1 mentioned: “*the different portals, the orange and blue one, the gun, boxes, this portal is for the exit*” (cf. Appendix J 1.36 – 1.41). Participant 2 spoke about “*looking for the exit; have to find the exit way*” (cf. Appendix J 2.29 – 2.32), while participant 3 stated that “*the aim of the game was to find the exit door; walk around and see what you can use to get to that exit door*” (cf. Appendix J 3.24 – 3.27).

Portal games are generally divided into a series of test chambers. Each chamber has an exit door that must be reached, often requiring that certain conditions have been met such as having weighed down a large button with a “*Weighted Cube*” (cf. 4.4.4), effectively (Larstuk, 2011). Solving the puzzling situations to reach an exit door requires the use of the Aperture Science Handheld Portal Device, the portal gun (cf. 4.4.2). The participants correctly identified the exploratory nature of the game, which is essential. Exploring and navigating actions are required to proceed in the game, in order to become more effective at developing critical thinking and problem solving skills.

6.6.2.3 Goal driven activities

Of the four participants, two noted that the Portal game was about being goal driven during the completion of the activities. Participant 2 stated that *“it was some kind of challenge in life; you have to find the exit way, the way out of that situation”* (cf. Appendix J 2.29 – 2.33), while participant 3 mentioned *“You must know what you want to achieve. You must know your goal”* (cf. Appendix J 3.20 – 3.21).

Literature points out that The GROW model assists with goal setting and problem solving (Gorell, 2013). The GROW model was utilised during the intervention programme as a means to structure or plan the problem solving situations in Portal, and to support the development of systematic working ways, persistence and accuracy as dispositions, as well as ensuring that reasoning complies with logic, relevance and clarity. The first letter in the GROW acronym means *“goal”*, and it was required that all participants first had to recognise what goal they needed to achieve during each of the intervention sessions.

Participant 3 however, seemingly did not benefit from the goal-driven nature of the game, as none of the five skills tested in the W-GCTA showed improvement (cf. Table 6.3). Participant 2 possibly benefitted from the goal driven nature of the game, with two of the five skills showing improvement, namely making inferences, and recognising assumptions. Furthermore, participant 2 showed improvement in terms of total raw score for the post-test as well (cf. 6.5.1, Graph 6.49).

6.6.3 Question 3

**How would you describe your experience playing the puzzle video game Portal?
What were you expected to do in the game?**

This question was asked specifically to probe the participants on how they felt about the intervention programme.

The following themes were identified for question 3.

6.6.3.1 Positive, enjoyable experience

Of the four participants, three noted how positive and enjoyable the experience was for them, with participant 1 noting that “*I enjoyed doing it*” (cf. Appendix J 1.45), while participant 2 stated “*Yes, it was really a positive experience; this one helped me too much; the game is just interesting*” (cf. Appendix J 2.49 – 2.57). Participant 3 said that the experience was “*positive*” (cf. Appendix J 3.43).

According to the literature, student motivation is viewed as a necessary precondition for the development of critical thinking skills and abilities (Fahim & Hajimaghsoodi, 2014) (cf. 2.8.2). Similarly, Halonen (1995) (cf. 2.8.2) notes that a person’s propensity, or disposition, to demonstrate higher-order thinking relates to their motivation (Fahim & Hajimaghsoodi, 2014) (cf. 2.8.2). Therefore, seeing as most of the participants stated that they had positive and enjoyable experiences, it could mean that they were motivated to play the game, which could have led to a positive atmosphere in which critical thinking could be nurtured (Greene & Yu, 2015; Mahapoonyanont, 2012; Stoddar, 2010) (cf. 2.8.1.1). The data however reveal that of the 4 participants involved in the intervention programme, not one of the participants managed to demonstrate growth in relation to all the critical thinking skills on which the research focussed. Even though all four enjoyed the experience, it ultimately had no significant bearing on the outcomes achieved in terms of developing all the critical thinking skills on which the research focused (cf. 6.5.1, Table 6.5). Nevertheless, the dispositions and standards for reasoning of all the participants, except participant 2, may have benefitted from the experience. Although the inexperience of participant 2 in playing games possibly did not have a very negative influence on the development of the critical thinking skills (cf. 6.6.1.1), the lack of experience might have had a stronger influence on the lack of growth noted for the dispositions and standards for reasoning during the game play.

6.6.3.2 Developmental, exploratory, and thoughtful experience

Three of the four participants described their experience playing Portal as a developmental, exploratory and thoughtful experience. Participant 1 particularly emphasised the developmental nature of the game by stating “*It developed me. It developed me really really good*” (cf. Appendix J 1.51 – 1.52). He continued to say that

his development depended on routine pressure being placed on him, by saying “*whenever it’s Monday, that thing would come into my mind, you know what I have to go do this, that pressure on me*” (cf. Appendix J 1.46 – 1.49). This observation by the participant, could possibly be linked with persistence as thinking disposition that was nurtured during the intervention. The routine pressure might have allowed him to overcome the obstacles presented in the game by constantly trying to solve problems. It is noteworthy to mention, that participant 1 developed from able to sophisticated level in the application of persistence (cf. Table 6.1).

Participant 3 outlined the exploratory nature of the game, with statements like “*You have to discover something, look everywhere what can I find to use*” (cf. Appendix J 3.37 – 3.39). Participant 3 also mentioned the thoughtful experiences she had while playing, by saying “*I was using my mind, thinking what I should do*” (cf. Appendix J 3.33 – 3.34), while participant 4 highlighted other thoughtful experiences, saying: “*I was facing some challenges so that I had to think on my own, overcome challenges I face; overcoming obstacles*” (cf. Appendix J 4.27 – 4.33). The viewpoint of participant 3, could also be linked to the critical thinking dispositions and standards for reasoning, most notably that of persistence and logic. The participant acknowledge having to overcome challenges, which could directly be linked with persistence. She continued by stating that she used her mind, thinking what she needs to do, and looking for things she can use to solve the puzzles, possibly pointing to the use of logic as well. Interestingly, persistence and logic developed from novice to skilled level for participant 3 (cf. Table 6.3).

Browne and Freeman (2000) (cf. 3.4.1.3) state that creating developmental tension can be facilitated through controversy, which increases the likelihood that evaluative thinking will take place (Browne & Freeman, 2000) (cf. 3.4.1.3). Controversy creates a state of discomfort, which aligns with what participant 1 stated about the pressure being placed on him. Linked to the aforementioned, participant 4 mentioned overcoming challenges, which could lead to discomfort. In particular, participant 4 seemed to have benefitted from the challenging game context, as three of the critical thinking skills on which the study focussed improved, as well as all the dispositions and standards for reasoning.

6.6.4 Question 4

What did you like/not like about the Portal puzzle video game?

This question was asked to gauge the experiences of participants, to look at specifically what frustrated them or what they found appealing about the Portal game, and by extension, the intervention programme.

The following themes were identified for question 4.

6.6.4.1 Enjoyment in general

Two of the four participants noted that they liked everything about the game and that it was enjoyable for them to play it. This is evident in participant 1's statements "*I liked everything about the game; everything they were perfect*" (cf. Appendix J 1.56 – 1.62), as well as participant 2 who said "*I liked everything about the game*" (cf. Appendix J 2.62).

Video games are meant to entertain and be enjoyable, as they are marketed and sold to adolescents so that they may play them and enjoy them (All *et al.*, 2016; Miller, 2005) (cf. 3.5.3). In the context of the study, it was hoped that if participants are enjoying what they are doing tangentially, it could possibly be argued that conditions would be established for them to acquire critical thinking more effectively (Armstrong, 2004) (cf. 3.2.3.8). Based on the post-test findings, all the participants, except participant 3, seemed to improve in making inferences. Participant 2 also improved in recognising assumptions (cf. Graph 6.2), and participant 4 also managed to improve in making deductions and evaluating arguments (cf. Graph 6.40, 6.42). Overall, participant 2 and 4 improved their total test scores as well (cf. Graph 6.49). These results could possibly indicate that the enjoyment of the game could hold merits for improving critical thinking.

6.6.4.2 Focus and attention enhanced

One participant noted that focus and attention were enhanced while playing the game and that this simplified the problem solving experience. This participant indicated: "*If you are not focusing on the game, thinking of something else, it would become difficult; but the minute you put your mind to it then it becomes easier and you can crack them all*" (cf. Appendix J 1.66 – 1.70).

Critical thinking comprises of relevant critical thinking dispositions or habits of mind (Costa & Kallick, 2005) (cf. 2.3.3). One of these habits of mind is thinking about thinking, otherwise known as metacognition or reflection (Paul, 1990). In the case of participant 1, his ability to focus and pay more attention on the task at hand could imply that he was reflecting more on his actions, and that reflecting seemingly helped in being more effective at solving problems. This observation supports the literature, where it is revealed that attentional capacity is enhanced by the use of games during learning (All *et al.*, 2016; Bavelier *et al.*, 2018; Granic *et al.*, 2014) (cf. 1.1).

6.6.4.3 Cognitive improvement

Participant 4 noted that he enjoyed the fact that the game improved his cognition, which is evident in the statement “*What I like about the game is that it taught me to think harder and boost my intelligence*” (cf. Appendix J 4.39 – 4.40). None of the other participants noted this facet as a likeable characteristic of the game. However, all participants did indicate that cognitive improvement was the main purpose of the game, as was seen in 6.6.2.1. Therefore, it is assumed that while the participants were aware of the cognitive element of the game, it is possible that not all of them liked the cognitive element, but just enjoyed playing the game (cf. 6.6.4.1).

The observation of participant 4 aligns with the view of Feuerstein *et al.* (2010) (cf. 3.2.3.6) on structural cognitive modifiability, which views the human organism as open, adaptive and amenable for change (Feuerstein, 1997; Tzuriel, 2001; Benjamin, 2005). Given the improvement noted in post-test results, as well as the growth noted in the application of the dispositions and standards for reasoning, it is assumed that the intervention programme would have played a role in developing the thinking skills, dispositions and standards for reasoning in diverse ways.

6.6.4.4 Difficulty and lack of time pose challenges

Although participant 4 achieved the most growth in relation to the critical thinking skills, he stated that he found the game frustratingly difficult at times and it put him off from playing. He mentioned: “*It was so challenging that it frustrated me*” (cf. Appendix J 4.41). However, the other three participants clearly indicated that the game, despite it being difficult and challenging, was still playable. This is evident in the words of participant 1:

“No nothing was too difficult, it’s just a matter of how you were thinking” (cf. Appendix J 1.65 – 1.66), as well as participant 2 who said *“Immediately when you start to play the game, you will think that it’s difficult, but once time goes by, you can see that the game just needs you to think”* (cf. Appendix J 2.21 – 2.24). Participant 3 felt the same way when asked if things in the game were too difficult, she responded by saying *“No, I don’t think so”* (cf. Appendix J 3.53).

Literature states that when mediating, the mediator (in this case the researcher) ought to mediate challenge, meaning that participants should be challenged with novel and complex experiences (Falik, 2001; Feuerstein & Feuerstein, 1991; Feuerstein *et al.*, 2010) (cf. 3.2.3.7). It is important though that the learning activities through which the challenge is provided should be structured in such a way that those involved in learning also receive the support and opportunities to develop the skills for succeeding. Therefore, the researcher played the role of a mediator, who provided support to the participants. If this does not happen, the challenge will defeat the notion of mediating feelings of competence. The Portal game is designed to get more difficult and challenging as the game progresses, which the participants noted. The fact that the participants were challenged means that the correct developmental tension was evident, allowing for the mediation of competence during the gameplay, with the support of the researcher.

Another issue regarded as a negative factor while playing the game was the statement made by participant 1, who stated *“It was too short; the thing was that the time was limited. There was not enough for us to play and I felt like you know, I could crack it”* (cf. Appendix J 1.57 – 1.60). None of the other 3 participants mentioned time as a challenging factor. The intervention was implemented for 13 weeks, and all 4 participants in the experimental group received the intervention programme once a week for two hours (cf. 4.2.3.3). The researcher assumes that more time to play the game, and to develop and apply the skills, dispositions and standards for reasoning on which the research focused, might have contributed to greater growth, transfer and retention levels (Arthur *et al.*, 1998; Farr, 1987 (cf. 3.2.3.9). Increased practice and repetition may also contribute to enhancing the correctness of the application of the skills, dispositions and standards for reasoning.

6.6.5 Question 5

Did playing this game benefit you in any way? How?

With this question, the researcher wished to gauge the value that the participants attached to the intervention programme.

The following themes were identified for question 5.

6.6.5.1 Cognitive benefits of Portal

Two of the four participants, participant 2 and 3, mentioned that the game benefitted them in terms of cognitive development, which is precisely what the purpose of the intervention programme was aiming to achieve. This is evident in statements from participant 2, who said *“This one helped me too much. This game is just interesting. It wants you to just think”* (cf. Appendix J 2.54 – 2.58). Participant 3 responded to the question whether the game benefitted her or not by saying *“Yes [it did]”*, explaining why, she said *“I need to think more when I am doing something”* (cf. Appendix J 3.61 – 3.65).

Literature reveals that higher order thinking is essential for working in a virtual interactive environment (VIE) presented by puzzle video games (Rice, 2007), such as Portal (cf. 3.5.5). Gee (2003a) (cf. 3.5.5) therefore argued that cognitive competence and expertise, could be enhanced by playing puzzle video games. When comparing the pre- and post-test results, it is clear that only 2 of the 4 participants (participant 2 and 4), scored higher in the post-test in relation to the development of the critical thinking skills (cf. Graph 6.49). More growth was observed among all the participants in relation to the development of the critical thinking dispositions and the standards for reasoning (cf. Table 6.6), for which the intervention programme appears to hold greater benefits.

6.6.5.2 Goal planning benefits

One participant, participant 3, pointed out that the game Portal enhanced her goal planning, evident by the statement *“You have to know what do I want to achieve in this game, and how I will do that”* (cf. Appendix J 3.66 – 3.67).

The GROW problem solving model (Table 1.1) is a simple method for goal setting and problem solving (Gorell, 2013), which was utilised within the intervention programme during each lesson, as a means to structure or plan the problem solving situations. The “G” in GROW stands for goal, which is defined as the end point, where the students want to be. The goal has to be defined in such a way that it is very clear to the students when they have achieved it (Gorell, 2013). Although only participant 3 mentioned the benefit of goal planning, all the participants demonstrated growth in working systematically (*cf.* Tables 6.1 – 6.4). The researcher therefore deduces that playing the video game Portal with the use of the GROW model, probably aided the development of goal planning, and indirectly to working more systematically to achieve the set goals.

6.6.5.3 Independent thinking benefits

Two participants, participant 1 and 4, mentioned that the video game Portal developed their ability to think independently, which is evident in the following statement: “*That you have to teach yourself how to think on your own, in some situations*” (*cf.* Appendix J 4.47 – 4.48). Participant 1 when asked if the game benefitted him in his everyday life in terms of independent thinking, he responded with “*Ja [yes], definitely*” (*cf.* Appendix J 1.99).

Literature states that learning is not a passive process where a student assimilates transmitted knowledge (Powell & Kalina, 2009) (*cf.* 2.8.1.3). Learning is rather a dynamic process where students actively discover new information and solve problems independently by applying higher order thinking skills to increase the development of individual student initiative, self-reliance and self-improvement (Borich, 2003; Ognibene, 2007; Philpott, 2009) (*cf.* 3.3.3). The data revealed diverse growth for participant 1 and 4 pertaining to the critical thinking skills, as well as all the dispositions and standards for reasoning (*cf.* Table 6.1, Table 6.4). Comparisons of the total pre- and post-test results also indicated that participant 4 improved his pre-test score (*cf.* Graph 6.49). It would appear that taking initiative that was encouraged during the Portal game play, and noted by participants 1 and 4, possibly contributed to enhancing the development of some of the elements of critical thinking.

6.6.6 Question 6

How did solving the puzzles in the game make you feel?

This question aimed to gauge the emotions and feelings that the Portal game elicited among the participants.

The following theme was identified for question 6.

6.6.6.1 Solving puzzles lead to excitement, happiness and accomplishment

All four participants noted that they felt excited and happy when solving the puzzles in the game. This is supported by participant 1 who said, “*It made me feel like I’ve achieved something*”, and “*It was so exciting; I can’t wait to see the next one*” (cf. Appendix J 1.77 – 1.82), participant 2 who stated “*It made me feel happy*” (cf. Appendix J 2.71), participant 3 who said “*I felt excited; I felt happy because I’m going to another step*” (cf. Appendix J 3.47 – 3.48), and participant 4 who said “*I had to think on my own, to overcome the challenges I face*” (cf. Appendix J 4.28 – 4.29).

Literature states that tangential learning is the process by which people self-educate if a topic is exposed to them in a context that they already enjoy (Armstrong, 2004) (cf. 3.2.3.8). Therefore, the researcher argued that if the participants will feel excited or happy while playing, the chances might be good that they will acquire the necessary critical thinking skills, dispositions and standards for reasoning effectively. As most of the participants indicated their excitement and happiness, the conditions seemed to be favourable for this outcome. The findings obtained for participants 1 and 3 however do not support the literature, as a decay in the application of critical thinking skills was noted when comparing the total pre- and post-test results (cf. Graph 6.49). Their post-test results were lower than their pre-test scores. Participant 2 and 4 scored higher in their post-tests (cf. Graph 6.49), implying that the exciting element of the game play maybe allowed them to tangentially learn the critical thinking skills for which improvement were noted.

Three of the four participants also commented on the sense of accomplishment felt when completing the puzzles. Participant 1 said: “*It made me feel like I’ve achieved something big*” (cf. Appendix J 1.77 – 1.78), and participant 2 stated: “*It seems like I made it, because*

that's what I wanted" (cf. Appendix J 2.71 – 2.72). Participant 3 went on to say: *"I have achieved my goal"* (cf. Appendix J 3.49).

In the literature, accomplishment is directly related to achieving goals (Gorell, 2013) (cf. 3.3.5), which was a crucial part of the intervention programme, seeing that all the participants had to make use of the GROW problem solving model (Gorell, 2013) (cf. 3.3.5), a strategy that assisted them to systematically work towards achieving goals. Feelings of accomplishment could also have increased the participants' levels of motivation to continue and to persist in completing the puzzles (Wouters & Van Oostendorp, 2017) (cf. 3.5.4), that contributed to the growth observed in the application of some of the skills, dispositions and standards for reasoning (cf. Tables 6.1 - 6.4).

6.6.7 Question 7

Do you think that your critical thinking or problem solving skills were enhanced while playing the game? Explain.

With this question, the researcher wished to gauge the participants' opinion regarding the role of the intervention programme and whether it could develop critical thinking and problem solving skills. Afterwards, the researcher realised that this question should actually be excluded, as the participants were not informed about the exact elements of critical thinking on which the intervention focused, and what they entail. Nevertheless, the responses yielded interesting and meaningful information to the researcher.

The following themes were identified for question 7.

6.6.7.1 Attention and focus enhanced

Two of the four participants noted that playing the video game Portal enhanced their focus and attention on completing tasks (cf. 6.6.4.2). Participant 1 mentioned: *"Every time I have something, my focus and attention, it has been expanded or something; I am now able to focus more"* (cf. Appendix J 1.89 – 1.92). Participant 2 also mentioned aspects involving focus and attention, but also noted that formal classrooms tend to be tedious and repetitive: *"It's because games just need you to concentrate all the time; the lecturer will be teaching and teaching and teaching, sometimes you just lose focus all of a sudden"* (cf. Appendix J 2.85 – 2.89).

An important intellectual trait on which the study focused, was systematic working ways, promoted through the use of the GROW model. Given the participants' responses, their ability to focus and pay more attention on the task at hand were probably enhanced by playing the puzzle video game (All *et al.*, 2016; Bavelier *et al.*, 2018; Green & Bavelier, 2012; Uttal *et al.*, 2013) (*cf.* 3.5.4). Greater focus and attention could have contributed to their reflecting more on their actions, which possibly contributed to managing impulsive working ways. This finding could be linked with the observation data for participant 1, in terms of growth noted in relation to working systematically. The game play of participant 2 did not testify to any growth regarding the dispositions and standards for reasoning.

Furthermore, the researcher argues that growth in systematic working ways, could possibly lead to work that displays greater accuracy, relevancy, logic and clarity. In this regard, the results obtained for participant 1 revealed that systematic working ways, accuracy, relevancy, logic and clarity demonstrated growth over the 13-week intervention period (*cf.* Graphs 6.7, 6.9, 6.10 -6.12).

6.6.7.2 Task involvement

One participant mentioned that his involvement in the task increased, as evident in the statement *"I look forward to spending more time on something"* (*cf.* Appendix J 1.92 – 1.93). According to the observation of the participant, involvement in the activities was important and nothing else seemed to matter. The participant seemingly found the game enjoyable and would probably spend time on solving the problems for the sheer sake of doing it.

6.6.7.3 Improved understanding of game expectations

Participant 3 noted that critical thinking in general was enhanced and did not specify which aspects of critical thinking were enhanced. This is evident in the statement *"Yeah, they improved, because first time I was playing I was not understanding what I was doing, but as time goes on I developed critical thinking and knowing what I must do"* (*cf.* Appendix J 3.73 – 3.76).

The researcher envisaged to develop elements of critical thinking in the context of the study, through the game Portal, where the participants had to solve a series of related

puzzles that were a variation on a single theme. Solving the puzzles involved pattern recognition, logic, or understanding a process (Miller, 2005) (cf. 3.5.4). In relation to the research findings, it is evident that participant 3 seemingly did not benefit from participating in the intervention programme as her post-test results for all the critical thinking skills were lower than her pre-test results (cf. Graph 6.49), possibly indicating that she did not develop critical thinking skills while playing the game, despite her improved understanding of the game's expectations. However, the application of all the dispositions and standards for reasoning seemingly benefitted, as growth was demonstrated during the observations (cf. Table 6.3).

6.6.7.4 Puzzle games enhance thinking skills

Participant 4 discussed in depth issues surrounding video games not being able to develop critical thinking, and that only puzzle video games like Portal could do that. When asked if he believes that thinking and problem solving can be enhanced while playing a video game, he responded with “No” (cf. Appendix J 4.59). The researcher then followed up by asking whether only games like Portal, and puzzle games, could develop those skills, participant 4 responded by saying “Yes” (cf. Appendix J 4.62). Further probing by the researcher entailed asking what benefits non-puzzle video games have for people, to which participant 4 replied “*The other games are just for entertainment, because we play mostly soccer*” (cf. Appendix J 4.65 – 4.66).

Although the participants were not enlightened about what the skills, dispositions and standards for reasoning entailed at the outset of the study, participant 4 correctly recognised the greater level of challenge involved in playing puzzle video games. Puzzle games focus on logical and conceptual challenges, and often add time-pressure or other action-elements (Rollings & Adams, 2006) (cf. 3.5.4). From the observation findings participant 4 demonstrated growth in three of the critical thinking skills, and all the dispositions and standards for reasoning (cf. Graph 6.26 – 6.36). The improved post-test results, as well as the growth noted in relation to the dispositions and standards for reasoning, possibly confirm that the puzzle video game intervention programme holds merits for developing the processes involved in critical thinking.

6.6.8 Question 8

Do you believe that playing puzzle video games can help you acquire certain knowledge or skills more effectively than in a formal classroom setting? Motivate.

The researcher wished to gauge the participants' beliefs about the merits of video games to help individuals acquire certain knowledge or skills more effectively than in a formal classroom setting.

6.6.8.1 Games motivate learning through fun

Participant 3, when asked if fun has anything to do with learning better in a video game, responded with "Yes" (*cf.* Appendix J 3.86), and a follow up question in which she was asked if one is motivated to learn more when something is fun, she again responded with "Yes" (*cf.* Appendix J 3.90). Participant 4 was also asked whether games make learning fun, and he responded by saying "Yes" (*cf.* Appendix J 4.82).

Video games are meant to entertain and be enjoyable, as they are marketed and sold to adolescents so that they may play them and enjoy them (Miller, 2005) (*cf.* 3.6.3). The researcher postulated that if participants are enjoying what they are doing, they might acquire critical thinking more effectively (Armstrong, 2004) (*cf.* 3.2.3.8). Findings however revealed that the four participants who took part in the intervention programme, benefitted differentially in relation to the development of their critical thinking skills (*cf.* Tables 6.1 – 6.4), and that the fun element seemingly did not have the same impact on all of the participants. Noteworthy, is that the observations of the dispositions and standards for reasoning showcased more growth, when compared to the observations of the skills. The latter observation might mean that the dispositions and standards for reasoning possibly benefitted more from the fun element of the game (Granic *et al.*, 2014) (*cf.* 3.5.4).

6.6.8.2 Engaging and experiential nature of games leads to better learning

Three of the four participants mentioned that video games are far more engaging and allow one to experience more and learn better learning when compared to a formal classroom. Participant 1 stated that games engage your senses: *"I think the gaming one is more effective, because it covers all senses. You can see visuals; you can hear something. So it's more effective than just sitting in class, you will just be there"* (*cf.*

Appendix J 1.104 – 1.108). Participant 3 noted that with video games *“It involves your experience”* (cf. Appendix J 3.83). Participant 4 stated: *“I think I can learn better from playing games, because in games you will be focusing and listening so that you can think for yourself”* (cf. Appendix J 4.75 – 4.77).

Experiential learning is the process of learning through experience, and is more specifically defined as *“learning through reflection on doing”* (Breunig, 2009; Svingby & Nilsson, 2011) (cf. 3.2.3.5). Experiential learning is distinct from rote or didactic learning, in which the student plays a comparatively passive role. Experiential learning concentrates on the learning process for the individual and contributes significantly to the student’s overall understanding of the real-time environment through active involvement in concrete experiences (Kolb, 2014; McCarthy & McCarthy, 2006) (cf. 3.2.3.5). The researcher concludes, that through the experiential nature of the game Portal, participants were expected to reflect on what they were thinking, thus giving hands-on type of feedback in relation to the task at hand. The data obtained, revealed that all the participants showed growth in terms of reflecting about their thoughts and actions with logic, clarity and relevancy (cf. Tables 6.1 – 6.4), possibly supporting the benefits of reflecting on learning.

6.6.8.3 Formal classes are tedious and repetitive, leading to a loss of concentration

Two participants explicitly mentioned that formal classes tend to be tedious and repetitive, in which concentration can be lost. Participant 2 mentioned that *“if ever in class, the lecturer will be teaching and teaching and teaching* (implying repetition), *sometimes you just lose focus all of a sudden”* (cf. Appendix J 2.87 – 2.89). Participant 4 stated that *“sometimes in a classroom you get bored and then you lose concentration”* (cf. Appendix J 4.78 – 4.79).

According to Watson (2015), education systems are faced with a dual challenge. Classroom atmospheres often testify to silence, and students lack the confidence to question information. In order to create optimal conditions for the development of critical thinking, the researcher reduced teacher authority during the implementation of the intervention to allow for more active and independent learning (Green & Yu, 2015;

Mahapoonyanont, 2012; Stoddar, 2010) (*cf.* 2.8.1.1). From the findings, it is interesting to note that the two participants who noted that formal classroom environments could lead to deficient critical thinking were the 2 participants that actually improved on their total post-test scores, implying some critical thinking development (*cf.* Graph 6.49). This could imply, that the two participants may have benefitted from the intervention programme that aimed to develop critical thinking in a more informal (Coombs *et al.*, 1973; Rogers, 2014; UNESCO, 2012) (*cf.* 3.5.2), experiential learning environment (*cf.* 3.2.3.5).

The next section provides a visual summary of the themes extracted from the interview data.

6.6.9 Visual representation of the interview data

In order to create a visual understanding of how the various themes extracted from the data relate to one another, the researcher provides the following visual representation in Figure 6.1.

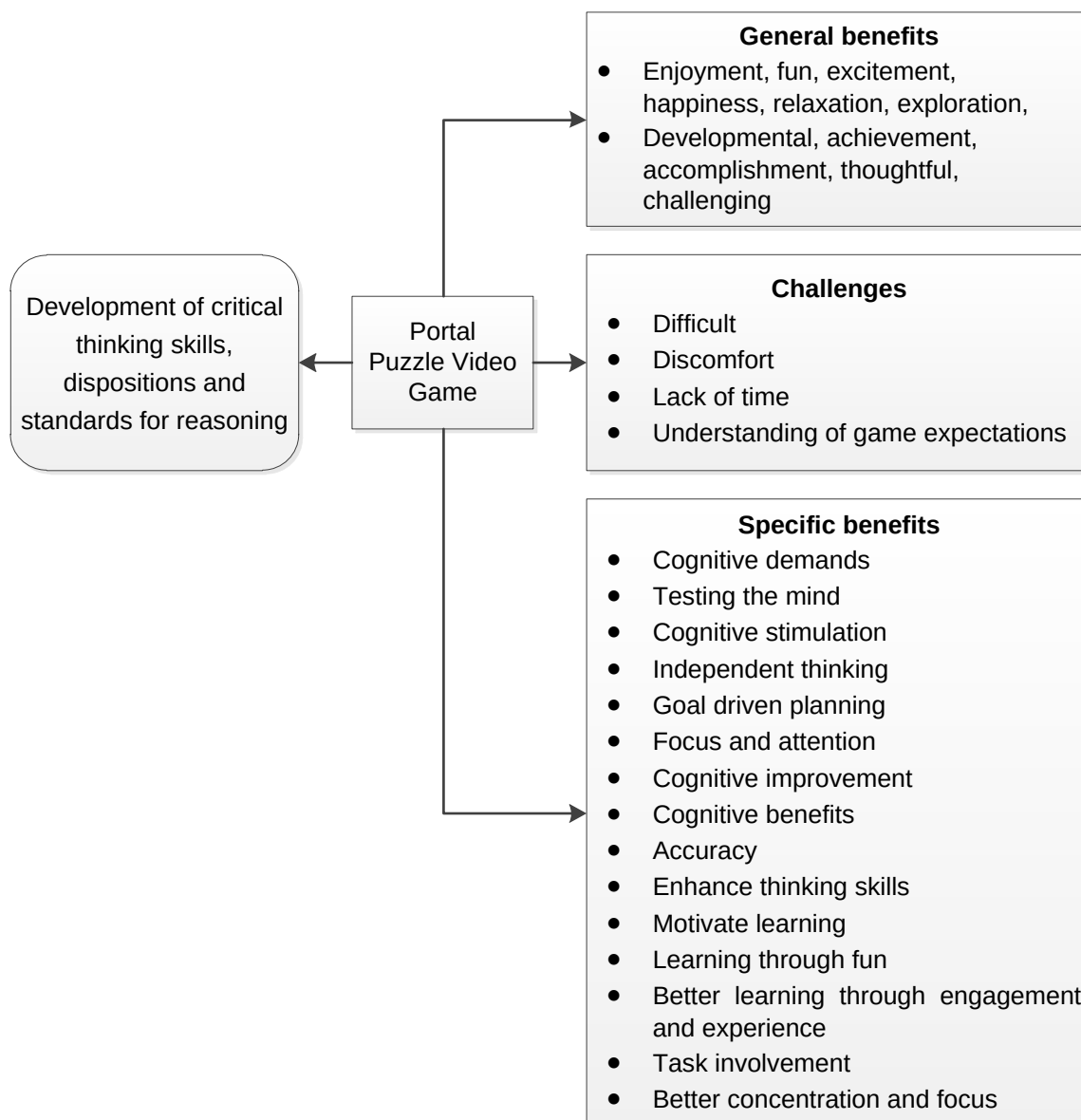


Figure 6.1: Visual representation of interview data

The above figure highlights the findings that emanated from the interviews. Using the Portal puzzle video game during the intervention to enhance the growth of critical thinking skills, dispositions and universal standards for reasoning, revealed general benefits, specific benefits, as well as challenges. The general benefits included aspects of enjoyment, fun, excitement and happiness, as well as developmental achievement, challenge, and accomplishment. In addition, the specific benefits included a number of **cognitive benefits** that were mentioned (cognitive demands, testing the mind, cognitive stimulation, enhancing thinking skills, cognitive improvement, independent thinking, goal driven planning, accuracy, attention, and improved concentration). The aforementioned

benefits support what transpired from the literature review, where the promotion of cognitive learning is highlighted as a positive effect of using games during teaching and learning (All *et al.*, 2016; Granic *et al.*, 2014; Green & Bavelier, 2012; Wouters & Van Oostendorp, 2017) (*cf.* 3.5.3.4). In addition, **emotional benefits**, such as motivation to learn, task involvement, engagement, and experiencing fun, also transpired from the responses of the participants, supporting the viewpoints of Granic *et al.* (2014), Wouters and Van Oostendorp (2017) (*cf.* 3.5.3.4), who highlight the positive emotional effects from including games during teaching and learning. A few **challenges** included game difficulty, discomfort playing the game, and lack of time and understanding game expectations, which were not specifically supported by the literature review.

The following section integrates all the data collected in this study in order to make final interpretations, and to gain further insight into the data.

6.7 INTEGRATION AND INTERPRETATION OF DATA

Combining and integrating the different data sets would enable the researcher to provide a comprehensive understanding of the development of critical thinking in the context of the study.

As the focus of the study involved four individual case studies, an integrated analysis is presented for each participant.

The **quantitative** test data addressed the outcomes expected from involvement in a puzzle video game intervention in relation to the development of the critical thinking skills on which the study focused, while the combined **quantitative** and **qualitative** observation data explored the growth in relation to the application of the critical thinking skills, dispositions and standards for reasoning demonstrated by the participants during the intervention. In addition, **qualitative** interview data collected after the intervention gauged the participants' experiences about their involvement in a puzzle video game. The researcher used the mixing of different sources of data to integrate the information and compare data sources with one another in order to present a composite assessment of what transpired during the research (Creswell, 2009).

6.7.1 Participant 1

According to the W-GCTA test results, Table 6.1 revealed that participant 1 started the study with two critical thinking skills seemingly developed at practicing level, namely recognition of assumptions and making deductions. Over the course of the intervention the skill for making deductions decayed to beginning level, and the skill to identify assumptions, stagnated at practicing level. The development of one skill, namely making inferences, started at beginning level and ended at practicing level, which indicate possible growth taking place during the intervention. Two of the critical thinking skills, namely doing interpretations and evaluating arguments, apparently remained at the developmental levels with which the participant entered the study, namely practicing and advanced/master level, respectively.

Given the aforementioned, the researcher concludes that the intervention probably contributed the most to the development of the skill to make inferences, and that making deductions, benefitted the least, given the decay in development observed during the post-test. Three of the skills, namely recognising assumptions, doing interpretations and evaluating arguments, seemingly did not develop further at all during the intervention, but their application also did not appear to decay. Evaluating arguments seemed to have been well-developed at the outset of the study (*cf.* Table 6.1).

The observations, supported by the anecdotal records, contradicted the post-test results of participant 1. The observations revealed growth for all the skills (*cf.* Graphs 6.2 – 6.6, Table 6.1), however the post-test results only revealed growth for making inferences. This could be due to the fact that growth was evident only during the game play of the video game Portal, and that the skills were not internalised successfully, and their application not transferred to the W-GCTA test context. A noteworthy finding emanating from the observations would be that all dispositions and standards for reasoning started at novice or able level (*cf.* Graphs 6.7 - 6.12, Table 6.1), and improved to sophisticated level, providing evidence that the intervention was apparently more successful in terms of developing the dispositions and standards for reasoning of this participant.

The interview data revealed that participant 1 had some experience playing video games, but no experience playing puzzle games (*cf.* 6.6.1). In addition, he mentioned that his

experience with the intervention programme was enjoyable, and that the routine pressure of the complex puzzles helped him with developing skills for problem solving (*cf.* 6.6.2). The game was enjoyed by participant 1 (*cf.* 6.6.3) and he found it to be not too difficult (*cf.* 6.6.4). He continued by stating that the game Portal benefitted his academic work (*cf.* 6.6.5), felt that his attention and focus were enhanced (*cf.* 6.6.4) and that his task completing benefitted as he did not rush things off (*cf.* 6.6.7). He expressed feeling a sense of encouragement and accomplishment during the game play (*cf.* 6.6.6). Participant 1 found that games are more engaging than formal teaching, and indicated that the use of games can teach content more effectively than in a formal classroom (*cf.* 6.6.8).

Participant 1 experienced the puzzle game play as positive and acknowledged the contribution of the game play for developing problem solving skills, which include critical thinking. It is possible that the positive experience of the participant with the puzzle video game contributed to the growth that was observed for making inferences and the application of the dispositions and standards for reasoning. The participant's experiences of enhanced attention, focus and taking more care not to rush things off, could testify in particular to the improved application of the dispositions to work systematically with accuracy and persistence.

Despite this discrepancy noted between the post-test results and the observations, participant 1 felt that the intervention programme benefitted him. The researcher argues, that if the intervention probably included more time to practice and apply the skills on which the research focused, the application of the skills during the game might have shown greater growth, and might have been retained better.

6.7.2 Participant 2

Participant 2 started the study with low scores for all five skills, which could be considered beginning thinker levels of performance. Only two of the skills showed growth in the post-test to practicing levels of thinking, namely making inferences and recognising assumptions. The skills to make deductions, do interpretations and evaluate arguments, stagnated at beginning levels of thinking during the post-test (*cf.* Graph 6.13, Table 6.2).

The growth observed for making inferences and identifying assumptions during the post-test, was not supported by the observations. Furthermore, the lack of growth reported by the post-tests for making deductions, doing interpretations and evaluating arguments, was supported by the observations that also did not testify to growth for any of the critical thinking skills (*cf.* Graph 6.14 – 6.18, Table 6.2). The observations revealed no growth for the dispositions and standards for reasoning (*cf.* Graph 6.19 – 6.24, Table 6.2). A noteworthy observation is the fact that the application of none of the critical thinking skills, showed any decay.

The interview data revealed that participant 2 had no experience whatsoever playing video games, let alone puzzle games (*cf.* 6.6.1). She continued by stating that she had the intervention provided cognitive stimulation (*cf.* 6.6.2), that she had a positive experience with the intervention programme (*cf.* 6.6.3), and that all aspects of the video game Portal were enjoyable with no negative aspects (*cf.* 6.7.4). Participant 2 acknowledged that cognitive benefits were evident for the intervention programme (*cf.* 6.6.5), and that playing the game produced feelings of happiness and gave her a sense of achievement (*cf.* 6.6.6). She commented that her problem solving skills were enhanced by the attention grabbing nature of the game (*cf.* 6.7.7), that formal classrooms tend to be tedious and repetitive, and that the use of games during teaching are more effective than formal teaching (*cf.* 6.7.8).

Although it appears that the participant experienced the game play as positive and acknowledged its cognitive benefits, the limited growth noted in relation to the critical thinking skills, dispositions and standards for reasoning of participant 2, could possibly be attributed to her complete lack of experience in playing video games, which made her struggle to play the game properly, and therefore not contributing to the development of the elements of critical thinking.

6.7.3 Participant 3

It was disappointing that the post-test results revealed no growth from one level to another for participant 3 in relation to any of the critical thinking skills. Participant 3 started with two skills at beginning level of thinking, namely making inferences and doing interpretations, which at the end of the intervention remained at beginning level, implying

stagnation. Making deductions started out at practicing level and remained at practicing level during the post-test. Two skills, namely recognising assumptions and evaluating arguments, revealed decay in performance. Recognising assumptions started out at advanced/master level but at the end of the intervention only appeared to be at practicing level of thinking. In a similar way, evaluating arguments started at practicing level, but ended at beginning level, which showcased a decay in performance (*cf.* Graph 6.25, Table 6.3). The observations pointed to growth for all of the skills (*cf.* Graphs 6.26 - 6.30), which contradict the decay and stagnation evidenced in the post-test results for some of the skills (*cf.* Graph 6.25, Table 6.3). As in the case of participant 1, the researcher argues that the participant might not have been successful in internalising the skills for which growth was noted, and could therefore not transfer and apply the skills successfully to the W-GCTA context.

It is encouraging that during the observations it was noted that the application of all the dispositions and standards for reasoning that started out at novice level, apparently developed to skilled level, with the exception of clarity developing to able level. The implication of the aforementioned is that the intervention programme appeared to be more beneficial for the development of the dispositions and standards for reasoning for participant 3.

According to the interview data, participant 3 had some experience in playing video games, but was inexperienced with playing puzzle video games (*cf.* 6.6.1). The game provided cognitive stimulation and supported goal driven work (*cf.* 6.6.2). She had a thoughtful and exploratory experience while playing the game (*cf.* 6.6.3), and had no issues playing the game (*cf.* 6.6.4). She went on to say that the intervention programme benefitted her cognitive abilities and her ability to plan to achieve goals (*cf.* 6.6.5). She felt a sense of achievement and excitement playing the game (*cf.* 6.6.6), believed that she achieved a better understanding of the game (*cf.* 6.6.7), and feels that video games are more enjoyable than formal classrooms (*cf.* 6.6.8).

Although participant 3 experienced a sense of enjoyment and achievement with the puzzle video game, it seemingly did not enable her to achieve growth in any of the critical thinking skills. As the game play assisted her to improve the planning of her work to achieve goals, it could be concluded that the puzzle video game possibly supported the

growth that was observed in relation to the dispositions for working systematically with persistence and accuracy.

6.7.4 Participant 4

Participant 4 started at the outset of the intervention with two skills at unreflective/challenged level, namely making inferences and deductions, which eventually grew to practicing and beginning levels, respectively. Initially, the skill for doing interpretations started at beginning level and developed to practicing level at the end of the intervention. The skill for evaluating arguments, started at beginning level and remained at beginning level, which implied some stagnation. The skill for recognition of assumptions, started at advanced/master level and showed a slight decay to practicing level at the end of the intervention (*cf.* Graph 6.37, Table 6.4). The post-test data were not completely supported by the observation data, according to which growth was observed for all the critical thinking skills, except recognition of assumptions (*cf.* Graphs 6.38 – 6.42, Table 6.4). Similar to participant 1 and 3, participant 4 might not have been successful in internalising all the skills for which growth was observed, and could therefore not transfer and apply the skills successfully to the W-GCTA context.

A noteworthy finding from the results obtained for participant 4, is that three of the five critical thinking skills seemingly developed during the research. Another interesting finding is that all dispositions and standards for reasoning started out at able level, and developed to sophisticated level (*cf.* Graphs, 6.43 – 6.48, Table 6.4), which could possibly be linked to the influence of the intervention programme.

The interview data revealed that participant 4 had a lot of experience playing games but had never played puzzle games before (*cf.* 6.6.1). He indicated that cognitive stimulation was supported by the game play (*cf.* 6.6.2). Participant 4 went on to state that his experience with the intervention programme entailed solving problems and progressing from one stage to the next (*cf.* 6.6.3), and that the game improved his cognitive abilities, although playing the game was difficult (*cf.* 6.6.4). He further states that the intervention programme benefitted his independent thinking (*cf.* 6.6.5), as he had to think on his own to overcome challenges (*cf.* 6.6.6). According to participant 6, playing any video game does not develop your critical thinking and problem solving skills, only puzzle video games

can do that (*cf.* 6.6.7). He concluded by stating that games make learning fun, and that attention and focus improve with games, compared to learning in formal classrooms that get boring where concentration gets lost (*cf.* 6.6.8).

Participant 4 felt that the intervention programme benefitted him and that he believed that puzzle games do indeed enhance critical thinking and problem solving skills, which could be observed in the growth noted for the three skills and the dispositions and standards for reasoning. Therefore, it is assumed that given more time, perhaps participant 4's critical thinking skills would display greater growth and retention.

6.7.5 Integration and interpretation of data: Experimental and control group

According to Table 6.10, both groups set out as **beginning thinkers** (*cf.* 2.5.3) in relation to **making inferences, making deductions, and doing interpretations**. Beginning thinkers start recognising problems in their thinking, and steadily grow greater awareness of the role of assumptions and different points of view during thinking. They start to recognise the importance of dispositions and standards for reasoning and start to apply these during thinking, however still struggle to find solutions to problems (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.3). The latter argument is supported by the observations for the experimental group as many of the participants started out as novices regarding the application of dispositions and standards for reasoning, except for participant 4 who appeared to be able in the application of the dispositions and standards for reasoning at the outset of the study (*cf.* Tables 6.1 – 6.4).

In addition, the pre-test results reflected that both groups could be regarded as **practicing thinkers** (*cf.* 2.5.4) in relation to **recognising assumptions** and **evaluating arguments**. Practicing thinkers are more knowledgeable than beginning thinkers to monitor the role of assumptions, inferences, and points of view during thinking. Their dispositions to take charge of their thinking start to develop and they know how to monitor the influence of assumptions and points of view during thinking. Practicing thinkers are also knowledgeable to check their thinking for clarity, accuracy, relevance, logic, and systematicity and display greater perseverance when involved with thinking tasks (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4). The latter argument does not apply to the experimental group, who according to the observations, appeared to be mainly at novice

level for the application of the standards of reasoning at the outset of the study, except for participant 4, who was observed to be at able level (*cf.* Tables 6.1 – 6.4).

Table 6.11 indicates that the experimental group and control group apparently developed from being beginning thinkers, towards becoming **practicing thinkers** in relation to making **inferences**. The post-test results for both groups regarding **recognising assumptions** indicated no growth, and both groups remained at **practicing** level of thinking. Similarly, the post-test results for making **deductions and doing interpretations** also remained at **beginning** level of thinking. The post-test results indicated that the application of skills to **evaluate arguments**, declined slightly from **practicing** to **beginning** level for the experimental group, with the control group remaining at **practicing** level.

According to the post-test data, both groups of participants however seem to require more exposure to opportunities that would develop the critical thinking skills on which the research focused, in order to become master thinkers and advanced thinkers (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.5 2.5.6). Being students at higher education level, it is particularly important to have well-developed critical thinking skills to among others, elaborate on arguments, develop the implications of arguments, understand, analyse and evaluate arguments as well as opinions (Pienaar, 2001) (*cf.* 1.1), for which the critical thinking skills to make inferences and deduction, identify assumptions, do interpretations and evaluate arguments are essential (Paul & Elder, 2007) (*cf.* 2.3.5).

With reference to the critical thinking skills, growth was mainly noted only in relation to making **inferences** among the participants in the experimental and control group. It seems as if the participants in the experimental group (1, 2, 4) and control group (5, 6, 7, 8) are beginning to master the skill to draw reasonable conclusions flowing from given information (Chartrand & Rose, 2008; Facione, 2009) (*cf.* 2.3.2).

With the exception of participant 2 (experimental group) and participants 6 and 7 (control group), who achieved growth in relation to **recognising assumptions**, the other participants still seem to experience problems to instinctively evaluate their thinking in order to avoid taking things for granted during reasoning (Elder & Paul, 2010; Papp *et al.*,

2014) (*cf.* 2.5.6), and being sensitive to how assumptions can shape one's viewpoint (Elder & Paul, 2007) (*cf.* 2.3.5).

The data indicate that only participant 4 (experimental group) and participant 7 (control group) seemingly are in the process of developing the skill to **deduce** whether certain conclusions flow from given information (Watson & Glaser, 2002b) (*cf.* 5.7.1.1). The researcher therefore argues, that the other participants might not yet be capable to identify rational implications in any given situation before deciding to act upon the situation (Elder & Paul, 2007) (*cf.* 2.5.3).

Identifying solutions to problems, require the application of critical thinking skills for **doing interpretations**. It seems as if only participant 4 in the experimental group can apply the skill to understand and communicate the meaning of information (Reynolds, 2011) (*cf.* 2.3.2). In the context of the research, doing interpretations appears to be one of the critical thinking skills that require more opportunities for development and practice.

When comparing the pre-test and post-test results obtained for the **evaluation of arguments**, participant 1 appeared to have mastered the skill to evaluate arguments, as the pre- and post-test results remained at advanced/master level throughout the research. For participants 3 and 8, who also started the research at advanced/master level, the post-test results however revealed a decline. Participant 7 in the control group, was the only participant who seemingly improved in evaluating arguments, as the post-test result revealed an improvement in comparison to the pre-test result. No noteworthy growth was achieved by participants 2 and 4 (experimental group) and participants 5 and 6 (control group) for the evaluation of arguments during the post-test. Overall, the researcher is of the opinion that the participants need more opportunities to become effective at recognising reasons, assumptions, and conclusions in arguments (Halpern, 2007; Pienaar, 2001) (*cf.* 2.3.2).

To conclude, in comparison to the experimental group where two participants managed to achieve better results during the post-test, only one participant, namely participant 7, apparently managed to achieve better results during the post-test (*cf.* Graph 6.54). Making inferences was the skill for which the most growth was observed, and evaluation of arguments was the skill for which the least growth was observed among the

participants of the experimental and control group. Of all the participants in the experimental and control group, participant 7 was the participant who likely achieved the most growth in relation to the application of the critical thinking skills, although not having been part of the intervention.

Given the aforementioned interpretations that emanated from the data, the researcher formulates tentative hypotheses that could be followed up in more rigorous experimental research studies.

6.8 FORMULATING TENTATIVE HYPOTHESES

As a quasi-experimental design was implemented with only four participants, no hypotheses could be formulated at the outset of the study. On conclusion of the study, and based on the research findings, the researcher wishes to present a few tentative hypotheses that could be followed up in more rigorous studies in true experimental contexts with more participants (Leedy & Ormrod, 2005). The subsequent, tentative null, directional, and non-directional alternative hypotheses are postulated:

- H_o = The PVG-CEP will not promote growth in relation to the development of critical thinking among 1st year BEd students.
- Ha^1 = The PVG-CEP will promote growth in relation to the development of critical thinking among 1st year BEd students.
- Ha^2 = The PVG-CEP will have an influence on the development of critical thinking among 1st year BEd students.

6.9 CHAPTER SUMMARY

This chapter presented the analysis and interpretation of the test, observation and interview data obtained during the study for each of the participants who took part in the study (*cf.* 6.3.1 - 6.3.4, 6.6)

Participant 1's case study was examined first (*cf.* 6.3.1), and although the observations pointed to growth in relation to all the critical thinking skills, the post-test results indicated growth for one skill only, namely making inferences. Decay was noticed in the application of one skill, namely making deductions, and stagnation was noted for recognising

assumptions, doing interpretations and evaluating arguments. In addition, growth was observed for all the dispositions and standards for reasoning

Participant 2's case (*cf.* 6.3.2), pointed to growth regarding two skills in the post-test, namely making inferences and recognising assumptions. The application of all the other skills seemed to have stagnated during the post-test. The observations did not showcase growth for any of the critical thinking skills, and all the dispositions and standards for reasoning seemingly did not benefit from involvement in the intervention

The case study of participant 3 (*cf.* 6.3.3) was disappointing, as no growth regarding any of the critical thinking skills took place, although the observations noted growth in relation to all the skills. The post-test results for two of skills noted decay, namely for recognising assumptions and evaluating arguments, while stagnation was reported for making inferences and deductions, as well as for doing interpretations. The observations showed growth for all the dispositions and standards for reasoning.

The post-test results for participant 4 (*cf.* 6.3.4) were encouraging, and highlighted growth in the application of three skills, namely making inferences and deductions, as well as for doing interpretations. For one of the skills stagnation was noted, namely evaluating arguments. For recognising assumptions, decay seemingly took place. The observation data did not fully support the post-test results obtained, as the observations revealed growth for all the critical thinking skills. Noteworthy, is the apparent growth revealed during the observations for all the dispositions and standards for reasoning.

Of all the skills on which the research focused, making inferences apparently benefitted the most, as three of the four students in the experimental group experienced growth in the application of skills to make inferences (*cf.* Table 6.5). All the dispositions and standards for reasoning apparently benefitted and showed growth, except for participant 2. (*cf.* Table 6.6). Participant 4 seemingly benefitted the most from the intervention, as the post-test results indicated growth in relation to three of the critical thinking skills, and participant 3 the least, as no growth was observed in the post-test for any of the critical thinking skills (*cf.* Table 6.5). Participant 2 benefitted the least in terms of the dispositions and standards of reasoning that showed no growth.

The test and observation data obtained for the individual sub-test for each participant in the control group (*cf.* 6.4) revealed the following. According to the post-test data, the control group, who did not take part in the intervention, also managed to improve the application of some of the critical thinking skills (*cf.* Table 6.7). Participant 7 demonstrated improvement in four skills, namely making inferences, recognising assumptions, making deductions and evaluating arguments. The post-test results of participant 6 improved in relation to the application of making inferences, and recognising assumptions. Both participants 5 and 6 improved their post-test results for making inferences. For participant 8, growth was only observed for making inferences. Similar to the experimental group, the application of skills to make inferences, appeared to have shown the most growth. It is assumed that normal academic lecturing possibly contributed to the growth noted among the critical thinking skills of the control group.

Section 6.5 compared the data sets that were captured in this study for the experimental and control groups, in order to gain deeper insight into the nature of the data and make connections to further explain phenomena (*cf.* 6.5). The Mann-Whitney U test was used to compare the pre-test and post-test results of the participants in the experimental and control groups, and the Wilcoxon signed-rank test was utilised to compare the differences between the pre-test and post-test results within each of the groups (*cf.* 6.5.4). No statistical significant differences were noted between the pre-test and post-test results within, and between the experimental and control groups in relation to the five sub-tests on which the W-GCTA focused. It could therefore be concluded that both groups were more or less similar in terms of the development of their critical thinking skills at the outset and end of the research, and the effect of the puzzle video game intervention therefore not convincing.

Section 6.6 outlined the data analysis for the interviews that were conducted with the 4 participants in the experimental group that took part in the intervention programme (*cf.* 6.6). According to the interviews, the use of the Portal puzzle video game during the intervention to enhance the growth of critical thinking skills, dispositions and universal standards for reasoning, seemingly hold general benefits in terms of fun and enjoyment. Specific benefits referred to cognitive and emotional benefits. In addition, challenges that

included game difficulty, discomfort playing the game, lack of time and understanding game expectations, were cited by the participants.

Section 6.7 sought to integrate and compare the data sets that were captured in this study in order to gain deeper insight into the nature of the data, and make connections to further explain the development of critical thinking by means of the Portal puzzle video game (*cf.* 6.7). In short, the integration of data revealed that the observations supported by the anecdotal records, did not fully confirm the post-test results achieved by the participants. The observations often revealed growth in relation to critical thinking skills that was not evident in the post-test scores of the participants. The observations appeared to be more accurate in terms of revealing growth for the dispositions and standards for reasoning on which the study focused. Although challenges related to game difficulty and lack of time were mentioned to the intervention, the fun and enjoyment that the participants experienced, as well as the benefits noted in relation to growth in cognitive and emotional abilities, indicate the potential value of the puzzle video game intervention for developing skills, dispositions and standards for reasoning, which possibly contributed to the growth noted for some of the skills, dispositions and standards for reasoning.

It appeared that doing inferences was the skill for which the most growth was observed, and evaluation of arguments the skill for which the least growth was observed among the participants in the experimental and control group. Two participants in the experimental group, participants 2 and 4, and one participant in the control group, participant 7, managed to improve their total post-test scores. Of all the participants, participant 7 appeared to be the participant who achieved the best scores in the post-test, with improvement noted for four of the critical thinking skills, although not having been exposed to the PVG-CEP (*cf.* 6.3.5).

The final section highlighted the tentative null and alternative hypotheses that were formulated at the conclusion of the study (*cf.* 6.8), that could guide future studies using the Portal puzzle video game for enabling growth in relation to critical thinking.

The next chapter, Chapter 7, presents the findings, conclusions and recommendations for the study. In addition, some novel guidelines are presented for the future

implementation of the PVG-CEP or any other puzzle video game to develop critical thinking.

CHAPTER 7

SUMMARY, FINDINGS, AND RECOMMENDATIONS

7.1 INTRODUCTION

This study was conducted with the purpose of identifying the potential benefits of the PVG-CEP for the development of critical thinking among first-year BEd students. The main aim and objectives that were formulated at the outset of the study (*cf.* 1.5) are revisited in this chapter, in order to determine whether they were achieved.

It is essential that the literature study and the data gathered by means of the W-GCTA, observations supported by anecdotal records, and interviews, should have answered the primary and secondary questions (*cf.* 1.4) on which this study was based, enabling the researcher to achieve the overall aim and objectives of the study. This chapter addresses the following topics.

7.2 An overview of the study

- 7.2.1 Chapter 1
- 7.2.2 Chapter 2
- 7.2.3 Chapter 3
- 7.2.4 Chapter 4
- 7.2.5 Chapter 5
- 7.2.6 Chapter 6

7.3 Findings from the literature review

7.4 Findings from the empirical research

7.5 Findings in relation to the aim and objectives of the study

7.6 Data analysis and interpretation: Interview data

- 7.6.1 Recommendations for developing critical thinking skills
- 7.6.2 Recommendations for developing dispositions
- 7.6.3 Recommendations for developing universal standards for reasoning
- 7.6.4 Recommendations for using puzzle video games to develop critical thinking
- 7.6.5 General recommendation

7.7 Novel guidelines to develop critical thinking with puzzle video games

- 7.7.1 Relevance
- 7.7.2 Effectiveness
- 7.7.3 Efficiency
- 7.7.4 Impact
- 7.7.5 Sustainability

7.8 Limitations of the study

7.9 Suggestions for further research

7.10 Contribution of the study

- 7.10.1 Contribution to theory
- 7.10.2 Contribution to practice

7.11 Conclusions

7.2 AN OVERVIEW OF THE STUDY

The overview of the study intends to provide a brief summary of the gist of the preceding chapters of the study.

7.2.1 Chapter 1

This chapter began with a discussion involving the issue of developing critical thinking, exploring the use of technology, more explicitly video games (*cf.* 1.1), by taking into consideration an international as well as a national perspective.

Numerous completed research studies in relation to critical thinking and its development were consulted to confirm the importance of developing critical thinking in Higher

Education institutions, in particular in the context of teacher education. It was established that this topic has received attention on a national level, and that internationally the topic was being researched extensively (*cf.* 1.1). Various studies conducted internationally and nationally report on the fragile and deficient nature of critical thinking skills among pre-service teachers. However, a gap in terms of specific research associated with the improvement of critical thinking through the use of puzzle video games was identified. Countless international studies document the effects of specific teaching strategies on the development of critical thinking skills of pre-service teachers, but none of the studies, however, documents the merits of puzzle video games (*cf.* 1.1) for developing critical thinking. It was noted that local research studies have not focused specifically on utilising a puzzle video game for developing critical thinking (*cf.* 1.1).

The importance of well-developed critical thinking skills was noted in the critical cross-field outcomes of the CAPS, stating that students need to think both critically and creatively (*cf.* 1.1). The present study can therefore be considered crucial in terms of meeting these critical cross-field outcomes, as the study's purpose was to explore the use of a puzzle video game for developing critical thinking.

The main aim and objectives of the study entailed determining how sophisticated first-year BEd students were in the application of critical thinking skills, and based on the findings to establish and explore how a PVG-CEP could support the development of critical thinking among first-year BEd students (*cf.* 1.5).

The empirical research design comprised a literature study and an empirical study (*cf.* 1.6). The research paradigm or framework (*cf.* 1.6.2) for this particular research was acknowledged as pragmatism. Quasi-experimental research (*cf.* 1.6.3) within an embedded mixed method experimental design using descriptive survey and case study research as strategies of inquiry (*cf.* 1.6.4) was employed with a group of eight purposively selected BEd first-year students, who were randomly assigned to an experimental and control group (*cf.* 1.6.5). The control group was exposed to a 13-week intervention with the PVG-CEP (*cf.* 1.9).

Quantitative, pre- and post-test data were collected with the W-GCTA (*cf.* 1.7.1), which served the purpose of testing the five critical thinking skills that the intervention

programme focused on, namely making inferences, recognising assumptions, making deductions, doing interpretations and evaluating arguments.

The reliability (*cf.* 1.7.1.2) and validity of the W-GCTA were guaranteed by taking cognisance of previous findings that emanated from previous pilot studies (*cf.* 5.10.1.1, 6.2), and by adhering to criteria for validity, which included face, content, criterion and construct validity. Additionally, the validity of the research design was examined in terms of how the design adhered to criteria for internal, external, construct and statistical conclusion validity (*cf.* 1.7.1.1).

The qualitative data collection instruments used in the study were semi-structured, one-to-one interviews, and combined quantitative and qualitative observations supported by anecdotal records (*cf.* 1.7.2.1; 1.7.2.2). The observations comprised the use of a quantitative four-point rating scale with qualitative descriptors that was used to make some qualitative judgement about the development of the skills, dispositions and standards for reasoning that were observed. The observations aimed to combine low-inference observations (simply reporting on observations) to a higher degree of qualitative inference (making judgements about events). The interviews were conducted with the four selected student participants in the experimental group at the end of the intervention, in order to understand their perspectives, experiences and thoughts on how the video game that they played, possibly contributed to the development of their critical thinking. The rigour of the interview data as well as the observations were safeguarded by adhering to the criteria for credibility, transferability, dependability and conformability (*cf.* 1.7.2.1 - 1.7.2.3).

The data analysis of the W-GCTA test data for the experimental and control groups involved the use of both descriptive, and non-parametric, inferential statistics employing the Mann-Whitney U test and Wilcoxon Signed Ranks Test for between and within group analyses (*cf.* 1.8.1). Line graphs were used to present the observation data visually for each participant in the experimental group. A qualitative descriptive analysis was used for the analysis of the observation data. The data analysis of the interviews entailed inductive and deductive content analyses (*cf.* 1.8.2). Once the different sets of data were analysed, they were integrated and combined to come to a clearer and deeper

understanding regarding the development of critical thinking that took place through the use of a puzzle video game (*cf.* 6.7).

The research was executed by taking cognisance of ethical procedures (*cf.* 1.10).

7.2.2 Chapter 2

In order to conceptualise critical thinking in the context of the study, the researcher tracked its conceptual development through different stages. The chapter began by exploring the origin of the term critical thinking (*cf.* 2.2.2), linked to three philosophers, namely Socrates, Plato and Aristotle who used questioning to encourage in-depth thinking. Four distinct developmental phases in the development of the conceptualisation of critical thinking were explored (*cf.* 2.2.2.1-2.2.2.3). The first phase, spearheaded by John Dewey (1910) (*cf.* 2.2.2.1), viewed critical thinking as reflective thinking. During the second phase, Glaser (1941) identified critical thinking as an essential skill during problem solving (*cf.* 2.2.2.2), and Russell (1943) concurred with Dewey that critical thinking could be regarded as reflective thinking (*cf.* 2.2.2.2). The work of Ennis (1964) (*cf.* 2.2.2.3) stands central to the third phase in the development of the conceptualisation of critical thinking, according to which critical thinking involves making the correct assessment of statements, implying drawing the right conclusions instead of just drawing conclusions. In addition, the meta-cognitive nature of critical thinking was highlighted by Norris (1985), and Paul (1988) (*cf.* 2.2.2.3), who also noted that critical thinking could be regarded as domain specific and general in nature (*cf.* 2.2.2.3). The final and most recent developmental phase concerned with the conceptualisation of critical thinking, focuses on the work of Facione (1990; 2009), Halpern (2007), Paul and Elder (2006), and Sternberg (2007) (*cf.* 2.2.2.4), who conceptualised critical thinking as a construct comprising different elements that include cognitive and meta-cognitive skills (Facione, 1990, 2009; Halpern, 2007; Paul & Elder, 2006), dispositions (Facione, 2009; Paul & Elder, 2006) and standards for reasoning (Paul & Elder, 2006) (*cf.* 2.2.2.4). These elements are applied in order to develop critical thinking intellectual traits (Paul & Elder, 2006) (*cf.* 2.3.4).

The researcher's conceptualisation of critical thinking in the context of the study (*cf.* 2.3.7, *cf.* Figure 2.2), that combined the viewpoints of Watson and Glaser (2002a), with the

viewpoints of Facione (2009) and Paul and Elder (2006), included the following: Critical thinking is multi-dimensional in nature and comprises the application of interrelated core cognitive and meta-cognitive skills (*cf.* 2.3.2), dispositions (*cf.* 2.3.3), and standards for reasoning (*cf.* 2.3.6) to different elements of reasoning (*cf.* 2.3.5). Intellectual traits will develop as a result of the application of the dispositions and standards for reasoning (*cf.* 2.3.4).

Important information about critical thinking in action (*cf.* 2.4) was clarified. Critical thinking in action comprises elements of logical, critical, creative, and big picture thinking modes (Beyer, 1983; Grosser & Olivier, 2017) (*cf.* 2.4). The logical thinking mode (*cf.* 2.4.1), is a cause-and-effect thinking mode that provides a variety of logical results or outcomes that assist or enable the mind to achieve solutions. The critical questioning mode (*cf.* 2.4.2) entails asking questions to obtain different and alternative perspectives to solve problems. The application of the creative thinking mode (*cf.* 2.4.3), moves away from foreseeable thinking and emphasises the creation of creating new meaning or structure or seeing things from a different perspective. Finally, the application of the big picture thinking mode (*cf.* 2.4.4), involves the ability to fit newly acquired ideas and information into previously gained ideas and information.

The development of critical thinking involves six developmental levels as espoused by Elder and Paul (2010) and Papp *et al.* (2014). These developmental levels were central to the study to describe the development that took place among the students, and included the unreflective thinker (*cf.* 2.5.1), the challenged thinker (*cf.* 2.5.2), the beginning thinker (*cf.* 2.5.3), the practicing thinker (*cf.* 2.5.4), the advanced thinker (*cf.* 2.5.5) and the master thinker (*cf.* 2.5.5).

In order to provide a rationale for the study, the importance of critical thinking for teacher education was elucidated (*cf.* 2.6). The development of critical thinking is a cornerstone of the CAPS that guides teaching and learning in South Africa (Department of Basic Education, 2011) (*cf.* 2.6.1). In addition, critical thinking skills are essential in coping with challenges in the rapidly changing digital society of the 21st century (Barell, 2010) (*cf.* 2.6.2), and needs to be thought of as a life skill (Brettenny, 2017; Brookfield, 2012; McAllister *et al.*, 2009) (*cf.* 2.6.3).

A section concerning the gathering of information on students' critical thinking skills was undertaken to guide the researcher in relation to the why, and how of measuring critical thinking (*cf.* 2.7). A plethora of available measurement instruments that could be utilised to assess critical thinking, such as self-constructed, closed and open ways of assessing critical thinking, were identified (Norris & Ennis, 1989). The purpose of critical thinking assessment was elucidated, which included diagnosing the levels of the students' critical thinking, giving students feedback about critical thinking, motivating them to become better at critical thinking, informing teachers about the success of their efforts to teach students to think critically, providing help in deciding whether a student should enter an educational programme, as well as providing information for holding schools accountable for the critical development of their students (Ennis, 2001) (*cf.* 2.7.1). In the context of the study, establishing the levels of students' critical thinking, was regarded as the main purpose of critical thinking assessment.

A wide variety of instruments (*cf.* 2.7.2) to assess critical thinking development was presented, namely multiple choice tests (*cf.* 2.7.2.1), direct classroom observation (*cf.* 2.7.7.2), individual interviews (*cf.* 2.7.2.3), student-teacher journals (*cf.* 2.7.2.4) and constructed response tests (*cf.* 2.7.2.5). The researcher employed a multiple choice test and direct observations in the context of the study to make decisions about the critical thinking development of the research participants.

Various information-gathering techniques on critical thinking were highlighted (*cf.* 2.7.3), which included aspect specific techniques (*cf.* 2.7.3.1), comprehensive techniques (*cf.* 2.7.3.2), general knowledge techniques (*cf.* 2.7.3.3), subject specific techniques (*cf.* 2.7.3.4) and techniques with a variety of tasks (*cf.* 2.7.3.5). For the purpose of the study, comprehensive techniques were employed to gather data in relation to various elements of critical thinking, namely skills, dispositions and standards for reasoning.

Commercially available tests to assess critical thinking were identified (*cf.* 2.7.4), which comprised of the Academic Profile Test (*cf.* 2.7.4.1), Assessment of Reasoning and Communication Test (*cf.* 2.7.4.2), California Critical Thinking Skills Test (*cf.* 2.7.4.3), California Critical Thinking Disposition Inventory Test (*cf.* 2.7.4.4), Cornell Critical Thinking Test Level X (*cf.* 2.7.4.5), Cornell Critical Thinking Test Level Z (*cf.* 2.7.4.6),

Cambridge Thinking Skills Assessment Test (*cf.* 2.7.4.7), Ennis-Weir Critical Thinking Essay Test (*cf.* 2.7.4.8), International Centre for the Assessment of Thinking Critical Thinking Essay Test (*cf.* 2.7.4.9), Test of Everyday Reasoning (*cf.* 2.7.4.10) and lastly, the Watson-Glaser Critical Thinking Appraisal (*cf.* 2.7.4.11). The researcher determined that the Watson-Glaser Critical Thinking Appraisal would be the most suitable test for assessing the critical thinking skills comprehensively. It appeared to be a valid tool in the South African context, having been utilised in local studies, and the W-GCTA does not expect pre-knowledge about specific subject content, that might place students at a disadvantage when completing the test. The W-GCTA also linked well with the PVG-CEP intervention, as the puzzle video game utilised in the study, Portal, also required participants to use the same skills to solve puzzles, as those on which the W-GCTA focused for solving the problems in the test scenarios.

The final section involved the factors that could influence the development of critical thinking (*cf.* 2.8), which included education factors such as classroom atmosphere (Green & Yu, 2015; Mahapoonyanont, 2012; Stoddar, 2010) (*cf.* 2.8.1.1), the use of imbedded or explicit instruction (Marin & Halpern, 2011) (*cf.* 2.8.1.2), and the role of the facilitator (Brookhart, 2010; Duron *et al.*, 2006; Paul, 1985; Paul & Elder, 2006) (*cf.* 2.8.1.3). Student factors (*cf.* 2.8.2) were also discussed, involving among others, the importance of reading ability (Grabe, 2009; Liu, 2010) (*cf.* 2.8.2.1), motivation for success (Fahim & Hajimaghsodi, 2014) (*cf.* 2.8.2.2) and intention to study (Tzuriel, 2013) (*cf.* 2.8.2.3). Further discussions pertained to personal factors (*cf.* 2.8.3), which included social and cultural challenges (Manalo *et al.*, 2013; Watson, 2015) (*cf.* 2.8.3.1), as well as language ability (Feuerstein, 2007; Floyd, 2011; Lun *et al.*, 2010; Manalo & Sheppard, 2016; Paton, 2005) (*cf.* 2.8.3.2).

7.2.3 Chapter 3

Chapter 3 discussed the teaching of critical thinking in formal, informal and non-formal learning contexts (*cf.* 3.2.1 - 3.2.2), in order for the researcher to gain insight about which context would be best suited to nurture critical thinking skills.

A detailed explanation of developing critical thinking in formal, informal and non-formal learning contexts was provided (Abrami *et al.*, 2008; Case, 2005; Cerasoli *et al.*, 2014;

Eaton, 2012; Mardis, 2013; Rogers, 2014; Swann, 2012) (*cf.* 3.2.1, 3.2.2). The literature review encouraged the researcher to implement the intervention in a context that displayed elements of formal, informal and non-formal learning. The participants took part in the intervention programme within a controlled formal classroom environment in which some form of guidance was provided by the researcher, and the GROW problem solving model was used to guide the solving of the puzzle problems during the intervention. Although the intervention took place in a formal classroom learning environment, participants were informally involved in self-directed, experiential learning not aligned to achieving objectives in relation to curriculum learning material, by playing a video puzzle game. In addition, non-formal, extra-curricular learning that was not aligned to achieving learning objectives in an organised way was promoted, as participants' interest was regarded as a driving force during their involvement in the intervention.

Teaching and learning theories and their relation to the development of critical thinking in formal learning contexts were explored to identify how they could be applied in the context of the design and implementation of the intervention (*cf.* 3.2.1). The following teaching and learning theories were explored: Behaviourism (Skinner, 2011) (*cf.* 3.2.3.1), cognitivism (Ertmer & Newby, 1993; Knowles *et al.*, 2014; Merrill, 2009) (*cf.* 3.2.3.2), constructivism (Bauersfeld, 2012; Tobias & Duffy, 2009; Killen, 2015; Powell & Kalina, 2009) (*cf.* 3.2.3.3), transformative learning (Dirkx *et al.*, 2006; Grabove, 1997) (*cf.* 3.2.3.4), experiential learning (Breunig, 2009; Merriam, Caffarella & Baumgartner 2012; Svingby & Nilsson, 2011; Kolb, 2014;) (*cf.* 3.2.3.5), structural cognitive modifiability (Feuerstein *et al.*, 2010) (*cf.* 3.2.3.6), mediated learning (Fraser, 2006) (*cf.* 3.2.3.7), tangential learning (Armstrong, 2004; Leland, 2016) (*cf.* 3.2.3.8), and transfer of learning (Bransford *et al.*, 2000) (*cf.* 3.2.3.9). The outcome of this review convinced the researcher that all of these theories, with the exception of behaviourism, would apply in the context of the intervention as they support the development of critical thinking.

Aligned to the teaching and learning theories, various teaching methods and strategies to develop critical thinking were discussed, as the intervention comprise the use of formal learning as well (*cf.* 3.3). This was done as the researcher wished to gauge which strategies could be regarded as best suited to nurture critical thinking, and ultimately utilised as part of the intervention, in order to enrich the implementation of the

intervention. The following teaching methods and their related strategies were explored: Direct teaching (Burden & Byrd, 2003; Chai & Khine, 2008; Gunter *et al.*, 2010; Kramer, 2006; Monyai, 2006; Tuovinen & Sweller, 1999) (*cf.* 3.3.1), indirect teaching (Arends, 2004; Borich, 2003; Kramer, 2006) (*cf.* 3.3.2), independent teaching (Borich, 2003; Ognibene, 2007; Philpott, 2009) that involved problem solving and enquiry-based learning (Hung, 2011; Killen, 2015; Yew & Schmidt, 2012) (*cf.* 3.3.3), as well as interactive teaching (Arends, 2004; Kramer, 2006) (*cf.* 3.3.4). In the context of the intervention that focused on the independent solving of puzzle situations, the intervention supported the use of an indirect and independent instructional strategy, the GROW model (Gorell, 2013) (*cf.* Table 1.1), to enrich the implementation of the intervention.

The characteristics of a classroom conducive to the development of critical thinking (*cf.* 3.4), were discussed, as the researcher aimed to foster an environment during the implementation of the intervention that would support the development of critical thinking. These characteristics included the asking of frequent evaluative questions (Brookfield, 2012; Browne & Freeman, 2000; Green & Murris, 2014) (*cf.* 3.4.1), encouragement of active learning (Bean, 2011) (*cf.* 3.4.2) and creating developmental tension (Mathews & Lowe, 2011) (*cf.* 3.4.3).

As part of informal and non-formal learning, a detailed analysis of the role of serious games and game-based learning to develop critical thinking was presented (*cf.* 3.5.2). Serious games are games intended for a principal purpose other than pure entertainment (Djaouti *et al.*, 2011). Game-based learning denotes to the appropriating of definite gaming principles and relating them to real-life settings to engross users (Trybus, 2010). (*cf.* 3.5.2). The focus of the study was on game-based learning as, according to the researcher, the video game Portal could not be considered entirely as a serious game. Portal games are regarded as a sub-genre of puzzle video games that involve action and the application of physics principles (*cf.* 3.5.4.1, 3.5.4.2).

The role of video games to develop critical thinking (*cf.* 3.5.3) as evidenced in completed research was explored. From the research, two schools of thought were identified, namely one that accentuates controversies and negative effects of video games that among others, relate to issues such as violence and aggression (DeWall *et al.*, 2011), sexual themes (Thorsen, 2005), portrayal of gender (Walling, 2002), lesbian, gay, bisexual and

transgender characters (Sheff, 2011), portrayal of race (Everett & Watkins, 2008), portrayal of countries (Brown, 2013), addiction (Han *et al.*, 2010; Hauge & Gentile, 2003), online harassment (Coloroso, 2004), criminal activity (Bardzell *et al.*, 2007) and religion (Wagner, 2012) (*cf.* 3.5.3.3). The second school of thought identifies the positive effects that video games and what they hold for people, such as developing cognitive skills (All *et al.*, 2016; Bavelier *et al.*, 2018; Granic *et al.*, 2014; Greenfield, 1994; Nauert, 2013), enhancing attentional capacity. (All *et al.*, 2016; Green & Bavielier, 2012; Uttal *et al.*, 2013), providing relief from stress, anxiety and frustration (Granic *et al.*, 2014; Olson, 2010), increasing achievement and affect (emotional) (Wouters & Van Oostendorp, 2017). Moreover, positive effects are reported for the use of video games during physical rehabilitation (Primack *et al.*, 2012), education (Aarsand, 2007), the development of business skills (Herz, 1997; Beck & Wade, 2004), pro-social behaviour and collective decision making (Saleem *et al.*, 2012), as well as for addressing mental health disorders (Hsieh *et al.*, 2016) (*cf.* 3.5.3.4).

Puzzle video games and its subgenres were scrutinised (*cf.* 3.5.4). Puzzle video games include action puzzle games (Nelson & Strachan, 2009), hidden object games (Juul, 2007), reveal the picture games (DeMaria & Wilson, 2003), physics games (Wolf, 2008), tile-matching games (DeMaria & Wilson, 2003) and traditional puzzle games (Juul, 2007). The video game used in this study, Portal, can be considered an action puzzle game, that requires of the player to manipulate game pieces in a real-time environment, often on a single screen and with a time limit, to solve the puzzle or clear the level, involving a number of physics principles (*cf.* 4.3.4). A discussion of the Portal video game series that was used in the study, followed (*cf.* 3.5.4.3). The setting and characters of the Portal series were described, mainly looking at the protagonist Chell and the main adversary GLaDOS, as well as the backstory of the Aperture Science facility in which the game play takes place. The main activity within the game itself involved the game player who represents Chell who has to move from one test chamber to the next by solving complex puzzles using a portal device, in order to escape from the chambers.

The role of Portal in education was outlined, in which it was noted that various universities and schools have had success introducing Portal to their students. Special attention was paid to the possibility of developing critical thinking through the use of the Portal game

(*cf.* 3.5.5). According to Rice (2007), higher order thinking is essential for working in a VIE that is presented by puzzle video games. Cognitive VIEs are software products intended to foster higher order thinking by users. Portal could be regarded as an example of a puzzle video game played in a VIE.

7.2.4 Chapter 4

Chapter 4 focused on the design of the intervention that was used in the context of the study. The six phases of intervention research were elucidated and linked to the implementation of the intervention used in the study. In the context of the study, the researcher implemented four phases of intervention research, namely problem analysis and project planning, information gathering and synthesis, design, and early development and pilot testing (*cf.* 4.2.2).

The nature of the PVG-CEP intervention was clarified (*cf.* 4.3). The thirteen-week intervention programme was underpinned by cognitive, constructivist, experiential learning, transformative learning, structural cognitive modifiability, mediated learning, tangential learning and transfer of learning theories (*cf.* 4.3.2), and included the application of the GROW problem solving model (*cf.* 4.3.3). A comprehensive overview of the thirteen weeks Puzzle Video Game – Cognitive Intervention Programme was presented (*cf.* 4.2.2.3). The intervention was not bound to subject content and participants were involved individually in taking part in the intervention (*cf.* 4.3.4).

The researcher only provided procedural help to the participants, and no instruction or demonstration in relation to the skills, dispositions and standards for reasoning on which the research focused, was provided to the participants (*cf.* 4.4). Game instruction to the participants involved clarification about the game mechanics (*cf.* 4.4.1), devices (*cf.* 4.4.2), game structures (*cf.* 4.4.3), and the test chambers where the game play takes place (*cf.* 4.4.4). A number of teaching and learning principles were supported by the PVG-CEP, namely scaffolding, incremental, engaging and challenging learning, enhancing focus by eliminating distractions, and mandatory pausing to reflect (*cf.* 4.4.5).

The observation criteria linked to the game play in Portal that were employed in the study to assess the application of the skills, dispositions and standards for reasoning in the context of the study, were presented (*cf.* 4.5). The criteria linked with the various critical

thinking skills that were tested in the W-GCTA and developed during the intervention, namely making inferences and deductions, recognising assumptions, doing interpretations, and evaluating arguments, as well as with the dispositions (systematic working ways, persistence, accuracy), and the standards for reasoning (logic, clarity, relevancy).

7.2.5 Chapter 5

Chapter 5 provided an extensive explanation of the research methodology employed in the study. The research was framed within a pragmatic framework (*cf.* 5.2), as the researcher aimed to solve a problem that required the collection of quantitative and qualitative data.

The aim of the study was two-fold, namely to determine how sophisticated first-year BEd students are in the application of critical thinking, and based on the findings, to establish and explore how a PVG-CEP can support the development of critical thinking (skills, dispositions and standards for reasoning) among first-year BEd students (*cf.* 5.3.1).

Intervening variables that could possibly influence the research findings were identified (*cf.* 5.3.2), namely motivation, culture, language, interest and ability. The researcher could not control for the influence of the variables on the research findings, and only focused on the impact of the puzzle video game as independent variable on the dependant variable, namely critical thinking skills.

The research design (*cf.* 5.4) used within the study was quasi-experimental research (*cf.* 5.4.1) framed in an embedded mixed method experimental research design (*cf.* 5.4.2). As this study was a mixed method study, both quantitative and qualitative strategies of enquiry (*cf.* 5.5) were used. The quantitative strategy of enquiry (*cf.* 5.5.1) used descriptive survey research, where objective, quantitative pre- and post-test data regarding the development of the participants' critical thinking skills were gathered using the W-GCTA. Quasi-experiments aim to demonstrate causality between an intervention and an outcome in non-randomly selected experimental and control groups (Creswell, 2009; Creswell, 2014; Leedy & Ormrod, 2013). The implementation of the intervention programme formed part of the experimental study. The qualitative strategy of enquiry (*cf.* 5.5.2) involved the use of a multiple case study to collect data from eight first-year BEd

students at the North-West University, thus including a group of individuals bounded in time and place.

Research participants were sampled from the first-year BEd students in the Faculty of Education of the North-West University, on the Vaal Triangle Campus (*cf.* 5.6). Due to time and logistical constraints, a non-probability, convenient, and purposive sample of eight first-year BEd students, who were randomly assigned to an experimental and a control group, were used (*cf.* 5.6.1). Certain criteria were applied in order to select the participants. The participant had to pass the TAG/TALL university admission test that established academic preparedness. The TAG/TALL test results were grouped into four categories, namely: Group 1: 80% - 100%, Group 2: 70% - 79%, Group 3: 60% - 69%, and Group 4: 50% - 59%. From each group, two participants were purposively selected. Participants were excluded from the research if they failed the TAG/TALL test, had played the game Portal before, and if they were lectured by the researcher. The participants for the qualitative phase of the study (*cf.* 5.6.2) included a purposive criterion sample as only the four student participants in the experimental group who were selected for the quantitative part of the study, were involved in this component (*cf.* 5.6.2.1). Due to time constraints, only the experimental group received exposure to the 13-week PVG-CEP, during which the application of the elements of critical thinking on which the research focused, was observed.

The data collection instruments employed in the study (*cf.* 5.7) firstly comprised a quantitative data collection instrument, namely the W-GCTA (*cf.* 5.7.1.1), that assessed the application of the five critical thinking skills on which the research focused, namely making inferences, recognising assumptions, making deductions, doing interpretations and evaluating arguments prior to and after the implementation of the PVG-CEP. Secondly, data collection also comprised the use of observations that made use of a quantitative rating scale with qualitative descriptors (*cf.* 5.7.2.1), combined with evidence contained in anecdotal records (*cf.* 5.7.2.2), as well as video recordings that verified the observations of the researcher and co-observer during the implementation of the intervention (*cf.* 5.7.2.1). Observations were chosen in order for the researcher to acquire a profound insight into, and understanding of the development of the practical application of critical thinking during the implementation of the PVG-CEP intervention.

A four-point rating scale (Cohen *et al.*, 2007) with qualitative descriptors was used to make some judgement about the skills, dispositions and standards for reasoning that were observed. The quantitative rating scale was merely used to guide the researcher in identifying developmental levels among the research participants, to which qualitative descriptions, which included judgments on observed behaviours were used (McMillan & Schumacher, 2006).

Furthermore, semi-structured face-to-face interviews were conducted with the four selected student participants in the experimental group at the end of the intervention, in order to understand their perspectives, experiences and thoughts on the development of critical thinking with the use of the puzzle video game (*cf.* 5.7.2.2). The interview data were used to support and enrich the quantitative data collected with the W-GCTA, as well as the qualitative data collected with the observations.

As part of the qualitative research, the researcher had to clarify how he would ensure that his subjective involvement with participants would not compromise data collection (*cf.* 5.8). Various issues, which were derived from Theron and Grosser (2010) and Merriam (2009), were considered by the researcher. The researcher ensured that (i) the influence of historical, social and cultural experiences; (ii) his status as researcher; (iii) the assumptions that he held on entering the research field; and (iv) his personal connection to the research site, did not compromise data collection.

The data gathered was analysed in two separate phases, as the study employed a combined qualitative and quantitative approach (*cf.* 5.9). Descriptive and inferential statistical procedures were used for the analysis of the quantitative test data. Descriptive statistics were used to organise and summarise data meaningfully in order to promote an understanding of the data characteristics. In this regard, frequencies, percentages, means, medians, and standard deviations were calculated (*cf.* 5.9.1). In this study where a small sample was utilised (less than 30), it could not be assumed that the study variable was normally distributed, therefore non-parametric statistical procedures were applied (McMillan & Schumacher, 2006), to examine differences in pre- and post-test scores between and within the experimental and control groups respectively, by means of the Mann-Whitney U test and Wilcoxon Signed Ranks Test (*cf.* 5.9.1).

The test data were interpreted by using a researcher designed scale according to which the total raw test scores of the participants out of 80, were equated to a level of thinking, namely: 0 – 20: Unreflective and challenged thinkers, 21 – 40: Beginning thinkers, 41 – 60: Practicing thinkers, and lastly 61 – 80: Advanced thinkers, growing towards becoming master thinkers. The scores out of 16 obtained for the individual sub-tests, were also equated to the same levels of thinking: 0 - 4: Unreflective and challenged thinkers 5 - 8: Beginning thinkers, 9 - 12: Practicing thinkers, and 13 -16: Advanced thinkers

In order to conduct the observations (*cf.* 5.9.2), the researcher used a four-point scale observation schedule according to which a qualitative, descriptive account of the development of the participants' skills, dispositions and standards for reasoning was recorded. The following scale was used: 1: Novice; 2: Able; 3: Skilled; 4: Sophisticated (*cf.* 5.9.2). The observations in relation to the skills, were ultimately converted to the various levels of thinking that were used to interpret the W-GCTA test results.

Qualitative, anecdotal records accompanied the ratings of the students for each of the 13 data collection points during the intervention. Video recordings of the game play were used as a checking tool for the observers to verify the evidence they gathered during the observations and the anecdotal records. After each observation session, the observers verified their observations with one another and made use of the anecdotal records and video recordings to come to final conclusions about their observations.

A content analysis was applied to the qualitative interview data (*cf.* 5.9.3). All the interviews were tape-recorded, and afterwards verbatim transcripts were compiled. The data analysis was done by means of an inductive, as well as a deductive content analysis. The deductive data analysis approach implied that the researcher identified relevant categories of information from the literature in relation to the problem on which the research focused in advance (Nieuwenhuis, 2016b), against which the research findings were compared. This was done in order to indicate whether the data support or refute the literature. By means of an inductive content analysis the researcher identified codes in the data that best answered the question that was posed during the interview. This implies that the data speaks for itself and that no interpretations or bias that is not related to the data, is evident (Nieuwenhuis, 2016c).

The researcher applied various procedures to ensure the rigour of the study (*cf.* 5.10). For the quantitative study, the reliability and validity of the W-GCTA that was used in the study to collect data, was established with a previous pilot study involving BEd first-year students (*cf.* 5.10.1). The validity of the quantitative research design was ensured (*cf.* 5.10.1.2), by considering criteria for statistical conclusion validity, internal validity, external validity and construct validity. The validity of the quasi-experimental research design was upheld by considering the following criteria: Internal validity and external validity (*cf.* 5.10.1.3). In order to ensure the trustworthiness of the qualitative study (interviews and observations), the researcher complied with criteria for credibility, transferability, dependability and confirmability (*cf.* 5.10.2).

A variety of ethical considerations were taken into account during the study. The following aspects were considered: Ethical issues in the research problem (*cf.* 5.11.1), ethical issues in the purpose and questions (*cf.* 5.11.2), ethical issues in data collection (*cf.* 5.11.3), ethical issues in data analysis and interpretation (*cf.* 5.11.4) as well as ethical issues in writing and disseminating the research (*cf.* 5.11.5).

7.2.6 Chapter 6

The data obtained from the W-GCTA pre- and post-tests, observations supported by anecdotal records, as well as the interviews with the experimental group, were analysed and interpreted in this chapter (*cf.* 6.3.1 – 6.3.4). The W-GCTA pre- and post-test data collected for the control group were also analysed and presented (*cf.* 6.4).

In essence, the data analysis for each participant revealed the following.

Participant 1

- Improvement in one critical thinking skill from beginning to practicing level, namely making inferences during the post-test, although the observations revealed growth for all the skills.
- All 11 dispositions and standards for reasoning that were performed at novice and able level at the start of the study, seemingly improved to sophisticated level (*cf.* Table 6.1).

Participant 2

- Participant 2 demonstrated growth in two of the critical thinking skills, namely making inferences and recognising assumptions, which started out at beginning level, and apparently developed to practicing level, even though the observations reported no growth for any of the critical thinking skills.
- Disappointingly, none of the dispositions and standards for reasoning testified to growth during the observations (*cf.* Table 6.2).

Participant 3

- Participant 3 demonstrated no growth in relation to the application of critical thinking skills when comparing the pre-and post-test results. The observations that showcased growth for all the critical thinking skills, did not support the lower post-test results that participant 3 obtained.
- The observations testify, that all dispositions and standards for reasoning started out at novice level and developed to skilled level, with the exception of clarity that improved to able level (*cf.* Table 6.3).

Participant 4

- Participant 4 could probably be regarded as the participant who benefitted the most from the intervention, as growth was observed for three of the critical thinking skills, namely making inferences from unreflective/challenged to practicing level, making deductions from unreflective/challenged to beginning level, and doing

interpretations from beginning to practicing level. The observation data that noted growth for all the skills, did not align entirely with the post-test results.

- A noteworthy finding is that according the observations, all the dispositions and standards for reasoning started out at able level and developed to sophisticated level, again testifying to growth (*cf.* Table 6.4).

The data analysis for the participants in the control group (*cf.* 6.4) who did not take part in the intervention, also revealed some growth in the post-tests, in relation to the critical thinking skills. The following growth trends were observed:

- **Participant 5:** Making inferences developed from beginning to practicing level of thinking.
- **Participant 6:** Making inferences developed from an unreflective and a challenged level of thinking, to a beginning thinker level, and recognising assumptions developed from beginning to practicing level of thinking.
- **Participant 7:** Growth was noted for four of the critical thinking skills. Two skills developed from beginning to practicing level, namely making inferences and deductions. One skill, namely recognising assumptions, developed from an unreflective and a challenged level to practicing level of thinking. Finally, for evaluating arguments growth was noted from practicing to advanced/master level.
- **Participant 8:** Making inferences developed from a beginning level of thinking to a practicing level of thinking.

According to the data, making inferences saw the greatest improvement among all the participants in the control group, with participant 7 achieving growth in four of the skills on which the study focused (*cf.* Table 6.7), without taking part in the intervention. This observation is also noted for the experimental group, where three of the participants demonstrated growth in making inferences (*cf.* Table 6.5). Evaluation of arguments could be regarded as the skill that showed the least growth during the research among all the participants in the experimental and control group.

The data sets that were captured in this study for the experimental and control groups were compared in order to gain deeper insight into the nature of the data and to construct hypotheses that could be tested in future studies (*cf.* 6.8). The Wilcoxon signed-rank test

was used for the comparisons within the experimental and control groups. No statistical significant differences occurred within the experimental group between the pre- and post-tests for any of the five skills on which the W-GCTA focused (*cf.* Table 6.8). Similarly, no statistical significant differences occurred within the control group between the pre- and post-tests for any of the five skills on which the W-GCTA focused (*cf.* Table 6.9). The data analysis with the Mann-Whitney U test also did not reveal any statistical significant differences for the comparisons between the pre-test and post-test scores of the experimental and control group for any of the five sub-tests on which the W-GCTA focused. It could therefore be concluded that both groups were more or less similar in terms of the development of their critical thinking skills at the outset and end of the research (*cf.* 6.5.3).

The data analysis for the interviews (*cf.* 6.6) revealed three categories of data that emanated from their experiences with the PVG-CEP. The three categories were: General benefits, specific benefits, and challenges. The general benefits included aspects of enjoyment, fun, excitement, happiness, challenge, task involvement and accomplishment. The specific benefits included benefits in relation to cognitive and emotional development, such as independent thinking, being goal driven, working with accuracy, motivation to learn and improved concentration. A few challenges included difficulty, discomfort playing, lack of time and understanding game expectations (*cf.* Figure 6.1, 6.9).

The final section of the chapter triangulated the data sets that were captured in this study (test data, observation data supported by anecdotal records, and interview data) in order to gain deeper insight into the nature of the data and make connections to further explain phenomena (*cf.* 6.7).

According to data, participant 1 (*cf.* Table 6.1) demonstrated growth in only one skill, namely making inferences, as well as in the application of all the dispositions and standards for reasoning. The observation data, that revealed growth in the application of all the skills, did not support the post-test results, which implied that apparently only skills to make inferences were transferred to the test scenario. The interview data noted that although the participant had no experience with playing puzzle video games, he found the intervention enjoyable, that his attention and focus was enhanced, he did not rush

things off, and found games to be more engaging than formal teaching (*cf.* 6.7.1 - 6.7.8). The positive experience of participant 1 possibly contributed to the growth noted for making inferences, and the application of the dispositions and standards for reasoning.

Participant 2 demonstrated growth in two skills, namely making inferences and recognising assumptions (*cf.* Table 6.2), which was not supported by the observations. The observation data testified to no growth for any of the dispositions and standards for reasoning. Although participant 2 had no experience in playing any video games, she also experienced the game play as positive, with benefits in relation to developing a sense of achievement, critical thinking, problem solving and better attention. She viewed the use of games during teaching to be more effective than formal teaching (*cf.* 6.7.1 – 6.7.8). Her inexperience with game play, possibly contributed to the limited growth observed for the various elements of critical thinking

Participant 3 apparently did not improve the application of any of the critical thinking skills on which the research focused (*cf.* Table 6.3). The observation data that noted growth for all the critical thinking skills, did not support the post-test results that revealed no growth. Growth was noticed during the observations for all the dispositions and standards for reasoning. Participant 3 had some experience playing video games, but no specific experience in playing puzzle games. She also experienced the intervention as positive, noting benefits for developing thinking, planning and achieving goals, and regarded the use of experiential learning as more enjoyable than formal teaching (*cf.* 6.7.1 – 6.7.8). The positive experience reported, possibly contributed more to the development of this participant's dispositions and standards for reasoning, and not so much to the development of the critical thinking skills.

Participant 4's post-test results displayed growth for the application of three skills, namely to make inferences and deductions, as well as for doing interpretations (*cf.* Table 6.4). The growth noted was supported by the observations that also revealed growth for making inferences and deductions as well as for doing interpretations. In addition, the observations also revealed growth for evaluating arguments, which was not supported by the post-test results. The lack of growth noted during the observations for recognising assumptions, was confirmed by the lower post-test result for recognising assumptions. According to the observations, growth was noted for all the dispositions and standards

for reasoning. The interview data obtained revealed that participant 4 had a lot of experience playing games but that he had never played puzzle games before. The participant highlighted the fun element of the game, as well as the difficulty involved in solving the puzzle problems. He noted that the game contributes to improving cognitive abilities, and advances problem solving, as well as independent thinking. He is of the opinion that in comparison to formal classroom teaching, the use of games could avoid loss of concentration and enhance attention and focus (*cf.* 6.7.1 – 6.7.8). This participant's experience with game play in general, possibly contributed to the higher levels of growth that he achieved in comparison to the other participants who were not so experienced.

Flowing from the data, some tentative hypotheses (*cf.* 6.8) were formulated for rigorous follow-up studies with larger groups of students in true experimental conditions.

The next section reports the major findings from the literature review that was conducted at the beginning of the study.

7.3 FINDINGS FROM THE LITERATURE REVIEW

The literature review comprised two chapters, namely Chapter 2 and 3. Chapter 2 foregrounded the conceptualisation of critical thinking and its development, and Chapter 3 delineated the nature of teaching and learning contexts that would promote the development of critical thinking, with special emphasis on the use of a puzzle video game, namely Portal. The findings derived from the literature reviews were used by the researcher in the construction of the 13-week intervention programme, and to meaningfully interpret the data obtained from the empirical research. The following important findings emanated from the literature review.

- A first major finding in relation to the conceptualisation of critical thinking revealed that the conceptualisation developed across the ages to become more than just thinking that is in-depth, and encouraged by questioning (Socrates, Plato, Aristotle) (Gutek, 2009) (*cf.* 2.2.2). The conceptualisation of critical thinking evolved to thinking that is reflective in nature (Dewey, 1910; Russell, 1943) (*cf.* 2.2.2.1), thinking that is essential in problem solving (Ennis, 1964) (*cf.* 2.2.2.2), thinking that involves the correct assessment of statements (Norris & Ennis, 1989) (*cf.* 2.2.2.3), and thinking that is meta-cognitive, domain specific as well as general in nature (Paul, 1990) (*cf.* 2.2.2.3).

Recent conceptualisations of critical thinking, focus on the work of Facione (1990, 2009), Paul and Elder (2006), Halpern (2007) and Sternberg (2007), who conceptualise critical thinking as being multi-dimensional in nature.

- The researcher obtained a clear description of the multi-dimensional nature of critical thinking (Adler & Perkins, 2016; Cottrell, 2011; Grosser & Olivier, 2017; McPeck, 2015) (*cf.* 2.3.1), that comprises a number of elements. These elements include interrelated core cognitive and meta-cognitive skills (Facione, 1990; 2009) (*cf.* 2.3.2), dispositions (Facione, 2000; 2009; Paul & Elder, 2006) (*cf.* 2.3.3), universal standards for reasoning (Paul & Elder, 2006) (*cf.* 2.3.6), that are always applied to a number of elements of thought (Elder & Paul, 2007) (*cf.* 2.3.5), in order to develop intellectual traits (Paul & Elder, 2006) (*cf.* 2.3.4).
- The literature review created awareness of the characteristics of critical thinking in practice (*cf.* 2.4). Good critical thinking comprises elements of logical (*cf.* 2.4.1), critical (*cf.* 2.4.2), creative (*cf.* 2.4.3), and big picture (*cf.* 2.4.4) thinking modes (Beyer, 1983; Grosser & Olivier, 2017), that are used to analyse information, determine consistencies and inconsistencies, identify patterns in information, determine cause and effect, predict, identify alternative and formulate conclusions.
- The researcher was alerted to the six developmental stages involved in working towards becoming a master in critical thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5). These stages involve progressive development from being an unreflective thinker, a challenged thinker, a beginning thinker, a practicing thinker, an advanced thinker, and finally a master thinker (*cf.* 2.5.1 – 2.5.6).
- Literature emphasised the importance of critical thinking for teacher training (*cf.* 2.6), by discussing the place of critical thinking in the CAPS that guides teaching and learning in South African classrooms (*cf.* 2.6.1). Well-developed critical thinking skills are foundational to achieving the objectives of the CAPS (Department of Basic Education, 2011) (*cf.* 2.6.1). In addition, critical thinking skills are required in the rapidly changing digital society of the 21st century (*cf.* 2.6.2), and could be regarded as a life skill (Brookfield, 2012; Mc Allister *et al.*, (2009) (*cf.* 2.6.3).
- The researcher obtained information about a variety of methods on gathering information about students' critical thinking skills, with various available measurement

instruments that could be used to assess critical thinking, such as self-constructed, closed, and open ways of assessing critical thinking (Norris & Ennis, 1989) (*cf.* 2.7).

- The purpose of critical thinking assessment was also scrutinised. That assessment looks at diagnosing the level of students' critical thinking, giving them feedback, informing teachers about the success of their efforts to teach students critical thinking, providing information for holding schools accountable for the critical development of their students, as well as providing help in deciding whether a student should enter an educational programme (Ennis, 2001) (*cf.* 2.7.1).
- A wide variety of instruments to assess critical thinking development was found, namely multiple choice tests (Norris & Ennis, 1989) (*cf.* 2.7.2.1), direct classroom observation (*cf.* 2.7.2.2), individual interviews (*cf.* 2.7.2.3), student-teacher journals (*cf.* 2.7.2.4), and constructed response tests (Larsson, 2017) (*cf.* 2.7.2.5).
- Various information-gathering techniques on critical thinking were highlighted by the literature (Norris & Ennis, 1989) (*cf.* 2.7.3), which included aspect specific techniques (*cf.* 2.7.3.1), comprehensive techniques (*cf.* 2.7.3.2), general knowledge techniques (Norris & Ennis, 1989) (*cf.* 2.7.3.3), subject specific techniques (*cf.* 2.7.3.4) and techniques with a variety of tasks (Bensley *et al.*, 2016; Ku, 2009; Norris & Ennis, 1989) (*cf.* 2.7.3.5).
- Findings also revealed commercially available tests to determine critical thinking, including the Academic Profile Test (*cf.* 2.7.4.1), Assessment of Reasoning and Communication Test (*cf.* 2.7.4.2), California Critical Thinking Skills Test (*cf.* 2.7.4.3), California Critical Thinking Disposition Inventory Test (*cf.* 2.7.4.4), Cornell Critical Thinking Test Level X (*cf.* 2.7.4.5), Cornell Critical Thinking Test Level Z (*cf.* 2.7.4.6), Cambridge Thinking Skills Assessment Test (*cf.* 2.7.4.7), Ennis-Weir Critical Thinking Essay Test (*cf.* 2.7.4.8), International Centre for the Assessment of Thinking Critical Thinking Essay Test (*cf.* 2.7.4.9), Test of Everyday Reasoning (*cf.* 2.7.4.10) and lastly the Watson-Glaser Critical Thinking Appraisal (*cf.* 2.7.4.11).
- The literature alerted the researcher to factors that could influence the development of critical thinking (*cf.* 2.8), which included a discussion about educational factors (*cf.* 2.8.1) such as classroom atmosphere (Cheng & Wan, 2017; Green & Yu, 2015; Mahapoonyanont, 2012; Stoddar, 2010; Watson, 2015) (*cf.* 2.8.1.1), according to

which it was found that classroom atmospheres often testify to silence and students lacking the confidence to question information. Imbedded and explicit instruction was also explored (Marin & Halpern, 2011; Willingham *et al.*, 2015) (*cf.* 2.8.1.2). The imbedded approach to critical thinking transpires when the development of critical thinking skills is intertwined into the subject content. Explicit instruction ensues when the development of critical thinking skills is taught during separate lessons, which concentrate explicitly on critical thinking skill development. The role of the facilitator/teacher appears to be an important factor in the development of critical thinking (Brookhart, 2010; Ertmer & Newby, 2013; Kwan & Wong, 2015; McNeeley, 2007; Pintrich & Schunk, 2002; Schunk, 2000) (*cf.* 2.8.1.3). A teacher has to guard against using a passive, teacher-centred, behaviourist approach to teaching. Student factors that could impact on the development of critical thinking were also discovered, such as reading ability (Grabe, 2009; Liu, 2010) (*cf.* 2.8.2.1), which involves the ability to process text, comprehend its meaning, and to assimilate it. Motivation for success was also unpacked (Fahim & Hajimaghsodi, 2014) (*cf.* 2.8.2.2), referring to motivation being a necessary precondition for being willing to become involved in the application of critical thinking. A student's intention to study is also a crucial prerequisite for the development of critical thinking (Shamir *et al.*, 2006) (*cf.* 2.8.2.3). Intention can be shaped by a teacher's deliberate determination to alter a student's attention, awareness, perception, processing, or reaction to information. Lastly, personal factors were uncovered (*cf.* 2.8.3), such as societal and cultural challenges (Higgins *et al.*, 2008; Manalo *et al.*, 2013; Watson, 2015) (*cf.* 2.8.3.1). Many cultures demand respect and obedience from children, such as the African culture (Rothstein, 2000) (*cf.* 2.8.3.1), which implies an uncritical approach to information that relies heavily on culturally available knowledge and ways of processing information (Higgins, 2008; Higgins *et al.*, 2003; Higgins *et al.*, 2008) (*cf.* 2.8.3.1). Links between language and critical thinking were also discovered (Feuerstein, 2007; Floyd, 2011; Lun *et al.*, 2010; Manalo & Sheppard, 2016; Paton, 2005) (*cf.* 2.8.3.2), concluding that language ability could influence the production of critical, evaluative thinking.

- The ways in which formal, informal and non-formal learning contexts could nurture critical thinking were uncovered (Cerasoli *et al.*, 2014; Mardis, 2013; Rogers, 2014; Swann, 2012; UNESCO, 2012) (*cf.* 3.2.1, 3.2.2). It is important that teaching and

learning support cognitive learning (Ertmer & Newby, 1993; Knowles *et al.*, 2014; Merrill, 2009) (*cf.* 3.2.3.2), constructivist learning (Bächtold, 2013; Duffy, 2013; Tobias & Duffy, 2009; Killen, 2015; Powell & Kalina, 2009) (*cf.* 3.2.3.3), transformative learning (Dirkx *et al.*, 2006; Grabove, 1997) (*cf.* 3.2.3.4), experiential learning (Breunig, 2009; Caffarella & Baumgartner, 2012; Kolb, 2014; Svingby & Nilsson, 2011) (*cf.* 3.2.3.5), structural cognitive modifiability (Feuerstein *et al.*, 2010) (*cf.* 3.2.3.6), mediated learning (Fraser, 2006) (*cf.* 3.2.3.7), tangential learning (Armstrong, 2004; Leland, 2016) (*cf.* 3.2.3.8), and transfer of learning (Bransford *et al.*, 2000) (*cf.* 3.2.3.9), in order to promote the development of critical thinking.

- The researcher obtained information about various teaching methods and strategies that would best develop critical thinking (*cf.* 3.3). In this regard, indirect (Borich, 2003; Bruce *et al.*, 2009; Chai & Khine, 2008; Kramer, 2006; McKee *et al.*, 2007) (*cf.* 3.3.2), independent (Borich, 2003; Chai, & Khine, 2008; Ognibene, 2007; Philpott, 2009) (*cf.* 3.3.3), and interactive instruction (Arends, 2004; Maxim, 2010; Powell & Kalina, 2011) (*cf.* 3.3.4) were identified as suitable approaches to develop critical thinking. These approaches to instruction are student-centred, and view students as active participants in the learning experience, and encourage independent learning and thinking through problem solving (Barrett, 2010; Hung, 2011; Schmidt *et al.*, 2011; Yew & Schmidt, 2012) (*cf.* 3.3.3), and enquiry (Killen, 2015; Dostál & Gregar, 2015) (*cf.* 3.3.3). Some of the strategies that could promote the development of critical thinking dispositions and standards for reasoning, involved working according to clearly defined success criteria, checking for correctness and reflection guided by questions (*cf.* 3.3.5).
- The literature provided guidance in relation to activities that could be employed in classrooms to develop critical thinking (Browne & Freeman, 2000) (*cf.* 3.4). Among others, asking frequent evaluative questions (Brookfield, 2012; Green & Murris, 2014), encouraging active learning (Bean, 2011) and creating developmental tension, appear to be important activities for developing critical thinking (Mathews & Lowe, 2011) (*cf.* 3.4.1. – 3.4.3).
- Against the background of developing critical thinking by employing informal and non-formal learning game-based learning in particular, puzzle video games seem to hold

among others, benefits for developing higher order, critical thinking (Pho & Dinscore, 2015; Lugmayr *et al.*, 2017; Trybus, 2010) (*cf.* 3.5.2).

- The literature review enabled the researcher to become acquainted with information about playing the puzzle video game Portal, which appeared to hold numerous benefits for developing critical thinking (*cf.* 3.5.5). According to Rice (2007), higher order thinking is essential for working in a VIE presented by puzzle video games. Cognitive VIEs are software products intended to foster higher order thinking by users. Portal could be regarded as an example of a puzzle video game played in a VIE.

The next section discusses the pertinent findings that were revealed from the empirical research.

7.4 FINDINGS FROM THE EMPIRICAL RESEARCH

This section aligns the literature review with the findings that transpired from the data analysis and initial interpretation presented in Chapter 6 (*cf.* 6.3.5, 6.7).

- The participants in the experimental group did not excel in the practical application of critical thinking skills in the pre- and post-tests, and differential growth in relation to the skills was noted among the participants after their exposure to the PVG-CEP intervention. Two participants, participants 2 and 4, improved their post-test scores from beginning to practicing level of thinking, whereas participants 1 and 3 who seemingly entered the intervention at practicing level of thinking, remained at practicing level. Practicing level of thinking implies that the participants were becoming skilled at improving faulty thinking, and are starting to reflect about whether their thinking adheres to dispositions and standards for reasoning (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.4).

Making inferences, appeared to be the only skill that developed among three of the four participants, namely participants 1, 2, and 4, making deductions developed among one of the participants, participant 4, and doing interpretations only showed signs of growth for participant 4. Evaluation of arguments apparently did not benefit at all from taking part in the intervention.

Each participant thus benefitted in unique ways in terms of critical thinking development. Participant 4 seemingly benefitted the most from the intervention, as three of the five critical thinking skills on which the research focused, showed growth after the intervention (*cf.* Table 6.4). Participant 2 appeared to have benefitted the least in terms of growth noted for the dispositions and standards for reasoning (*cf.* Table 6.2), but managed to achieve growth for two critical thinking skills. Participant 3 demonstrated the least growth in relation to the critical thinking skills (*cf.* Table 6.3), but the development of all the dispositions and standards for reasoning showcased growth. Participant 1 achieved limited growth in relation to one critical thinking skill, and growth regarding all the dispositions and standards for reasoning (*cf.* Table 6.1). The researcher concludes, that all the participants still need more exposure to develop intellectual autonomy and expertise over their thought processes, to become sophisticated and advanced masters in thinking critically (Elder & Paul, 2010) (*cf.* 2.5.5, 2.5.6). The meta-cognitive skill of self-regulation could be developed stronger, to enable the participants to identify mistakes in their thinking (Facione, 2009) (*cf.* 2.3.2), and to continuously test whether their thinking adheres to the critical thinking dispositions and standards for reasoning (Elder & Paul, 2010) (*cf.* 2.5.5, 2.5.6). Overall, the researcher carefully argues that the intervention programme seemingly only benefitted participants 2 and 4, who managed to achieve higher post-test scores for the development of the critical thinking skills, whereas the post-test scores for participants 1 and 3 indicated decline (*cf.* Graph 6.49).

- Taking part in the intervention proved to be more beneficial for the development of the critical thinking dispositions and standards for reasoning on which the research focused (*cf.* Tables 6.1 – 6.4). From the interview data some dispositional elements such as paying attention (All *et al.*, 2016; Granic *et al.*, 2014; Green & Bavelier, 2012) and motivation to be involved in goal directed learning (All *et al.*, 2016; Connolly *et al.*, 2012, Granic *et al.*, 2014) (*cf.* 3.5.3.4), appeared to be aspects that seemingly benefitted from taking part in the PVG-CEP intervention, and possibly contributed to the growth noted for the dispositions.
- The data obtained for the control group did not reveal significant growth in relation to the critical thinking skills, which possibly indicates that the normal classroom teaching they were exposed to, probably did not intentionally foreground the development of

critical thinking (*cf.* 6.4). According to Table 6.7, and similar to the experimental group (*cf.* Table 6.5), it appeared that doing inferences was the skill for which the control group achieved the most growth. Participant 7 appeared to have achieved the best scores in the post-test.

- The experimental group and control group apparently developed from being beginning thinkers, towards becoming practicing thinkers in relation to making inferences. The post-test results for both groups regarding recognising assumptions indicated no growth, and both groups remained at practicing level of thinking. Similarly, the post-test results for making deductions and doing interpretations also remained at beginning level of thinking. It was disappointing to note that the post-test results indicated that the application of skills to evaluate arguments, decayed slightly from practicing to beginning level for the experimental group, with the control group remaining at practicing level. According to the post-test data, both groups of participants however seem to require more exposure to opportunities that would develop the critical thinking skills on which the research focused in order to achieve advanced and master levels of thinking, and to instinctively identify weaknesses in their thinking (Elder & Paul, 2010; Papp *et al.*, 2014) (*cf.* 2.5.5, 2.5.6, Tables 6.10, 6.11).
- Overall, growth was mainly noted only in relation to making inferences among the participants in the experimental and control group. It seems as if the participants in the experimental group (1, 2, 4) and control group (5, 6, 7, 8) are beginning to master the skill to draw reasonable conclusions flowing from given information (Chartrand & Rose, 2008; Facione, 2009) (*cf.* 2.3.2). It is likely that evaluation of arguments is identified as the skill for which the least growth was noted, and the participants therefore need more opportunities to become effective at recognising reasons, assumptions, and conclusions in arguments (Halpern, 2007; Pienaar, 2001) (*cf.* 2.3.2). Based on the data, the researcher is of the opinion that the critical thinking skills could be regarded as more challenging to develop, than the dispositions and standards for reasoning.
- In the context of the intervention, the participants had to apply different modes of thinking, that comprise elements of logical, critical, creative, and big picture thinking modes (Beyer, 1983; Olivier, 2012) (*cf.* 2.4.1 – 2.4.4). With respect to the

aforementioned, they had to determine consistencies and inconsistencies, make inferences and deductions, interpret and evaluate information, identify patterns in information, determine cause and effect, predict, and formulate conclusions (Grosser & Oliver, 2017) (*cf.* 2.4), as well as fit newly acquired ideas and information into previously gained ideas and information, which is a key characteristic of big picture thinking (Eyre, 2016) (*cf.* 2.4.4). In addition, they needed to structure or see things from a different perspective that involves the skills of analysis, synthesis and evaluation (Beyer, 1983; Wechsler *et al.*, 2018) (*cf.* 2.4.3). The logical thinking mode showed growth among all the participants, except participant 2. Differential trends in growth were noted for the critical, creative and big picture thinking modes, with limited growth noted for participant 1 and 2 regarding making inferences, as well as for making inferences and recognising assumptions, respectively. Furthermore, participant 4 demonstrated improved levels of growth for making inferences and deductions as well as doing interpretations, whereas participant 3 demonstrated no growth for any of the critical thinking skills.

- Aligned to the aforementioned findings, it could be argued that although the participants require more opportunities to develop their critical thinking skills, the development of important 21st century dispositions and standards for reasoning (Dede, 2010; Goldrick-Rab, 2010) (*cf.* 2.6.2) that are required to sift through, and interpret reliable information (Ten Dam & Volman, 2004) (*cf.* 2.6.3), possibly benefitted from taking part in the intervention. This observation is supported by the growth noticed during the 13-week intervention, except for participant 2 (*cf.* Table 6.6),
- The participants who took part in the study, still require more opportunities to further develop their critical thinking skills, in order to be able to nurture the skills among the students whom they will teach. The participants might still be ignorant of how their thinking is structured, how to assess its quality and how to further develop it (Paul & Elder, 2006) (*cf.* 2.5.1). It seems as if the participants need to develop an understanding of the problems in their thinking, and acquire ways to address the problems (Paul & Elder, 2010).
- Allowing independent learning, reducing teacher authority during the intervention (Green & Yu, 2015; Mahapoonyanont, 2012; Stoddard, 2010) (*cf.* 2.8.1.1), and facilitating active learning during the puzzle video game play (Brookhart, 2010;

Browne & Freeman, 2000; Kwan & Wong, 2015) (*cf.* 2.8.1.2, 2.8.1.3, 3.4.1.1 – 3.4.1.3), could be regarded as factors that possibly contributed to the growth noted for the application of some of the critical thinking skills, specifically for making inferences that improved among three of the four participants in the experimental group. The researcher strove to make the atmosphere of the intervention as open and friendly as possible, allowing the participants to share their views and reflect on their thinking, at the same time not enforcing views onto the participants, which could have contributed to the differential growth noted among the participants. Noteworthy growth was however mainly observed in relation to the application of the dispositions and standards for reasoning. In sum, the participants seemed to have benefitted in distinctive ways from a classroom atmosphere where a facilitation approach, and involvement in, and reflecting on thinking, stood central. The apparent lack of benefit that the intervention had for the development of the critical thinking skills of participant 3, might be linked to the fact that the participant might have felt that she did not want to share her thoughts during the game play, being afraid that she might be wrong. It could also be argued that she might never have been exposed to instruction that expected independent thinking of her, and could have been used to direct instruction in which the teacher is the sole provider of information (Gunter *et al.*, 2010) (*cf.* 3.3.1). The former argument would justify why she could not communicate with clarity, and reason about her thoughts and actions with relevancy during the intervention (*cf.* Appendix L).

- Developing critical thinking detached from subject content showed some signs of potential (*cf.* 6.3.5). The video game Portal was used as an explicit approach to critical thinking, as it was not tied to specific subject content (Marin & Halpern, 2011) (*cf.* 2.8.1.2). The researcher noticed that the use of the video game apparently had a differential influence on the participants, with participant 4 probably benefitting the most. For this reason, the researcher argues that a combined embedded (Bensley & Spero, 2014) and explicit approach to teaching critical thinking, might be more beneficial. The combined approach will allow more opportunities for practicing the skills in different contexts, which might aid better retention of the skills, dispositions and standards for reasoning.

- In support of structural cognitive modifiability theory (Feuerstein *et al.*, 2010) (*cf.* 3.2.3.6), varied changes in the application of the thinking skills, dispositions and standards for reasoning were noted among all the participants (*cf.* Table 6.1 – 6.4). The research findings support the viewpoints of Benjamin (2005), Feuerstein, (1997), and Tzuriel (2001) (*cf.* 3.2.3.6, 3.2.3.7), who argue that fragile and deficient thinking processes can be reversed. It is possible that the modifiability of skills, dispositions and standards for reasoning was supported by the involvement of the researcher who acted as a facilitator and mediator of learning (*cf.* 3.2.3.7) during the implementation of the intervention. The researcher's involvement entailed continuous questioning about the game play, as well as organising and guiding the game play, that possibly enhanced the effective functioning of the participants during the independent learning experience, thus promoting growth (Fraser, 2006) (*cf.* 3.2.3.2).
- The study reveals a number of findings and insights in relation to the transfer of learning theory (Arthur *et al.*, 1998; Perkins & Salomon, 1992; Schwartz *et al.*, 2005) (*cf.* 3.2.3.9).
 - (i) The study postulated that the critical thinking skills developed within the intervention programme, would possibly be transferred to the W-GCTA context, meaning that in this study far transfer, to a context that differs from the context in which the skills were developed (Perkins & Salomon, 1992) (*cf.* 3.2.3.9), was supported. Arthur *et al.* (1998) (*cf.* 3.2.3.9) also argue that training (intervention) conditions should be as similar to the retention conditions as possible for maximum retention of skills. Based on the data obtained, the researcher acknowledges that far transfer, of the critical thinking skills, was not promoted very successfully, which possibly links to the differences in contexts in which the critical thinking skills were acquired and applied, and then had to be transferred to. The W-GCTA test context relied on language ability to solve general problems, whereas the Portal game context did not rely on language ability for solving general problems, but on solving visual, three-dimensional puzzle problems in a video game. In particular, it appeared that the skills to make deductions, do interpretations and evaluate arguments were not at all transferred successfully to the W-GCTA test scenario context (*cf.* Table 6.5). The researcher often observed that the observation data did not support the

post-test results (*cf.* Tables 6.5). In this regard, the researcher argues that the participants might have acquired skills during the puzzle game context, which they could not transfer to the dissimilar, W-GCTA context. In addition, the participants did not explicitly acquire the general principles involved in the application of critical thinking before or during the intervention, that might have contributed to their being more effective at retaining and applying the skills in dissimilar situations (Bruner cited by Darling-Hammond & Austin, 2003) (*cf.* 3.3.3.9).

- (ii) Transfer of learning theory postulates that transfer occurs most commonly when instruction is “... *cued, primed, and guided...*” (Bransford *et al.*, 2000) (*cf.* 3.2.3.9). Although the implementation of the intervention programme was indeed *cued, primed* and *guided* by the researcher who acted as a mediator when participants struggled with the puzzles, and advised them to consult the GROW model to execute the process of solving the puzzles more systematically, it was hoped that the transfer of the critical thinking skills acquired and practiced during the intervention, would have been more effective to the W-GCTA context.
- (iii) The quality and quantity of a skill acquired plays a significant role in decay and long-term retention (Arthur *et al.*, 1998) (*cf.* 3.2.3.9), which implies that if skill acquisition is limited during the training (intervention) situation, then retention becomes questionable. All the participants were exposed to the same intervention having equal time to develop the various elements of critical thinking. Nevertheless, differentiation in terms of growth, decay and retention was observed. Given the disappointing post-test results, the researcher argues, that the 13-week implementation of the intervention might not have provided sufficient time for the skills to be practiced and retained effectively.
- (iv) Greater motivational levels will possibly contribute to greater skill retention over time (Arthur *et al.*, 1998) (*cf.* 3.2.3.9). The researcher hoped that the theory of tangential learning with its fun element (Armstrong, 2004; Leland, 2016) (*cf.* 3.2.3.8) that underpinned the intervention, would enhance motivation to learn and promote the acquisition of the skills, dispositions and standards for reasoning on which the study focused. Although the interview data pointed to

the fun and enjoyment aspects of the PVG-CEP, unfortunately, this argument did not seem to apply entirely in the context of the study, as many of the skills on which the study focused, did not seem to grow during the exposure to tangential learning (*cf.* Tables 6.1 – 6.4). This finding could indicate that the motivational effect to learn, was probably not successfully enhanced by learning through the use of games. The fun element in games supposedly does not captivate everybody.

Over and above, developmental tension was created through the nature of the puzzle game that became progressively challenging or difficult, ultimately implying that developmental tension was constantly assured (Browne & Freeman, 2000) (*cf.* 3.4.1.1 – 3.4.1.3). Literature points out that puzzle games focus on logical and conceptual challenges and focuses on puzzle solving as the primary game play activity (Rollings & Adams, 2006) (*cf.* 3.5.4), that could involve pattern recognition, logic, or understanding a process (Miller, 2005) (*cf.* 3.5.4). These games usually have a simple set of rules, where players manipulate game pieces on a grid, network or other interaction space. Players must unravel clues in order to achieve certain victory condition, which will then allow them to advance to the next level. Completing each puzzle will usually lead to a more difficult challenge, although certain games avoid exhausting the player by offering easier levels between more difficult ones (Rollings & Adams, 2006) (*cf.* 3.5.4). The high level of cognitive challenge in Portal might have discouraged some of the participants, therefore limiting growth and development.

- (v) Arthur *et al.* (1998) (*cf.* 3.2.3.9) contend that students with higher abilities will retain more skill because they acquire more during training than lower ability students do in the same amount of time. Although the researcher did not specifically assess for differences in ability between the participants, he had some indication of the academic readiness of the participants (their ability and skill, which included critical thinking) to cope with learning at higher education level) (Van der Silk & Weideman, 2008), based on the TAG/TALL results that were used to select the participants for the study. Participant 4 who demonstrated the most growth during the observations throughout the 13-week

intervention (*cf.* Table 6.5), actually had the lowest TAG /TALL test score (56%). Participant 3 showed poor performance in relation to the application of thinking skills during the observations, and her scores in the post-test were low too, indicating no growth in relation to any of the critical thinking skills and strategies. This finding does not correspond with her TAG/TALL results, as her score was above average, namely 64%. Participants 1 and 2 started with high TAG/TALL scores, 86% and 76% respectively, but participant 1 ultimately achieved growth only in relation to one of the critical thinking skills, and participant 2 achieved higher post-test scores in relation to only two of the critical thinking skills on which the research focused. The researcher argued that it was reasonable for him to assume that the participants, who according to the TAG/TALL results, achieved the highest levels of academic readiness, would have achieved the greatest growth during the intervention. This argument did not appear to apply in the context of the study.

- (vi) Another factor to consider in the interpretation of the findings is the time period between the last intervention session and the writing of the post-test (Arthur *et al.*, 1998) (*cf.* 3.2.3.9). The post-test was written one week after the last intervention session, and therefore it was carefully assumed that the short time lapse would not have had a tremendous impact on the decay of skills, that were possibly acquired during the intervention. This argument however, only seems to hold true for the growth noted regarding the application of the skill to make inferences, as the post-test results for three of the participants showed growth in relation to making inferences. In addition, it appeared that the time lapse between intervention and post-test also had a contrasting effect on the decay noted for the application of the skills in the post-test among the different participants (*cf.* Tables 6.1 – 6.4).
- The implementation of the intervention was framed within cognitive (Knowles *et al.*, 2014) (*cf.* 3.2.3.2) constructivist (Tobias & Duffy, 2009; Killen, 2015; Powell & Kalina, 2011) (*cf.* 3.2.3.3), transformative (Dirkx *et al.*, 2006; Grabove, 1997) (*cf.* 3.2.3.4) tangential (Armstrong, 2004; Leland, 2016) (*cf.* 3.2.3.8), and experiential teaching and learning theories (Breunig, 2009; Svingby & Nilsson, 2011) (*cf.* 3.2.3.5), as they support teaching and learning environments that would allow students to construct

own meaning and understanding, which could be regarded as important prerequisites for the development of thinking skills (Beard, 2010; Itin, 1999) (*cf.* 3.2.2.4). The data seem to support the value of framing teaching and learning within the mentioned frameworks, given the growth noted, especially for the dispositions and standards for reasoning, as well as for some of the critical thinking skills on which the research focused (*cf.* Tables 6.1 – 6.4). The element of independent, self-education in an enjoyable context that accompanied the video game play (*cf.* 6.7.1 – 6.7.8), could be regarded as instrumental for developing critical thinking (Sherry, 2001) (*cf.* 3.5.3). The interview data testified to the fun and motivational benefits of the puzzle video game (*cf.* 6.7.1 – 6.7.8). The researcher concludes that the experiential nature of the game Portal, which expected of participants to reflect on what they were thinking, possibly contributed mainly to the growth observed in relation to the disposition, and communicating thoughts and actions with logic, clarity and relevancy (*cf.* Tables 6.1 – 6.4).

- The intervention supported learning in a formal classroom context (Rogers, 2014), making use of informal, tangentially, self-directed, experiential learning (Cerasoli *et al.*, 2014; Dabbagh & Kitsantas, 2012; Mardis, 2013) that was not aligned to achieving learning objectives in an organised way (non-formal learning), as participants' interest was regarded as a driving force during their involvement in the intervention (Eaton, 2012; Rogers, 2014; Swann, 2012) (*cf.* 3.2.1, 3.2.1). The main activity involved the playing of the puzzle video game, and stimulating the development of critical thinking was regarded as a possible consequence of experiencing joy whilst playing the game (Coombs *et al.*, 1973; Rogers, 2014; UNESCO, 2012) (*cf.* 3.2.2). As there were some findings pointing to possible decay, or lack of transfer in relation to some of the critical thinking elements on which the study focused (*cf.* Tables 6.5, 6.6), it would seem to be more beneficial to combine informal and non-formal learning with a much stronger formal learning component, clearly conveying the intentionality (Isman & Tzuriel, 2008) (*cf.* 2.8.2) of the game play to the participants, to achieve greater benefits. In this regard, direct teaching comes to mind, as it is an effective strategy when the teacher's goal is to provide information, teach standard procedures and develop step-by-step skills (Arends, 2004; Burden & Byrd, 2003; Kramer, 2006; Monyai, 2006; Tuovinen & Sweller, 1999) (*cf.* 3.3.1). Critical thinking skills could be taught (Bligh,

2000; Boyles, 2004), demonstrated (Bruce *et al.*, 2009; McKee *et al.*, 2007), modelled (Abrami *et al.*, 2008; Zhao *et al.*, 2016), and its application reinforced by means of guided and independent practice, to enable students to become better at the application of critical thinking (*cf.* 3.3.1), before exposing them to the puzzle video game play. In essence, the differential influence that the puzzle video game had on the development of critical thinking among students, alerted the researcher to the fact that a one-size-fits-all approach to developing critical thinking should not be promoted.

In particular, regarding problem solving skills, very little instruction was given during puzzle game play to game players, who had to make use of their past experiences and intuitions to learn through trial-and-error (Granic *et al.*, 2014; Prensky, 2012). It would possibly be more beneficial to participants if they, before the time via linear, direct instruction, receive information about how to approach problem solving and select strategies for solving problems effectively.

- The intervention programme emphasised independent problem solving through enquiry (Barrett, 2010; Dostál & Gregar, 2015; Hung, 2011; Killen, 2015; Schmidt *et al.*, 2011) (*cf.* 3.3.3), and participants were expected to acquire critical thinking skills, dispositions and standards for reasoning during the game play. The use of a formal teaching strategy, namely the GROW problem solving model (Gorell, 2013) (*cf.* Table 1.1), that purposefully guided participants in systematic working ways and embedded the application of the dispositions and standards for reasoning on which the study focused within each of the steps of the strategy, may have, in particular, benefitted the growth and development of the dispositions and standards for reasoning, as presented in Tables 6.5 and 6.6.
- Completed research documenting the effects of games during teaching and learning, confirms positive effects for cognitive improvement in relation to lower cognitive skills, such as attention, perception, memory and executive functioning (All *et al.*, 2016; Baniqued *et al.*, 2013; Granic *et al.*, 2014; Green & Bavelier, 2012; Martinovic *et al.*, 2014) (*cf.* 3.5.3.4). There appears to be a lack of research to establish advancements for higher order skills (Arias, 2014) (*cf.* 3.5.2), such as critical thinking. As the focus of the researcher's study was on critical thinking skills, the preliminary findings of this small scale study do not convincingly and conclusively indicate that puzzle video

games hold benefits for advancing the development of higher order critical thinking skills through fun and motivating game play. The findings of the present research do not confirm the literature where it is stated that cognitive skills gained through video games are generalised to contexts outside the games (Bavelier *et al.*, 2012; Granic *et al.*, 2014) (*cf.* 3.5.3.4). The researcher concludes that the puzzle video game appeared to have had different effects on the development of critical thinking among the research participants. Besides, the educational value of the Portal video game is not yet convincing when observing the limited growth in relation to the critical thinking skills. According to Russell (1999), few studies conducted between 1928 and 1998, if any, were located in which the employment of technology (Computer Mediated Instruction, Computer Assisted Instruction) for purposes of providing instruction or teaching was found to be statistically significantly superior in terms of learning to other modes of instruction. The studies provide substantial evidence that “technology does not denigrate instruction” (p. xiii). The researcher takes cognizance of the view of Russell (1999), but argues that the findings of his study do not fully support Russell’s argument, as initial evidence of the potential of puzzle video games for enhancing the development of critical thinking could be deduced from the findings.

- The influence of experience versus inexperience with puzzle video game play on developing the elements of critical thinking in the context of the study, is not completely clear. Inexperience with playing video games might not necessarily have led to hampering the development of critical thinking in the context of the study (*cf.* 6.1.1.1). In particular, participant 2, who was the most inexperienced game player of the four participants, demonstrated improvement in two critical thinking skills (*cf.* Table 6.2). Participant 4 who had no experience with puzzle video games, also managed to achieve growth in three critical thinking skills as well as in relation to the dispositions and standards for reasoning (*cf.* Table 6.4). While this argument may be true, it could for example also be argued that the complete inexperience of participant 2, might have been partly responsible for the lack of growth noted for the development of the dispositions and standards for reasoning.
- The researcher acknowledges that certain student factors, such as reading ability, could have impacted on the application of critical thinking (Grabe, 2009; Liu, 2010; Pressley & Allington, 2014) (*cf.* 2.8.2.1) in the W-GCTA test. It would be necessary to

establish how able the participants were to comprehend and interpret the meaning of the test scenarios, to confirm findings in relation to growth, decay and retention of skills. In support of Feuerstein (2007), Floyd (2011), Lun *et al.* (2010), Manalo and Sheppard (2016), as well as Paton (2005) (*cf.* 2.8.3.2), language ability could have played an influential role in the application of effective critical, evaluative thinking in solving the problems in the W-GCTA test scenarios. All the participants complete their studies using English as an additional language, which could have obstructed active communication and feedback to the researcher about their game play during the intervention (Donald *et al.*, 2006) (*cf.* 2.8.3.2), and contributed to an inability to apply higher order thinking in solving the problem scenarios in the W-GCTA (Krashen & Brown, 2007) (*cf.* 2.8.3.2).

- An argument in the literature postulating that well-developed dispositions could enhance the quality of thinking (Facione, 2011; Profetto-McGrath, 2003) (*cf.* 2.3.3), was not supported by the study. Although the dispositions apparently benefitted from involvement in the PVG-CEP, the observed benefits in relation to improvement in the quality of the application of all the critical thinking skills, were not conclusively confirmed. The data obtained for participant 3, supports the argument of the researcher. Even though participant 3 managed to achieve growth in relation to all the dispositions and standards for reasoning, based on the post-test results, none of the critical thinking skills showed growth.

The next section discusses the findings of this study in relation to the aim and objectives set out in the beginning of the study.

7.5 FINDINGS IN RELATION TO THE AIM AND OBJECTIVES OF THE STUDY

The main aim of the study was two-fold. Firstly, to determine how sophisticated first-year BEd students are in the application of critical thinking, and secondly, based on the findings, to establish and explore how a PVG-CEP can support the development of critical thinking among first-year BEd students. The researcher endeavours to revisit the aim and objectives of the study in order to ascertain whether they have been achieved. Objectives 1 to 5 were literature related while objectives 6 to 8 were empirical related. The final

objective, objective 9, was based on the findings in order to inform future research on this topic.

Objective 1: To understand the elements of critical thinking

This objective was achieved through an in depth literature study in Chapter 2 that specifically focused on the conceptualisation critical thinking (*cf.* 2.2, 2.4, 2.4).

The elements of critical thinking (*cf.* 2.3.1) include interrelated core cognitive (analysis, inference, deduction, evaluation, interpretations, recognising assumptions) and meta-cognitive skills (explanation, self-regulation) (Facione, 1990; Reynolds, 2011; Watson & Glaser, 2002a) (*cf.* 2.3.2, 5.7.1.1). The critical thinking dispositions (Facione, 2000) link well with Costa and Kallick's Habits of Mind (Costa, 2009), and describe an individual's tendency or inclination to reason or think in a critical manner (*cf.* 2.3.3). Well-developed critical thinking skills will manifest in a number of observable intellectual traits during reasoning such as, intellectual humility, courage, empathy, autonomy, integrity, perseverance, confidence in reason and fairmindedness (Paul & Elder, 2006) (*cf.* 2.3.4). All critical thinking and reasoning always involves a number of activities, such as identifying the purpose of reasoning, questioning aimed at solving problems, reflecting on points of view, using data or information to understand reasoning, interpreting ideas and concepts, and identifying implications and consequences (Paul & Elder, 2007) (*cf.* 2.3.5). When reasoning or applying critical thinking skills, cognisance should be taken of universal standards to which reasoning or critical thinking should adhere to. These universal standards include reasoning with clarity, accuracy, precision, relevance, significance, breadth, logic, completeness, and fairness (Paul & Elder, 2006) (*cf.* 2.3.6).

Given the conceptualisation in the literature, the researcher developed his own conceptualisation of critical thinking for the context of the study (*cf.* 2.3.7). This conceptualisation comprised three different elements. Firstly, it involved the application of various core cognitive and meta-cognitive critical thinking skills, which align with the skills assessed in the W-GCTA test, and were also required for playing the Portal puzzle video game, namely cognitive skills such as making inferences, recognising assumptions, making deductions, doing interpretations, and evaluating arguments (Facione, 2009) (*cf.*

2.3.7), as well as a meta-cognitive skill that involves self-regulated, reflective thinking (Reynolds, 2011) (*cf.* 2.3.2).

The second element involved the application of critical thinking dispositions such as working systematically, with persistence and accuracy (Facione, 2000) (*cf.* 2.3.3), and the third element entailed adhering to standards for reasoning, which included logic, clarity and relevancy (Paul & Elder, 2006).

The number of dispositions and standards for reasoning that were addressed in the study, were reduced to enable more reliable observations during the implementation of the intervention, and to include only those regarded as most relevant in the context of the game.

Objective 2: To determine why critical thinking is important for first-year BEd students

Objective 2 was achieved through the literature review in Chapter 2 (*cf.* 2.6). Well-developed critical thinking skills are important for problem solving (Glaser, 1941; Hung, 2011; Schmidt *et al.*, 2011) (*cf.* 3.3.3). At university level, the demands for students to solve problems through critical reasoning and arguing about topics in an academic context are crucial (Pienaar, 2001). According to Pienaar (2001), higher-order critical thinking processes such as problem solving, is essential for critical reading and understanding. At the same time, these processes augur well with the set of critical, generic, exit-level outcomes that are valued at Higher Education level and stand central to the objectives to be achieved with the teacher-training programme at the university that took part in the study (*cf.* 1.1, 2.6.1). The CAPS Grades R-12 continues to support teaching and learning that should nurture the cognitive and meta-cognitive skills as well as dispositions and standard for reasoning that are important for critical thinking (Department of Basic Education, 2011) (*cf.* 1.1). Therefore, teachers should be trained to teach critical thinking to students at schools. It is assumed that in order to teach critical thinking, teachers need to possess the skills themselves before being able to teach these skills to students.

Critical thinking is regarded as a necessary skill for achievement and success in a 21st century society and workplace, to prepare students for achievement in a rapidly changing,

digital society (Dede, 2010; Goldrick-Rab, 2010; Trilling & Fadel, 2009) (*cf.* 2.6.2), and to enable them to become effective at problem solving; and dealing with work-place, global and life challenges (Barell, 2010; Dede, 2010; Eyre, 2016; Gardner, 2010) (*cf.* 2.6.2). Decision making takes place on a daily basis in relation to numerous issues, such as health, diet, and exercise. According to Brettenny (2017), and Brookfield (2012), making rational decisions that rely on critical thinking, are important for survival (*cf.* 2.6.3).

Objective 3: To establish how critical thinking could be effectively developed

This objective was achieved through an in depth literature study that analysed formal, informal and non-formal learning contexts (*cf.* 3.2.1, 3.2.2). The literature review encouraged the researcher to implement the intervention in a context that displayed elements of formal, informal and non-formal learning. The participants took part in the intervention programme within a controlled formal classroom environment in which some form of guidance was provided by the researcher with the use of the GROW problem solving model. Informally, the participants were involved in self-directed, experiential learning not aligned to curriculum learning material, by playing a video puzzle game (Abrami *et al.*, 2008; Case, 2005; Dabbagh & Kitsantas, 2012; Mardis, 2013; Rogers, 2014) (*cf.* 3.2.1, 3.2.2). Non-formal learning was supported (Eaton, 2012; Rogers, 2013; Swann, 2012) (*cf.* 3.2.2), as the video puzzle game play did not result in working towards achieving formal learning objectives in an organised way, but promoted the extra-curricular development of skills and capabilities.

The development of critical thinking is promoted when teaching and learning are structured on the principles of the following theories of teaching and learning: Cognitive (Ertmer & Newby, 1993; Knowles *et al.*, 2014; Merrill, 2009) (*cf.* 3.2.3.2), constructivist (Bächtold, 2013; Duffy & Jonassen, 2013; Tobias & Duffy, 2009; Killen, 2015; Powell & Kalina, 2009) (*cf.* 3.2.3.3), transformative (Dirkx *et al.*, 2006; Grabove, 1997) (*cf.* 3.2.3.4), experiential (Breunig, 2009; Svingby & Nilsson, 2011; Kolb, 2014) (*cf.* 3.2.3.5), structural cognitive modifiability (Feuerstein *et al.*, 2010) (*cf.* 3.2.3.6), mediated learning (Fraser, 2006) (*cf.* 3.2.3.7), tangential learning (Armstrong, 2004; Leland, 2016) (*cf.* 3.2.3.8), and transfer of learning theories (Bransford *et al.*, 2000) (*cf.* 3.2.3.9).

Additionally, indirect teaching (Arends, 2004; Borich, 2003; Chai & Khine, 2008; Kramer, 2006) (*cf.* 3.3.2), independent teaching (Borich, 2003; Ognibene, 2007; Philpott, 2009; Wallace *et al.*, 2007) that involves problem solving and enquiry-based learning (Barrett, 2010; Hung, 2011; Killen, 2015; Schmidt *et al.*, 2011; (*cf.* 3.3.3), as well as interactive teaching (Arends, 2004; Kramer, 2006) (*cf.* 3.3.4), support the development of critical thinking.

Classrooms conducive to the development of critical thinking (*cf.* 3.4), display the following characteristics: The asking of frequent evaluative questions (Browne & Freeman, 2000; Green & Murris, 2014) (*cf.* 3.4.1), encouraging active learning (Bean, 2011) (*cf.* 3.4.2), and creating developmental tension (Mathews & Lowe, 2011) (*cf.* 3.4.3).

Objective 4: To establish what role puzzle video games play in developing critical thinking

This objective was achieved by means of a literature review (*cf.* 3.5). Puzzle video games form part of a genre of video games that emphasise puzzle solving (Rollings & Adams, 2006) (*cf.* 3.5.4) for which the application of critical thinking is important. Puzzle solving tests the application of problem solving skills that include pattern recognition, sequence solving, and word completion. Players are often faced with limited time or attempts to solve a puzzle, or there might be simple puzzles made difficult by having to complete them in real-time (Rollings & Adams, 2006) (*cf.* 3.5.4). Puzzle video games emphasise working in a VIE, for which higher order thinking is essential (Rice, 2007) (*cf.* 3.5.4.3). Higher order thinking is essential for working in the virtual interactive environment (VIE) that is presented in puzzle video games, as these games comprise complex three-dimensional graphics, that offer numerous challenging opportunities for students to participate in higher level thinking (Rice, 2007). The interaction during game play does not merely imply mechanical efforts as in arcade games, but it develops mental processes. A player is activated to fervently learn novel knowledge and combine it with existing knowledge for new purposes (Gee, 2003b).

Video games in general appear to have positive (All *et al.*, 2016; Granic *et al.*, 2014) (*cf.* 3.5.3.4) and negative (Connolly *et al.*, 2012) (*cf.* 3.5.3.3) effects on people. The positive effects that video games have and what they hold for people include the among others,

the development of cognitive skills (All *et al.*, 2016; Greenfield, 1994; Nauert, 2013; Wouters & Van Oostendorp, 2017) as well as the application of logic thinking (Miller, 2005) (*cf.* 3.5.4).

A prominent finding from the literature review indicated that the greatest impact was noted for perception, spatial cognition and attention. A weak impact was noted for enhancing verbal cognition and controlling inhibition, and no impact for improving problem solving was found (Bavelier *et al.*, 2018) (*cf.* 3.5.3.4). Lower order thinking skills, such as perception, memory and executive function seem to benefit from involvement in game play (Baniqued *et al.*, 2013; Martinovic *et al.*, 2014). There appears to be a lack of well-designed quantitative studies that document the effects of game play for developing higher order thinking skills and dispositions (All *et al.*, 2016; Arias, 2014; Connolly *et al.*, 2012). Linked to the latter finding, the researcher wished to make an initial, exploratory contribution.

Objective 5: To identify which puzzle video games would be best suited to develop critical thinking

This objective was achieved through an in depth literature review on puzzle video games, through which the video game Portal was identified (Ramadge, 2011) (*cf.* 3.5.4.3). Puzzle video games present players with a problem that needs solving that require the application of critical thinking. Action puzzle games (Nelson & Strachan, 2009:1678), expect of participants to sort blocks or pieces correctly, such as Tetris, Klax and Lumines (Thompson, 2007). Others, present a pre-set game board or pieces and challenge the player to solve the puzzle by achieving a goal (Bomberman, The Incredible Machine) (Thompson, 2007). Hidden object games expect of players to find items from a list that are hidden within a picture (Juul, 2007). Reveal the picture games is a type of puzzle game that features piece-by-piece revealing of a photo or picture (Juul, 2007). A physics game is a type of puzzle video game where the player must use realistic physics to complete each puzzle (Wolf, 2008). During tile-matching video games, the player manipulates tiles in order to make them disappear according to a matching criterion (DeMaria & Wilson, 2003). Traditional puzzle games include solitaire, word puzzles, number puzzles, and association puzzles (Juul, 2007). Portal video games form a subgenre of puzzle video games, and was chosen to be part of the intervention, as the

literature revealed its merits for nurturing higher order thinking (Rice, 2007) (*cf.* 3.5.4.3), and for having found application in educational aspects outside of game development (Schiller, 2008; Yamasaki, 2016) (*cf.* 3.5.4.3). The Portal games include elements of action and the application of physics principles (*cf.* 3.5.4.2, 3.5.4.3).

Objective 6: To determine how effective BEd students are at applying critical thinking skills before and after taking part in the PVG-CEP intervention

This objective was achieved by analysing and interpreting the W-GCTA pre- and post-test results, supported by the observations, in relation to making inferences, recognising assumptions, making deductions, doing interpretations, and evaluating arguments (*cf.* 6.3, 6.4, 6.5).

Participant 1 (*cf.* Graph 6.1, Table 6.1), demonstrated apparent growth in one critical thinking skill, namely making inferences. For one skill, namely making deductions, decay was noted in the post-test results, and stagnation for three skills, namely recognising assumptions, doing interpretations, and evaluating arguments. According to the test-totals, participant 1 seemingly started the research at practicing level of thinking (*cf.* 2.5.4), which remained constant during the post-test (Graph 6.49).

Participant 2 (*cf.* Graph 6.13, Table 6.2) demonstrated growth in two critical thinking skills, namely making inferences and recognising assumptions. The pre- and post-test results for three skills, namely making deductions, doing interpretations, and evaluating arguments indicated similar levels of thinking, namely beginning levels of thinking (*cf.* 2.5.3), thus implying no growth. Overall, participant 2 seemingly started out as an apparent beginning thinker (*cf.* 2.5.3), who achieved limited growth towards practicing level of thinking (*cf.* 2.5.4) (*cf.* Graph 6.49).

According to Table 6.3, the post-test results of **Participant 3** indicated that none of the critical thinking skills improved. The pre- and post-tests result for doing interpretations and making inferences remained the same during the pre- and post-test, namely at beginning levels of thinking (*cf.* 2.5.3), and making deductions remained at practicing level of thinking during the pre- and the post-test (*cf.* 2.5.4). Decay was noted in the application of two skills, namely evaluation of arguments, from practicing to beginning levels of thinking, and recognising assumptions from advanced/master level to practicing level.

Overall, participant 3's post-test results did not improve, and he could be considered a practicing thinker at the outset of the study, who remained a practicing thinker (*cf.* 2.5.4), during the post-test, although some decline in the post-test result was noted (*cf.* Graph 6.49).

Participant 4 demonstrated growth for three skills, when comparing the pre- and post-test results (*cf.* Table 6.4). Making inferences apparently developed from an unreflective and a challenged level (*cf.* 2.5.1, 2.5.2), to practicing level of thinking (*cf.* 2.5.4). Making deductions, started out at an unreflective and a challenged level of thinking (*cf.* 2.5.1, 2.5.2), and developed to beginning level (*cf.* 2.5.3) of thinking during the post-test. Doing interpretations, which started out at beginning level of thinking (*cf.* 2.5.3), seemed to develop to practicing level of thinking (*cf.* 2.5.4) during the post-test. For one of the skills a decline in the post-test results was noted, namely for recognising assumptions, that started at advanced/master level of thinking (*cf.* 2.5.5, 2.5.6), and its application decayed to practicing level of thinking (*cf.* 2.5.4). Evaluating arguments, which started at beginning levels of thinking, apparently remained at beginning level of thinking during the post-test (*cf.* 2.5.3). In relation to the overall test results, participant 4 could be regarded as a beginning thinker at the outset of the study, showing signs of growth towards becoming a practicing thinker (*cf.* 2.5.4) based on the post-test results (*cf.* Graph 6.49).

Observation data were gathered to support the data obtained with the pre- and post-tests. Although the observations did not fully support the pre- and post-test results, the following evidence of congruence between test and observation data could be identified: The growth observed in relation to critical thinking skills among participants 1, 3 and 4, was confirmed by the growth noted in the observations as well. In addition, no growth was observed for participant 4 regarding the recognition of assumptions, and the post-test result also pointed to a decline, from advanced/master level of thinking to practicing level of thinking.

The effectiveness of the participants in the control group (*cf.* Graph 6.54) who did not take part in the intervention, indicated that **participant 5** demonstrated growth in one skill only, namely making inferences, which started in the pre-test on a beginning thinker level, improving to practicing thinker levels. Stagnation was evident for two skills, namely deduction and interpretation, which both started in the pre-test on beginning thinker

levels, stagnating in the post-test at beginning thinker levels. Decay was noted in the application of two skills, namely recognising assumptions and evaluating arguments. Recognising assumptions started in the pre-test at advanced/master levels, declining to practicing thinker levels in the post-test. Evaluating arguments started at practicing thinker levels in the pre-test, ultimately declining to beginning thinker levels in the post-test (*cf.* Graph 6.50). Overall, the pre- and post-test results report that participant 5 started at practicing level of thinking in the pre-test, and remained at practicing level during the post-test (*cf.* Graph 6.50).

In terms of the total test result, **Participant 6**, started out as a beginning thinker, and remained a beginning thinker, as revealed by the pre- and post-test totals (*cf.* Graph 6.50). Participant 6 apparently demonstrated growth for two skills (*cf.* Graph 6.51), namely making inferences and recognition of assumptions. Making inferences started out at an unreflective and a challenged thinker level in the pre-test, and improved towards a beginning thinking level in the post-test. Recognition of assumptions began at beginning thinker levels in the pre-test, and improved towards practicing levels in the post-test. Two skills apparently did not improve, namely making deductions and the evaluation of arguments. Making deductions started and remained at practicing thinker levels, whereas evaluation of arguments started and remained at beginning thinker levels. For one skill, decay in performance was noted, namely doing interpretations, which started at beginning thinker levels in the pre-test and decayed to unreflective/challenged thinking levels in the post-test.

Participant 7 also started as a beginning thinker in the pre-test for two skills, namely making inferences and deductions. During the post-test growth was noted towards becoming a practicing thinker (*cf.* Graph 6.52). Graph 6.52, indicates that participant 7 seemingly started as an unreflective and a challenged thinker for the recognition of assumptions during the pre-test, who developed to become a practicing thinker in the post-test. Furthermore, participant 7 started as a practicing thinker in relation to the evaluation of arguments in the pre-test, becoming an advanced/master thinker in the post-test. Similar levels of thinking were noted between the pre- and post-test results for doing interpretations that started and remained at practicing levels of thinking. The pre- and

post-test totals revealed that participant 7 who started at beginning level of thinking, ended at practicing levels of thinking (*cf.* Graph 6.54).

The post-test total result for **participant 8** (*cf.* Graph 6.54) showed decline. The participant started at practicing level, and ended at beginning level of thinking. Participant 8 started as a beginning thinker in the pre-test for making inferences, who showed growth towards becoming a practicing thinker in the post-test. For recognising assumptions, participant 8 started as a practicing thinker whose post-test result stagnated at the same level. Making deductions, was assessed in the pre-test at practicing thinking level, but the post-test results showed a decline towards a beginning thinking level. Regarding making interpretations, participant 8 started as a beginning thinker level and remained at beginning thinking level during the post-test. The application of skills to evaluate arguments demonstrated decay during the post-test, as the participant moved from advanced/master level during the pre-test to practicing level of thinking.

In addition, a comparisons of test results within and across the experimental and control groups indicated the following:

- No statistical significant differences occurred between the pre- and post-test results within the experimental group for any of the five skills on which the W-GCTA focused (*cf.* Table 6.8).
- No statistical significant differences occurred within the control group between the pre- and post-tests for any of the five skills on which the W-GCTA focused (*cf.* Table 6.9).
- No statistical significant differences were observed between the pre-test results of the experimental and control groups in relation to the five sub-tests on which the W-GCTA focused (*cf.* Table 6.10).
- No statistical significant differences occurred between the post-test results of the experimental and control groups in relation to the five critical thinking skills on which the W-GCTA appraisal focused (*cf.* Table 6.11).

Objective 7: To explore how effective BEd students are at applying critical thinking dispositions and standards for reasoning at the onset, and end of the PVG-CEP intervention.

This objective was achieved by means of the observations, accompanied by anecdotal records and video recordings throughout the intervention programme over the course of 13 weeks (*cf.* 6.3). There was no test available to establish the application of dispositions and standards for reasoning at the outset of the study. The researcher based his judgements on a comparison between the observations for the first week and week 13. Only the participants of the experimental group were involved in the observations that determined growth in relation to the dispositions and standards for reasoning.

Participant 1 demonstrated growth in relation to all the dispositions and standards for reasoning as follows:

- Systematic working ways: Growth noticed from novice to sophisticated level.
- Persistence: Growth noticed from able to sophisticated level.
- Accuracy: Growth noticed from novice to sophisticated level.
- Logic: Growth noticed from novice to sophisticated level.
- Clarity: Growth noticed from able/skilled/sophisticated level.
- Relevancy: Growth noticed from novice to sophisticated level (*cf.* Table 6.1, Graphs 6.7 – 6.12).

Participant 2 demonstrated no growth in relation to the dispositions and standards for reasoning (*cf.* Table 6.2, Graphs 6.19 – 6.24).

Participant 3 demonstrated growth in relation to all the dispositions and standards for reasoning as follows:

- Systematic working ways: Growth noticed from novice to skilled level.
- Persistence: Growth noticed from novice to skilled level.
- Accuracy: Growth noticed from novice to skilled level.
- Logic: Growth noticed from novice to skilled level.
- Clarity: Growth noticed from novice to able level.

- Relevancy: Growth noticed from novice to skilled level (*cf.* Table 6.3, Graphs 6.31 – 6.36).

Participant 4 demonstrated growth in relation to all the dispositions and standards for reasoning as follows:

- Systematic working ways: Growth noticed from able to sophisticated level.
- Persistence: Growth noticed from able to sophisticated.
- Accuracy: Growth noticed from able to sophisticated level.
- Logic: Growth noticed from able to sophisticated level.
- Clarity: Growth noticed from able to sophisticated level.
- Relevancy: Growth noticed from able to sophisticated level (*cf.* Table 6.4, Graphs 6.43 – 6.48).

Objective 8: To explore the student participants' perceptions and experiences regarding the development of critical thinking through a puzzle video game

This objective was achieved through empirical research at the conclusion of the intervention programme and post-tests. Semi-structured, one-on-one interviews were conducted with the four participants in the experimental group who took part in the intervention programme (*cf.* 6.6).

The interview data revealed that participant 1 had some experience playing video games, but no experience playing puzzle games (*cf.* 6.6.1). The routine pressure of the complex puzzles helped him with developing skills for problem solving (*cf.* 6.6.2). He noted that the game was enjoyable (*cf.* 6.6.3), not too difficult (*cf.* 6.6.4), and benefitted his academic work (*cf.* 6.6.5), and felt that his attention and focus were enhanced (*cf.* 6.6.4) and that he started taking care to not rush things off (*cf.* 6.6.7). He experienced a sense of encouragement and accomplishment during the game play (*cf.* 6.6.6), and thinks that games are more engaging than formal teaching and can teach content more effectively than in a formal classroom (*cf.* 6.6.8).

Participant 2 had no experience playing video puzzle games (*cf.* 6.6.1). Her experience with the game was positive (*cf.* 6.6.3), and provided cognitive stimulation (*cf.* 6.6.2), was

enjoyable (*cf.* 6.6.4), held cognitive benefits (*cf.* 6.6.5), produced feelings of happiness and gave her a sense of achievement (*cf.* 6.6.6). She believed that her problem solving skills were enhanced, due to the attention grabbing nature of the game (*cf.* 6.6.7). She regarded the use of games more effective than formal teaching that she found to be tedious and repetitive (*cf.* 6.6.8).

Participant 3 had some experience playing video games, but no specific experience in playing puzzle games (*cf.* 6.6.1). She described her experiences with the game as thoughtful; the game provided cognitive stimulation and supported goal driven work (*cf.* 6.6.2), provided opportunity for exploratory experience (*cf.* 6.6.3), and she indicated that she had no issues playing the game (*cf.* 6.6.4). According to her, the game benefitted her cognitive abilities and the ability to plan to achieve goals (*cf.* 6.6.5). During game play, she felt a sense of achievement and excitement (*cf.* 6.6.6), believed that her critical thinking and problem solving skills were enhanced (*cf.* 6.6.7). She found that video games allow for experiential learning, and are more enjoyable than formal classrooms (*cf.* 6.6.8).

Participant 4 had a lot of experience playing games but that he had never played puzzle games before (*cf.* 6.6.1), and found that cognitive stimulation was advanced by the game play (*cf.* 6.6.2). His experience with the intervention programme entailed solving problems and progressing from one stage to the next (*cf.* 6.6.3), that improved his cognitive abilities (*cf.* 6.6.4). Although he found the game play difficult, it benefitted his independent thinking (*cf.* 6.6.5), as he had to think on his own, and overcome challenges (*cf.* 6.6.6). According to participant 4, the puzzle game can develop critical thinking and problem solving skills (*cf.* 6.6.7), make learning fun, and improve attention and focus, which is not the case with learning in formal classrooms that get boring because concentration gets lost (*cf.* 6.6.8).

In summary, the participants cited general benefits, specific benefits, as well as challenges in relation to the development of critical thinking. The general benefits included aspects of enjoyment, fun, excitement and happiness, as well as developmental achievement, challenge and accomplishment. Specific benefits comprised cognitive and emotional benefits. Cognitive benefits include: Cognitive stimulation, enhancing thinking skills, cognitive improvement, independent thinking, goal driven planning, accuracy, attention, and improved concentration. Emotional benefits comprise motivation to learn,

task involvement, engagement, and experiencing fun. A few challenges included game difficulty, discomfort playing the game, lack of time and understanding game expectations.

Objective 9: To develop novel guidelines for including the use of puzzle video games during teaching to develop critical thinking among first-year BEd students.

This objective was achieved by evaluating the implementation of the PVG-CEP intervention and based on the outcome of the evaluation, to construct guidelines that could assist future implementers of Portal or any other puzzle video games to achieve greater success. The researcher reports the guidelines in section 7.7 of this chapter.

The next section will look at the recommendations that flow from the completed study.

7.6 RECOMMENDATIONS

7.6.1 Recommendations for developing critical thinking skills

The recommendations made by the researcher align with the findings obtained for the growth noted among the participants in relation to the application of the critical thinking skills according to the data, as well as the literature review.

Findings revealed that:

- Making inferences was the skill that apparently benefitted the most from the intervention in terms of growth.
- Participant 1 demonstrated improved growth in the application of inferential thinking.
- Participant 2 achieved growth in the application of making inferences and recognising assumptions.
- Participant 3 seemingly did not benefit from the intervention in relation to growth for the application of any of the critical thinking skills.
- Participant 4 apparently benefitted the most from the intervention, as the application of three of the critical thinking skills, namely making inferences and deductions and doing interpretations, testify to growth.

- One of the skills, namely evaluation of arguments revealed no growth among any of the participants. It could be argued that its application therefore possibly did not benefit from the intervention (*cf.* Table 6.5).

Given the aforementioned, the researcher acknowledges that limited growth took place among the participants regarding the application of critical thinking skills.

Recommendation 1: In order to develop the mentioned skills, it might be helpful to include a few sessions that first outline to future participants what each of the critical thinking skills entails, and provide practical examples of how each of these skills would be used within the Portal video game before involving participants in the actual game play. In this way, participants could be informed ahead of time and directed regarding what type of thinking is required when facing a certain obstacle/puzzle, and what would be expected of them in relation to the application of specific skills to solve puzzle situations (Rath, 2015) (*cf.* 3.5.3).

Recommendation 2: The researcher would recommend making critical thinking skills development a part of formal classroom based instruction, embedded into subject content, in conjunction with the explicit approach to teach critical thinking by using puzzle video game play. A combined embedded and explicit approach to teaching critical thinking (Marin & Halpern, 2011) (*cf.* 2.8.1.2) would allow for more opportunities to practice the application of critical thinking that might contribute to better growth and retention. In the context of the research it became clear that the development of critical thinking possibly requires multiple approaches. In addition, as part of the embedded approach in a formal classroom situation, the demonstration and application of critical thinking skills could precede the application in puzzle video game play in order for participants to familiarise themselves with the skills, before they enter the game play situation. In this regard, Sitzmann (2011) (*cf.* 3.5.3.4) argues that game play combined with other instructional methods, yield higher levels of learning.

Recommendation 3: Although Wouters *et al.* (2013) (*cf.* 3.5.3.4) argue that single players achieve higher learning gains than those playing in a group, the researcher recommends utilising an interactive approach to a game intervention, or to anyone considering using the Portal puzzle video game for educational purposes. Interactive

instruction depends significantly on discussion and sharing between participants. Students can learn from each other and teachers to develop social skills and abilities, to consolidate their thoughts and to develop cogent arguments (Arends, 2004; Kramer, 2006) (*cf.* 3.3.4) during the game play, which could be beneficial for the development of critical thinking. Being involved in discussions stimulate thinking critically about issues and developing skills of analysis, synthesis and evaluation, as well as generating new ideas, therefore stimulating divergent or lateral thinking (Brookfield, 2012) (*cf.* 3.3.4, 3.4.1).

7.6.2 Recommendations for developing dispositions

The recommendations made by the researcher align with the findings obtained for the growth and development noted among the participants in relation to the dispositions of persistence, accuracy and systematic working ways, as well as the literature review.

Findings revealed that all participants in the experimental group showed signs of growth for all of the dispositions, except for participant 2, for whom no growth was noted. In the context of using the Portal game in future for developing critical thinking dispositions, the researcher recommends the following that could possibly enhance greater growth.

Recommendation 1: In support of the suggestions by All *et al.* (2016) (*cf.* 4.4), who assert that an implementer or trainer in the context of game-based learning, should be able to provide help with the development of procedures, the researcher recommends the following. When implementing an intervention programme like the PVG-CEP, the implementer of the intervention should receive formal training in the application of mediated learning (Feuerstein & Feuerstein, 1991) (*cf.* 3.2.3.7), with specific emphasis on knowing how to effectively probe and promote the development of the critical thinking dispositions. This is needed in order for the implementer to understand the ways in which dispositions can manifest during learning, as an untrained mediator may miss the finer details and behaviours being displayed. Although the researcher was trained in applying mediated learning, he was of the opinion that the training which he received, did not specifically alert him to probe and assess the development of dispositions and standards for reasoning effectively.

Recommendation 2: The researcher also recommends that when students participate in a programme similar to the PVG-CEP, specific checklists with criteria be designed that participants will need to utilise during each problem solving activity, in order to promote accuracy, persistence and systematicity explicitly during the game play. In the context of the present study, this checklist would include ticking off every step of the GROW model for example, by stating questions such as “Did you identify your goal?” or “Did you check your environment for all objects?” An example of this checklist in relation to the game play in Portal, is provided below.

Table 7.1: Example of a checklist to promote accuracy and persistence

Checklist for test chamber		
	Yes	No
Did I locate the goal of this chamber?		
Did I manage to observe the test chamber and locate all obstacles?		
Was I able to identify which objects can help me solve the puzzle?		
Did I try to implement a solution which would help me progress?		
If I made mistakes, did I try to rethink my solution and try another approach?		
Did I try to recognise any assumptions I may have had regarding all puzzle elements?		

Recommendation 3: Although the researcher paid no attention to clarify the importance and value of applying dispositions when engaged in thinking tasks, the use of the GROW model seemed to have benefitted the participants to persist in working more systematically and accurately, given the growth noted for the dispositions (*cf.* Table 6.5, 6.6). It is however important when developing dispositions, to pay attention to a number of dimensions, namely: meaning, value, capacity, alertness and commitment (Anderson, 2010) (*cf.* 2.5.7). The meaning attached to a disposition should develop from narrow to complex, implying that dispositions should hold meaning for personal and academic life (Anderson, 2010). If the value of the disposition is clear, it is more likely that the motivation to apply the dispositions will increase (Anderson, 2010). As a set of strategies are required to apply the dispositions effectively, Anderson (2010) notes the importance of a

wide range of strategies to develop the dispositions. According to Anderson (2010) and Costa and Kallick (2009a), improving the application of dispositions promotes alertness to situations that call for their application. Alertness implies that students should develop from being externally reminded to becoming internally accustomed as to when and why dispositions should be applied. Anderson (2010) identifies two broad approaches for increasing alertness, namely reducing direction or prompts from external agencies and secondly, teaching students explicitly to recognise situations that call for the application of dispositions. Developing the commitment dimension involves somebody who can effectively self-assess, self-direct and self-manage the development and growth of their dispositions without relying on external direction or prompts from a lecturer (Anderson, 2010; Costa & Kallick, 2009a). By ensuring that the development of dispositions align with the aforementioned dimensions, might contribute to promoting greater willingness among participants involved in puzzle game play, to apply good critical thinking.

Recommendation 4: Given the multidimensional nature of critical thinking, the researcher argues that throughout the entire involvement of participants during a puzzle video game, they should be sensitised continuously to the fact that critical thinking skills, dispositions, and universal standards for reasoning have to be utilised together, to qualify their thinking as proper critical thinking. Students need to acknowledge that when involved in problem solving during the game play, the outcome of the problem solving process will not be effective if dispositions such as accuracy and universal standards of reasoning, precision, clarity and relevancy are not applied during the problem solving process (Adler & Perkins, 2016; Cottrell, 2011; Grosser & Olivier, 2017; McPeck, 2015) (*cf.* 2.3.1).

Recommendation 5: The researcher suggests using more than one strategy to nurture the development of the critical thinking dispositions, to extend the participants' repertoire of strategies that could contribute to greater systematicity, accuracy and persistence. In conjunction with the GROW model, the Elements of a Plan strategy (Feuerstein & Hoffman, 1995), also provides an example of how systematicity, accuracy and persistence could be pursued during task completion or solving problems.

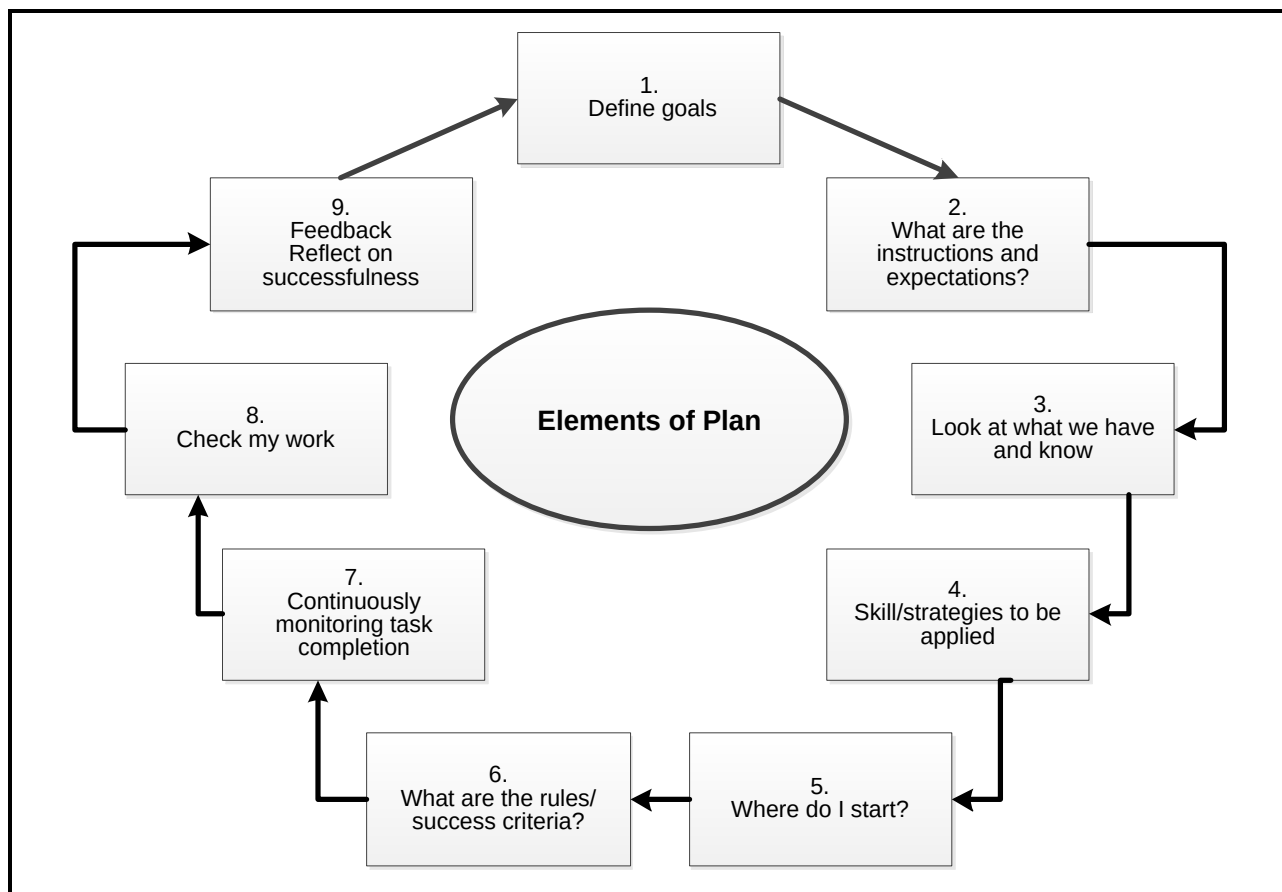


Figure 7.1: The Elements of a Plan strategy

(Adapted from Feuerstein & Hoffman, 1995, p. 5)

According to Figure 7.1, a step-by-step procedure guides problem solving and task completion. This recommendation aligns with the argument of Sitzmann (2011) (*cf.* 3.3), who argues that game play combined with other instructional methods, yield higher levels of learning.

7.6.3 Recommendations for developing universal standards for reasoning

Although the findings obtained revealed growth in relation to the universal standards for reasoning, namely logic, clarity and relevancy for all four participants (*cf.* Table 6.6), the researcher adds the following recommendations that could possibly encourage greater levels of growth.

Recommendation 1: The researcher recommends that the oral feedback procedure used during the game play, be supplemented with written feedback procedures, in the

form of written records that also need to be completed after solving each puzzle activity. Participants are then requested to reflect on their thoughts and actions during the game play in writing as well, therefore prompting the development of reasoning with clarity, logic and relevancy in written communication as well. An example of how written feedback could have been included during the Portal game play follows below in Table 7.2.

Table 7.2: Example of written feedback in Portal

1. Describe the test chamber. Which objects were located within the puzzle? _____ _____
2. Discuss the steps that you took in order to solve the puzzle. _____ _____
3. What mistakes or errors did you make in this puzzle? _____ _____
4. Why do you think you made these mistakes? _____ _____ _____ _____
5. Were any of your assumptions changed in this chamber? Explain. _____ _____

Recommendation 2: The researcher suggests that the role of the mediator during the implementation of the intervention should involve the use of continuous, purposeful questions to prompt participants to reflect on issues during the game play that could lead to improvement in reasoning with clarity, logic and relevance. Examples of questions that

could be used to nurture the development of logic, clarity and relevance during reasoning are provided in Table 7.3 below.

Table 7.3: Questions to prompt the development of standards for reasoning

Clarity	Logic	Relevance
How could you elaborate further?	How does all of this make sense together?	How does that relate to the problem?
Could you give me an example/more detail?	How does what you said first, fits with what you said last?	How does that bear on the question?
Could you illustrate what you mean?	Does what you say follow from evidence?	How does this help us with the issue?
Could you be more specific?	Why did your approach work?	Why did you perform that action?
Could you be more exact?	Why did your approach not work?	What were you thinking when you did this?
What were the consequences of your decisions?	Which steps did you take to solve this problem?	Can you tell me how you approached this problem?

(Adapted from Paul & Elder, 2006)

7.6.4 Recommendations for using puzzle video games to develop critical thinking

The researcher purposefully decided to make use of a puzzle video game Portal, as the game emphasises logical thinking, tests numerous problem solving skills comprising logic, pattern recognition, and sequence solving, for which critical thinking is required (Miller, 2005) (*cf.* 3.5.4.1).

Recommendation 1: It is recommended to use a variety of puzzle video games as they can test critical thinking in the best possible manner. There are a large variety of puzzle video games on the market, and the researcher would recommend using Portal, Quantum Conundrum, Antechamber and Perspective, which are all similar in game play, and very advanced in terms of puzzle dynamics, and require deep critical thought in order to solve the puzzles.

Recommendation 2: According to the literature, men and women appear to prefer distinct types of games. Although men and women tend to dislike cognitive challenging games, women appear to prefer puzzles, adventures, fighting and management games, and men prefer first person shooter, role playing strategy and competitive multi-player games (Amoru & Molomo, 2012) (*cf.* 3.5.3.2). The researcher suggests using a variety of games to compare and assess their potential for developing critical thinking among men and women. Examples of additional games to use for women and men respectively are: Age of Empires, Antichamber, Quantum Conundrum, Perspective and Total War. All of these games require critical thinking, with Age of Empires and Total War requiring tactical and strategic thinking in order to win in battles.

Recommendation 3: The researcher recommends that when choosing games that could potentially develop critical thinking, that the distinction amongst simple computer games and cognitive VIEs needs to be taken into account. The significant difference is that although simple games are valuable for classroom implementation (Squire & Jenkins, 2003) (*cf.* 3.5.4.3), cognitive VIEs deliver more appropriate examples for intricate exchanges, making them applicable situations within which higher order learning could happen (Rice, 2007) (*cf.* 3.5.4.3).

7.6.5 General recommendations

Recommendation 1: The researcher wishes to point out that the Department of Higher Education and Higher Education Institutions involved in teacher education should join hands in guiding lecturers in adopting specific video game-based approaches that would nurture critical thinking, in conjunction to the normal academic programme. This could take the form of extra classes that specifically require students to play games in a computer lab either after school or during a special period/timeslot during school hours.

Recommendation 2: Lecturers involved with teacher education should be trained to fully understand the meaning of critical thinking in an academic context, how it could best be nurtured and why it is important that it be nurtured.

Recommendation 3: The Department of Higher Education could initiate a nation-wide programme that requires universities to implement some form of puzzle video game initiative, in which compulsory modules are designed with the intention of developing

critical thinking among all students enrolled at those universities. This could lead to potential critical thinking development among all students, which could benefit them in terms of their academic work.

Recommendation 4: The researcher recommends that all lecturers be exposed to puzzle video games as well, in order to familiarise them with the function and purpose of these games, and to perhaps begin to implement these games supplementary to their subject specific modules in order to develop critical thinking outside of the classroom.

Recommendation 5: The findings of the present research will be revealed to the Department of Basic Education, with the aim of trying to motivate the use of puzzle video game play with the intention of developing critical thinking at primary and high schools across South Africa as an extra-curricular activity.

Recommendation 6: This particular study could be extended, in which subject specific video games, such as Age of Empires and Total War, or even standard video games such as Call of Duty and Battlefield that do not necessarily contain puzzles, be scrutinised for their effective usage within classroom settings for developing critical thinking.

Recommendation 7: It is crucial that teacher education moves away from a system that emphasises the banking of information to a system that acknowledges the importance of problem posing and dialogue to develop critical thinking.

Recommendation 8: According to Fahim and Hajimaghsoodi, (2014) (*cf.* 2.8.2.2) and Shamir *et al.*, 2006) (*cf.* 2.8.2.3) motivation and intention respectively, are necessary preconditions to support the willingness to become involved in the application of critical thinking. As the researcher did not establish the levels of motivation and intention at the outset of the study, it would be essential to establish the participants' levels of motivation and intention to become better at critical thinking, in order to gain a deeper understanding of the findings obtained.

The next section presents some novel guidelines that could enhance the development of critical thinking with puzzle video games.

7.7 NOVEL GUIDELINES TO DEVELOP CRITICAL THINKING WITH PUZZLE VIDEO GAMES

With the guidelines the researcher aims to streamline the process for implementing puzzle video games to develop critical thinking. The researcher therefore applied summative evaluation (McMillan & Schumacher, 2006) after the development and implementation of the puzzle video game intervention. The summative evaluation was objectives-oriented, and determined the extent to which the objectives with the intervention were successfully attained (McMillan & Schumacher, 2006). The outcomes of the evaluation process, provided the input for guidelines to be formulated that could improve future practice. The guidelines are not mandatory or binding, but provide broad advice for the future use of Portal or other puzzle video games with the purpose to develop critical thinking. In order to design the guidelines, the researcher made use of the frameworks suggested by the Austrian Development Cooperation (2009), and Markiewicz and Patrick (2016) to identify specific objectives that guided the summative evaluation process. These objectives included **relevance**, **effectiveness**, **efficiency**, **impact**, and **sustainability**, according to which guidelines were formulated.

7.7.1 Relevance

Relevance relate to the degree to which the aims of a development intervention was consistent with beneficiaries' needs, country and global needs and education priorities. In addition, consideration was given to the relevance of the data collection methods in the context of the research.

The intervention programme's objective was to develop critical thinking skills, dispositions and standards for reasoning through a puzzle video game. The beneficiaries in this case were the participants who took part in the experimental group. As these participants were BEd students, it is important for them to utilise critical thinking in their academic work, as well as to teach these skills one day to students whom they will teach (Department of Basic Education, 2011) (*cf.* 2.6.1). Over and above, critical thinking is regarded as a prerequisite for achievement and success in the 21st century and to preparing students for achievement in a quickly fluctuating, digital age (Dede, 2010; Goldrick-Rab, 2010) (*cf.*

2.6.2). Therefore, studies that would encourage the development of critical thinking skills would ultimately benefit participants in the 21st century.

Guideline 1: During the literature review it became clear to the researcher that the ideal to develop good critical thinkers through formal classroom-based teaching and learning has not yet been achieved (*cf.* 1.1). Therefore, the merits of other attempts, such as involving puzzle video games, should be explored to establish whether they could be regarded as beneficial in the long run for developing critical thinking. However, the puzzle game genre is wide and varied, and should therefore include exploration with different types of games that could promote critical thinking, such as Quantum Conundrum, Antichamber and Perspective, which are all very advanced in terms of puzzle dynamics, and require deep critical thought in order to solve the puzzles.

Guideline 2: The researcher would argue that the relevance of using puzzle video games with first-year BEd participants is high, as gaming is a rapidly growing entertainment medium which resonates with the youth today as a form of entertainment, and is widely distributed on a variety of platforms, including mobile devices. The researcher wishes to point out that it would be more relevant if the participants had a clear picture of what the critical thinking skills, dispositions and standards for reasoning entail, and why they need to acquire them before involving them in puzzle game play, as this would orientate them to better understand how the skills can be applied within the game play. Some form of background training would therefore be required to prepare participants adequately to benefit from game play. This could be facilitated by having sessions before actual game play commences.

Guideline 3: The researcher argues that the W-GCTA could be regarded as a relevant instrument to assess the development of critical thinking skills, when utilising a puzzle game intervention aimed at improving critical thinking skills in the South African context. Not only has reliability and validity been established for the use of the test with South African first-year BEd students (Lombard & Grosser, 2008) (*cf.* 5.10.1.1), but the test is also regarded to present the most comprehensive measure of critical thinking in comparison to other critical thinking tests (Watson & Glaser, 2002b) (*cf.* 5.10.1.1). The researcher would however suggest the use of a test specifically developed for the South African context, as the scenarios used in the W-GCTA might be unfamiliar to the South

African context. In addition, the UK English used in the test, might pose difficulty in interpreting the meaning of the various test scenarios.

As there is, to the best knowledge of the researcher, no critical thinking test that is constructed for the South African context, it would be meaningful if researchers and educationists, knowledgeable in the field of critical thinking, could construct a test for the South African context. Moreover, the test should also comprise sections that assess the integrated application of critical thinking skills, dispositions and standards for reasoning as well, in order to have a reliable and valid base line assessment of all the elements of critical thinking before taking part in a puzzle game intervention.

Guideline 4: The researcher would also argue that the skills developed during the intervention should also be developed beyond the intervention. With respect to the aforementioned, the researcher suggests that participants should be encouraged to play any other similar puzzle video game in their own time, at home, where the skills could be practiced, reinforced and probably retained better.

7.7.2 Effectiveness

In terms of effectiveness, the researcher considered firstly, whether the objectives that were to be achieved with the intervention were indeed achieved, and secondly how meaningful the effectiveness or impact of the intervention was.

The puzzle game intervention programme aimed to develop critical thinking skills, dispositions and standards for reasoning. The findings in relation to the critical thinking skills showed that three participants showed growth for making inferences, one participant showed growth for making deductions, one participant showed growth for recognising assumptions and one participant showed growth for doing interpretations. None of the participants achieved growth for evaluating arguments (*cf.* Table 6.5). In terms of the dispositions and standards for reasoning, findings revealed growth among all the participants for all the dispositions, which included systematic working ways, persistence, and accuracy, as well as for the standards of reasoning which comprised logic, clarity and relevancy, except for participant 2, who demonstrated no growth in relation to any of the dispositions and standard for reasoning (*cf.* Table 6.6).

In terms of how effective the intervention was, the researcher would argue that the intervention was only marginally effective in the development of critical thinking skills, as evaluation of arguments showed no growth whatsoever, and interpretation and assumptions only saw one participant achieving growth, leaving much room for improvement. The researcher argues that, in terms of dispositions and standards for reasoning, the intervention appeared to me more effective. The data obtained seem to necessitate that the PVG-CEP be redesigned in order to be more beneficial. In this regard, the researcher proposes the following:

Guideline 1: Future research with the Portal puzzle video game or any game should pay closer attention to the way in which participants provide feedback to the researcher in relation to what they are thinking or reflecting about when solving the various puzzles. If a written template with criteria is developed, according to which participants need to report at the end of every puzzle what they were thinking, how they approached the solving of the puzzle, what worked and did not work, it may provide the researcher with meaningful information about problem areas in relation to specific skills being developed that could be addressed before the next puzzle needs to be solved (*cf.* Table 7.2). Such a written report would give the researcher the opportunity to probe deeper into the nature and quality of the growth and development of skills, dispositions and standards for reasoning. The outcome of the written feedback could also allow for follow-up clarification discussions between the participant and the researcher, that will also expose the participants to expressing their thoughts and reflections more logically, relevantly and clearly, thus aiding the growth of standards for reasoning beyond the game context.

The written feedback would also enable a researcher to design focused attempts to enhance the weaknesses identified as the game progresses (Ennis, 2001) (*cf.* 2.7.1). Although not everybody might become advanced/master thinkers (*cf.* 2.5.5, 2.5.6), it is important that they learn what is required to become advanced/master thinkers.

Guideline 2: Further support could be given to participants to retain skills that they might acquire during the puzzle game play by perhaps allowing them to replay a test chamber that they had difficulty with before moving forward to the next level. Repetition could lead to better acquisition and retention of skills, dispositions and standards for reasoning.

Guideline 3: The intervention can be made more effective in terms of allowing interactive game play. Interactive game play would enable participants to learn from one another, communicate ideas and solutions and work as a team to solve problems. This could avoid situations where some participants got stuck, could not proceed, and could not give feedback about their thoughts and actions. Perhaps using strategy games such as Age of Empires or Total War that allow for strategic thinking as well as multiplayer interactivity could be considered.

Guideline 4: Participants might have been obstructed during the game play by not grasping the physics principles (Shute *et al.*, 2015) that applied during the solving of the puzzles in Portal (*cf.* 3.5.4.3). The researcher suggests that the physics principles underlying the game play in Portal be clarified and understood by participants before engaging them in the game.

Guideline 5: The development of critical thinking by means of puzzle video games might be more effective when informal and non-formal learning is combined with a much stronger formal learning component. Critical thinking skills, dispositions and standard for reasoning could first be explicitly taught (Bligh, 2000; Boyles, 2004), demonstrated (Bruce *et al.*, 2009; McKee *et al.*, 2007) and modelled (Abrami *et al.*, 2008; Zhao *et al.*, 2016), before participants are required to apply the skills in the puzzle video game context. It seems reasonable to argue that the puzzle video game intervention needs to enable participants first to understand the meaning and value of, and possess strategies to apply the skills, dispositions and standards of reasoning, before one can expect the participants to become committed and alert to their application (Anderson, 2010) (*cf.* 2.5.7).

7.7.3 Efficiency

Reflecting about efficiency involves considering the cost-benefit ratio, namely how economic the implementation of the intervention was in relation to the resources/inputs (funds, expertise, time, etc.) that were required for the results that were obtained.

Guideline 1: Given the findings that point to limited growth in terms of the critical thinking skills on which the research focused, the researcher argues that the input required for the implementation of the intervention might have outweighed the output.

In terms of time, the intervention could be regarded as efficient for participants, as the intervention did not disturb their normal lecturing time, and the time frames for their involvement were not too long to impact on their personal free time. The intervention lasted for 13 weeks and expected each participant to be involved in extra-curricular game play two hours per week when it suited them. However, if taking the researcher's own time into account, the intervention timetable was time consuming, as it took up eight hours a week additional to the researcher's normal lecturing duties. Perhaps a way to circumvent this would be to have a research team that could share the load in terms of handling the intervention, the observations and providing support to participants. This would necessitate that the team be trained in the video game Portal as well as the observation criteria and mediated learning support, in order to prevent, as far as possible, that dissimilar implementation occurs.

The observations were time consuming on the part of the researcher, who had to find a co-observer whom he had to train first. Moreover, the researcher had to deal with the analysis and interpretation of large volumes of data, as well as making decisions about the disparities that occurred between the observations of the researcher and co-observer. Guidelines to tackle this would be to limit the amount of skills, dispositions and standards for reasoning being observed. Including an independent evaluator as part of the intervention whose major purpose would be to observe with the aim to provide clarity in terms of disparities that might occur, would also ease the solving of problems regarding differences in observation.

Guideline 2: Resources needed for the intervention were minimal; only requiring a venue with a computer that has low-end hardware requirements and the video games Portal 1 and 2. The efficient structuring of the Portal games into chapters made it easy for the researcher to break up the activities into manageable sections that could be subdivided among the 13-week period. One participant noted that the 13-week intervention was too short for him. Perhaps a yearlong intervention should be considered where skills may be better developed. Arthur *et al.* (1998) (*cf.* 3.2.3.9) state that the quality and quantity of the skill acquired plays a significant role in decay and long-term retention. If skill acquisition is limited during the training situation, then retention becomes questionable. Therefore, it

is argued that if the duration of the intervention is increased, then the skills acquired could possibly be acquired and retained more effectively.

Guideline 3: The fact that all four participants in the experimental group had no background to the video game Portal (which was an exclusion criteria) meant that they all started very slow and needed a lot of support in the first two weeks to master the basic controls of the game. This could have hampered the efficient implementation of the intervention in the sense that the participants struggled for a while with game mechanics to enable them to move around effectively during the game play, and could not focus exclusively on solving the puzzles. The researcher strongly suggests that a few training sessions be added to the intervention, which will solely focus on preparing the participants in terms of how the game is played and how the controls work.

Guideline 4: Another guideline that could improve efficiency would be to have students reinforcing what they have acquired during one portal session, before the next session commences, ensuring proper retention of skills. In this regard, replaying the last test chamber from the previous session, in order to verify if the skills of that chamber were retained, is suggested. In addition, weaknesses could be pointed out explicitly and the participants motivated and guided to become better at their weaknesses (Anderson, 2010) (*cf.* 2.5.7).

Guideline 5: An obstacle that sometimes occurred related to late coming of participants for their game play sessions. To combat this, the researcher proposes that the entire intervention be done on the participants' own time either at home or on campus, where the researcher would be able to connect to the participants via a gaming streaming site like Twitch, that would enable the researcher to monitor and observe the participants' game play, and comment on the game play.

Guideline 6: Consideration should be paid to the utilisation of other strategies as opposed to the GROW strategy, to support the implementation of puzzle game play. In order to avoid a one-size-fits-all approach, other strategies or systematic plans could be used that may also benefit the participants in solving puzzle game problems (*cf.* Figure 7.1). The GROW model was mainly used as it fitted the game play of Portal, as each letter in the GROW model linked with observable traits in the game, such as a clearly

defined **goal** like an exit, **reality** being that the player needs to reach the exit, and that various **obstacles** prevent the player from getting to the exit. Lastly, the player must develop a **way** forward in order to progress to the exit. Perhaps allowing the students to become accustomed to other strategies, and allowing them to choose the one they are most comfortable with, may be the best solution in order to develop critical thinking in a puzzle video game context.

Guideline 7: The use of Portal to develop critical thinking itself may need to be considered when expecting participants to transfer the skills they probably acquired to a dissimilar context as in the case with the W-GCTA test. An example of other puzzle video games that are similar to Portal, namely Antechamber or Quantum Conundrum, could also be used to assess their effectiveness for transfer and retention of critical thinking to dissimilar situations. This will enable researchers to conclusively establish to what extent puzzle video games hold merits for the development of critical thinking and its application to contexts outside the puzzle video game.

7.7.4 Impact

The researcher considered whether the impact of the intervention was proportional to the overall situation of the participants. In this regard, positive and negative, primary and secondary long-term, direct or indirect, intended or unintended effects were considered.

Guideline 1: Positive/negative effects

According to the researcher, the intervention had some positive impact in terms of what it set out to achieve, namely the development of critical thinking skills, dispositions and standards for reasoning across the 13-week intervention period. The positive effects mainly relate to the qualitative growth that was noted for the dispositions and standards for reasoning. The qualitative observations regarding the development of the critical thinking skills seemingly yielded more positive effects than what the quantitative test measurement did. The researcher would therefore argue that standards for reasoning and dispositions also be tested quantitatively to reliably measure the impact of the intervention holistically. The growth of the dispositions and standards for reasoning was only assessed qualitatively in the context of the research.

Guideline 2: Primary/secondary effects

The primary effects of this intervention relate to the growth noted in relation to the development of critical thinking skills, dispositions and standards for reasoning. In playing the puzzle video game, the primary effects related to adapting thinking in order to solve the problems in the game, whilst secondary effects may have included include hand-eye coordination improving as well as attention levels due to finer focus being needed to solve the puzzles.

Guideline 3: Direct/indirect effects

The direct benefits of the intervention pertained to the development of critical thinking skills, dispositions and standards for reasoning. Indirectly, it is hoped that the skills, dispositions and standards for reasoning would ultimately be transferred to academic work, thus benefitting the participants in their assignments and when they do research or answer exam questions. Future research that employs puzzle video games for nurturing critical thinking should also establish whether growth that is noted during the gaming intervention also transfers to academic context.

Guideline 4: Intended/unintended effects

The intended effects envisaged with the intervention linked to growth that was expected in relation to the application of critical thinking skills, dispositions and standards of reasoning. Promising, unplanned effects that were observed during the implementation of the intervention included among others, enhanced attention and focus, goal driven work that was promoted by the challenging nature of the game play (*cf.* 6.6.4.2, 6.6.5.2). The mentioned unplanned effects open new angles for research in relation to the merits of puzzle video game interventions.

The researcher wishes to highlight further that in order to conclusively evaluate the effects of the PVG-CEP, and any other puzzle video game intervention, it would be necessary to look at other variables that could impact on critical thinking development, such as gender, motivation, age, culture, language ability and experience versus inexperience in puzzle video game play.

7.7.5 Sustainability

Considerations about the sustainability of the intervention involved looking objectively at the probability of continued long-term benefits.

Guideline 1: Sustainability could be assessed if the participants who took part in this study are requested to repeat the Portal puzzle video intervention to compare the first set of data with a new set of data to establish whether the growth that was noted for skills, dispositions and standards for reasoning, is retained, and whether additional growth might take place during a second implementation of the intervention.

Guideline 2: It would be very valuable if the participants could be exposed to a long-term puzzle video game intervention in order to establish the effect of growth, decay and retention of skills, dispositions and standards for reasoning over a long period of time. This suggestion is made, as Arthur *et al.* (1998) state, that the quality and quantity of the skill acquired plays a significant role in decay and long-term retention. If skill acquisition is limited during the training situation, then retention becomes questionable. Therefore, in order to maximise skill acquisition, it would be important to have extended opportunities to develop the said elements of critical thinking.

The following section highlights some of the limitations which the researcher observed during the implementation of the study.

7.8 LIMITATIONS OF THE STUDY

A number of limitations were identified regarding the research. Bearing these limitations in mind, the researcher acknowledges that only tentative conclusions regarding the potential benefits of the PVG-CEP intervention for the development of critical thinking among first-year BEd students can be formulated. The researcher identified the following limitations:

- The researcher focused only on developing critical thinking among 1st year BEd students, and did not include other year groups (2nd – 4th years), and students from other faculties. The sampled participants limit the study; as deeper insights into the development of critical thinking could be gleaned from studying the entire group of

BEd students, as well as students from other faculties. Domain specific studies could enhance insights into critical thinking further.

- Being a first, exploratory pilot study, the current sample was bound to only eight participants and therefore the results of this study cannot be generalised to other BEd students.
- The researcher used convenient sampling due to time and logistical constraints, and the researcher acknowledges that the convenient sample also limits the generalisability of the research findings.
- Further exploration in order to examine the effect of variables on the outcome of the research, could improve the internal validity of a study on critical thinking. These variables could include biographical variables, such as gender, age, culture, language ability, and experience versus inexperience in puzzle video game play. Establishing the influence of variables would however require more participants to be involved in the research.
- The researcher could not focus on all of the critical thinking dispositions and standards for reasoning as identified by the literature review (*cf.* 2.3.3, 2.3.6). Therefore, the impact of the intervention is not clear for all the dispositions and standards for reasoning.
- The study was limited to the use of the W-GCTA UK test. A critical thinking test specifically designed for the South African population could improve the reliability and validity of the findings. The multiple-choice questions in the test could be regarded as a draw-back, as the answers provided no indication of how a participant ended up with solutions to the problems posed in the test scenarios.
- Applying the raw score corrected for guessing option in scoring the W-GCTA test (*cf.* 5.10.1.1), might have provided a different picture of the participants' ability to apply critical thinking during the pre- and post-tests.
- The limited amount of time used for the intervention programme could also have limited the effectiveness of the programme. A longitudinal study may reveal more substantial results.

- The researcher did not involve the participants in the evaluation of the intervention. Involving the participants in the evaluation of the intervention could have enriched the novel guidelines formulated by the researcher, as the participants had first-hand experience of the game's merits and limitations.
- The researcher could have involved an external evaluator for an outside perspective and neutral stance toward the worth of the intervention.
- The researcher realised that he was still a novice in conducting interviews, as he established afterwards that he missed valuable opportunities to ask follow-up questions during the interviews that could have provided him with richer data. In this regard, a number of responses of the participants merely stated "yes" or "no", which the researcher did not follow up (*cf.* Appendix H 1:99; 2:98, 3:86, 4:52, 59, 62).
- The researcher is not sure to what extent normal classroom teaching during academic lectures addressed the development of critical thinking, which could have contributed to the findings observed among the participants of the experimental and control group. Normal academic lecturing might have influenced the outcome of the research.
- The researcher acknowledges that the classification used to interpret the W-GCTA test results, and the rating scale that guided the observations, might not have accurately captured the critical thinking developmental levels of the participants, which could have contributed to the discrepancies noted between the W-GCTA test results and the observations. Even though discrepancies were noted between the test results and the observations, there were also instances where congruence between the observations and classification levels for the test results were noted (*cf.* 7.5, objective 6).

In addition, participants might have resorted to guessing some of the answers, and therefore the test results might not have provided a true indication of their ability to think critically. When using the W-GCTA in future, it would be necessary to obtain deeper insight into the thinking processes of the research participants that lead to their test responses, in order to classify their test scores accurately according to the critical thinking developmental levels.

Nevertheless, the classification and rating scale provided an initial representation of how the nature of the participants critical thinking skills, dispositions and standards for reasoning could be interpreted. The classification and rating scale could be adjusted to be made more meticulous for follow-up studies.

Following the above-mentioned limitations, a few suggestions for further research will be proposed in the subsequent section.

7.9 SUGGESTIONS FOR FURTHER RESEARCH

Following the outcome of the study, the researcher makes the following suggestions for further research:

- Including more participants in the intervention can help to generalise the findings; therefore, the research should be conducted with more students in true experimental contexts.
- This same study can be done with other year groups, such as 2nd, 3rd and 4th year in the Faculty of Education to investigate any similarities and/or differences in the development of critical thinking among different year groups. Moreover, the same study can be carried out in different faculties as well, to understand the nature of critical thinking development across the entire range of degrees offered at university level.
- Further research needs to be conducted on how to address the implementation of the PVG-CEP within different university institutions, and to assess its effectiveness on a much wider scale.
- Interpretations of performance in the PVG-CEP in relation to different variables, such as gender, age, culture, socio-economic background, language ability and experience versus inexperience with puzzle video game play, could enrich and further explain the findings of the present study.
- Comparing the effects of the PVG-CEP intervention with the effects of ordinary classroom teaching that nurtures critical thinking in subject content would provide deeper insight into the possibilities of dealing with the development of critical thinking within, and detached from subject content.

- Research needs to establish the extent to which skills, dispositions and standards for reasoning acquired out of subject context, are effectively transferred to subject context.
- Conducting research to determine the time required for critical thinking skills to be acquired, and retained successfully.
- Developing measures to assess and align the responses of participants to the W-GCTA with the critical thinking developmental levels that could be employed in future research with the W-GCTA.
- Constructing a measuring instrument for future research that assesses the interrelated application of critical thinking skills, dispositions and standards for reasoning.
- Combining statistical methods collected from single subject designs to demonstrate whether data are displaying accelerating, declining or stationary trends, such as the split-middle method of trend estimation (Nourbakhsh & Ottenbacher, 1994), would enable the researcher to achieve greater depth in the data. Additionally, combining statistical methods to analyse the data combined with the visual analysis that was utilised in the study, would increase the reliability of the research findings, and provide a more nuanced and complete understanding of the development of critical thinking.

The next section summarises the contribution of the present study.

7.10 CONTRIBUTION OF THE STUDY

The researcher wishes to distinguish between the contribution of the present study to existing theory and to practice.

7.10.1 Contribution to theory

The present study contributes in the following ways to existing theory about the developing of critical thinking:

- The study enriches the theory on ways to develop critical thinking. A number of research studies (De Araujo *et al.*, 2015; Hwang *et al.*, 2012; Kadam *et al.*, 2012; Lin & Chen, 2016; Smith & Middleton, 2003) investigated the merits of video games in general in order to nurture cognitive stimulation with samples of students at school

level as well as university level. In the context of the study, exploring the merits of, in particular, puzzle video games for nurturing critical thinking among students, therefore contributes a new dimension to theoretical knowledge in the field of critical thinking development. This study provides initial findings that point to the latent potential of a commercial puzzle video game for the development of critical thinking (Djaouti *et al.*, 2011 Trybus, 2010) (*cf.* 3.5.2).

- The study extends existing research on developing critical thinking, by suggesting a novel way to develop critical thinking. This research demonstrated how certain critical thinking skills, dispositions and standards for reasoning could be developed using the video game Portal as part of informal and non-formal learning, in conjunction with a formal teaching strategy, namely the GROW model (Gorell, 2013) (*cf.* Table 1.1). This type of approach is novel, and the findings can be used to extend the knowledge base of critical thinking development in terms of the contribution of an integrated formal, informal, and non-formal learning approach for developing critical thinking.

7.10.2 Contribution to practice

Many international studies have been done regarding the development or nurturing of critical thinking in the classroom (*cf.* 1.1), but none of the studies have focused on the possibility of developing critical thinking with puzzle video games. This study highlighted the possible benefits of a PVG-CEP for the development of critical thinking among first-year BEd students in a first small scale exploratory pilot study, which paves the way for further research into the field of developing critical thinking with puzzle video games. The findings of this study could be beneficial to many stake holders in education, such as teachers, departmental facilitators, students and lecturers involved in teacher education. Lecturers could be made aware of the merits of using informal puzzle games in addition to classroom teaching in order to improve the development of critical thinking among their students. Students at school might also benefit in terms of critical thinking development if their teachers are made aware of the potential of utilising puzzle video games for nurturing critical thinking, possibly as an informal homework activity (dependant on the availability of hardware requirements to the students).

7.11 CONCLUSIONS

It is unsettling that from the times of Plato, the development of critical thinking has been an important outcome in education, which seemingly has not yet been achieved. This leaves one with the following questions: What would happen if this ideal is not achieved? Will we continually perpetuate generation after generation with uncritical thinkers who simply conform?

The researcher acknowledges that the present research into the development and application of critical thinking skills, dispositions and standards for reasoning among first-year BEd students is open to further scrutiny. Little is known about the extent to which teacher-training programmes actually prepare students to think critically and to teach for critical thinking. This study creates an awareness of the fragile nature of the elements of critical thinking that need to be addressed among BEd students. What the findings revealed is that the most important challenge facing teacher education appears to be an intellectual and practical one. Firstly, strategies and tools have to be identified to improve the quality of preservice teachers' critical thinking. Secondly, preservice teachers have to be supplied with a repertoire of strategies and tools to advance the development of the minds of students whom they will teach. Preservice teachers themselves need to become effective critical thinkers in order to promote skilled reasoning and intellectual self-discipline as well as self-reflective, self-directed, self-monitored and self-corrective thinking among students at school. All Higher Education institutions should accept the challenge to direct the training of teachers to predispose them to be more adept at engaging in critical thinking tasks.

REFERENCES

- Aarsand, P. A. (2007). Computer and video games in family life: The digital divide as a resource in intergenerational interactions. *Childhood*, 14(2), 235-256.
- Abrami, P.C., Bernard, R.M., Borokhovski, E., Wade, A., Surkes, M.A., Tamim, R., & Zhang, D. (2008). Instructional interventions affecting critical thinking skills and dispositions: A stage 1 meta-analysis. *Review of Educational Research*, 78(4), 1102-1134.
- Ackermann, E. (2001). Piaget's constructivism, Papert's constructionism: What's the difference. *Future of Learning Group Publication*, 5(3), 438.
- Adachi, P. J., & Willoughby, T. (2011). The effect of violent video games on aggression: Is it more than just the violence? *Aggression and Violent Behaviour*, 16(1):55-62.
- Adams, E., & Rollings, A. (2006). *Fundamentals of game design*. New Jersey: Prentice Hall.
- Adler, A., & Perkins, D. N. (2016). *Teaching thinking: Issues and approaches*. London: Routledge.
- Admission Testing Service. (2013). *Thinking skills assessment*. Retrieved from www.admissiontestingservice.org/for-test-takers/thinking-skills-assessment
- Akyüz, H. I., & Samsa, S. (2009). Critical thinking skills of preservice teachers in the blended learning environment. *International Journal of Human Sciences*, 6(2), 538-550.
- All, A., Nuñez Casellar, E. P., & Van Looy, J. (2016). Assessing the effectiveness of digital game-based learning: Best practices. *Computers and Education*, 92-93, 90-103.
- Allamnakhrah, A. (2013). Learning critical thinking in Saudi Arabia: Student perceptions of secondary preservice teacher education programme. *Journal of Education and Learning*, 2(1), 97-210.

American Psychological Association. (2015). *APA review confirms link between playing violent video games and aggression*. Retrieved from <https://www.apa.org/news/press/releases/2015/08/violent-video-games>

Amoru, A., & Molomo, B. (2012). Gendered play and evaluation of computer video games by young South Africans. *Gender, Technology and Development*, 16(2), 77-196.

Anderson, J. (2010). *Succeeding with habits of mind*. Victoria: Hawker Brownlow Education.

Anderson, J. (2012). *Developing habits of mind: Workshop notes*. Workshop held on 12 September 2011. North-West University, Vaal Triangle Campus: Vanderbijlpark.

Anderson, C. A., & Bushman, B. J. (2001). Effects of violent video games on aggressive behaviour, aggressive cognition, aggressive affect, physiological arousal, and prosocial behaviour: A meta-analytic review of the scientific literature. *Psychological Science*, 12(5), 353-359.

Anderson, C. A., & Dill, K. E. (2000). Video games and aggressive thoughts, feelings, and behaviour in the laboratory and in life. *Journal of Personality and Social Psychology*, 78(4), 772 -790

Anderson, C. A., Shibuya, A., Ihori, N., Swing, E. L., Bushman, B. J., Sakamoto, A., Rothstein, H. R., & Saleem, M. (2010). Violent video game effects on aggression, empathy, and prosocial behavior in Eastern and Western countries: A meta-analytic review. *Psychological Bulletin*, 136(2):151 - 173.

Andiliou, A., & Murphy, P. K. (2014). Creative solutions and their evaluation: Comparing the effects of explanations and argumentation tasks on students' reflections. *Frontline Learning Research*, 4, 92–114.

Annetta, L. A. (2008). Video games in education: Why they should be used and how they are being used. *Theory into Practice*, 47(3), 229-239.

Arends, R. I. (2004). *Learning to teach* (6th ed.). Boston: McGraw-Hill.

- Arias, M. (2014). Using video games in education. *Journal of Mason Graduate Research*, 1(2), 49-69.
- Armstrong, J. (2004). The natural learning project. Econ WPA. In D. C. Brenenstuhl & S. C. Certo, (Eds.). *Exploring experiential learning: simulations and experiential exercises* (pp. 69-77). Tempe: Bureau of Business and Economic Research, College of Business Administration, Arizona State University.
- Arnab, S., Berta, R., Earp, J., De Freitas, S., Popescu, M., Romero, M., Stanescu, I., & Usart, M. (2012). Framing the adoption of serious games in formal education. *Electronic Journal of E-learning*, 10(2), 159-171.
- Arthur, W. (Jr.), Bennett, W. (Jr.), Stanush, P. L., & McNelly, T. (1998). Factors that influence skill decay and retention. A quantitative review and analysis. *Human Performance*, 11(1), 57-101.
- Arum, R., & Roksa, J. (2011). *Academically adrift. Limited learning on college campuses*. Chicago: The University of Chicago Press.
- As'ari, A. R., Mahmudi, A., & Nuerlaelah, E. (2017). Our prospective mathematics teachers are not critical thinkers yet. *Journal on Mathematics Education*, 8(2), 145-156.
- Austrian Development Cooperation. (2009). *Guidelines for project evaluations*. Vienna: Austrian Development Agency.
- Babbie, E. & Mouton, J. (2001). *The practice of social research*. New York: Oxford University Press.
- Bächtold, M. (2013). What do students “construct” according to constructivism in science education? *Research in Science Education*, 43(6), 2477-2496.
- Bailin, S., Case, R., Coombs, J. R. & Daniels, L. B. (1999). Conceptualizing critical thinking. *Journal of Curriculum Studies*, 31(3), 285-302.
- Bakir, S. (2015). Critical thinking dispositions of pre-service teachers. *Educational Research and Reviews*, 10(2), 225-233.

- Ballard, M., Visser, K., & Jocoy, K. (2012). Social context and video game play: Impact on cardiovascular and affective responses. *Mass Communication and Society*, 15(6), 875-898.
- Bandura, A. (2015). On deconstructing commentaries regarding alternative theories of self-regulation. *Journal of Management*, 41(4), 1025-1044.
- Baniqued, P. L., Lee, H., Voss, M. W., Baak, C., Cosman, J. D., & De Souza, S. (2013). Selling points: What cognitive abilities are tapped by casual video games? *Acta Psychologica*, 143(1), 74-86.
- Bardzell, J., Jakobsson, M., Bardzell, S., Pace, T., Odom, W., & Houssian, A. (2007). *Virtual worlds and fraud: Approaching cybersecurity in massively multiplayer games*. Proceedings of the 2007 DiGRA International Conference: Situated Play, DiGRA 2007, Tokyo, Japan, September 24-28, 2007. Digital Games Research Association.
- Barell, J. 2010. Problem-based learning: The foundation of 21st century skills. In J. Bellanca, & R. Brandt (Eds.), *21st Century skills: Rethinking how students learn* (pp. 175-199). Bloomington, IN: Solution Tree Press.
- Barnes, C.A. (2005). Critical thinking revisited: past, present and future. *New Directions for Community Colleges*, 130, 5-13.
- Barnett, R. (2015). A curriculum for critical being. In M. Davies, & R. Barnett (Eds.), *The Palgrave handbook of critical thinking in higher education* (pp. 63–76). New York: Palgrave Macmillan.
- Barrett, T. (2010). The problem-based learning process as finding and being in flow. *Innovations in Education and Teaching International*, 47(2), 165-174.
- Bartholow, B. D., Sestir, M. A., & Davis, E. B. (2005). Correlates and consequences of exposure to video game violence: Hostile personality, empathy, and aggressive behaviour. *Personality and Social Psychology Bulletin*, 31(11), 1573-1586.
- Bauersfeld, H. (2012). “Language games” in the mathematics classroom: Their function and their effects. In P. Cobb, & H. Bauersfeld (Eds.), *The emergence of mathematical*

meaning: Interaction in classroom cultures (pp. 271 - 291). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bavelier, D., Achtman, R. L., Mani, M., & Föcker, J. (2012). Neural bases of selective attention in action video game players. *Vision Research*, 61, 132-143.

Bavelier, D., Bediou, B., Adams, D. M., Mayer, R. E., Tipton, E., & Green, C. S. (2018). Meta-analysis of action video game impact on perceptual, attentional and cognitive skills. *Psychological Bulletin*, 144(1), 77-110.

Bean, J. C. (2011). *Engaging ideas: The professor's guide to integrating writing, critical thinking, and active learning in the classroom*. New Jersey: John Wiley & Sons.

Beard, C. (2010). *The experiential learning toolkit: Blending practice with concepts*. London: Kogan Page Publishers.

Beck, J. C., & Wade, M. (2004). *Got game*. Boston: Harvard Business School Press.

Benedetti, W. (2008). *Playing the blame game: Why search our souls when video games make such an easy scapegoat*. Retrieved from <https://www.engadget.com/2008/02/19/msnbc-video-games-an-easy-scapegoat/>

Benjamin, L. (2005). *The development and evaluation of a metacognitive programme for young students in the South African context* (Thesis- DPhil). Cape Town: University of Western Cape.

Bennerstedt, U., Ivarsson, J., & Linderöth, J. (2012). How gamers manage aggression: Situating skills in collaborative computer games. *International Journal of Computer-Supported Collaborative Learning*, 7(1), 43-61.

Bennett, S., & Kalish, N. (2006). *The case against homework: how homework is hurting our children and what we can do about it*. New York: Crown Publishers.

Bensley, D. A., & Spero, R. A. (2014). Improving critical thinking skills and metacognitive monitoring through direct infusion. *Thinking Skills and Creativity*, 12, 55-68.

Bensley, D. A., Rainey, C., Murtagh, M. P., Flinn, J. A., Maschiocchi, C., Bernhardt, P. C., & Kuehne, S. (2016). Closing the assessment loop on critical thinking: The challenges of multidimensional testing and low test-taking motivation. *Thinking Skills and Creativity*, 21, 158-168.

Bensley, L., & Van Eenwyk, J. (2001). Video games and real-life aggression: Review of the literature. *Journal of Adolescent Health*, 29(4), 244-257.

Berk, L. E. (2012). *Infants, children, and adolescents*. Boston: Pearson/Allyn & Bacon.

Beyer, B. (1983). Common sense about teaching thinking skills. *Educational Leadership*, 41(3), 44-49.

Beyer, B. K. (1987). *Practical strategies for the teaching of thinking*. Boston, MA: Allyn and Bacon.

Bhalla, J. (2013). Computer use by school teachers in teaching-learning process. *Journal of Education and Training Studies*, 1(2), 174-185.

Bitzer, E., & Wilkinson, A. (2008). *Higher education as field of study and research. Higher Education in South Africa*. Stellenbosch: SUN Press.

Bjorklund, D. F. (2005). *Children's thinking: Cognitive development and individual differences* (4th ed.). California: Thomson Wadsworth.

Bligh, D. A. (2000). *What's the use of lectures?* San Francisco, Calif.: Jossey-Bass.

Bok, D. (2006). *Our underachieving colleges. A candid look at how much students learn and why they should be learning more*. Princeton, NJ: Princeton University Press.

Bonk, C. J., & Smith, G.S. (1998). Alternative instructional strategies for creative and critical thinking in the accounting curriculum. *Journal of Accounting Education*, 16(2), 261-293.

Borich, G. D. (2003). *Observation skills for effective teaching* (4th ed.). New York: Merrill Prentice Hall.

Bowell, T. (2017). Response to the editorial education in a post-truth world. *Educational Philosophy and Theory*, 49(6), 582–85.

Boxer, P., Groves, C. L., & Docherty, M. (2015). Video games do indeed influence children and adolescents' aggression, prosocial behaviour, and academic performance: A clearer reading of Ferguson (2015). *Perspectives on Psychological Science*, 10(5), 671-673.

Boyd-Batstone, P. (2004). Focused anecdotal records assessment: A tool for standards-based, authentic assessment. *The Reading Teacher*, 58(3), 230-239.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., Lim. T., Ninaus, M., Ribeiro, C., & Pereira, J. (2016). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers and Education*, 94, 178-192.

Boyles, N. N. (2004). *Constructing meaning through kid-friendly comprehension strategy instruction*. Gainesville, Fla.: Maupin House.

Bramwell, T. 2007. *Portal*. Eurogamer. Retrieved from <https://www.eurogamer.net/articles/portal-first-impressions>.

Bransford, J., Brown, A., Cocking, R., Pellegrino, J., & Donovan, M. (2000). *How people learn: Brain, mind, experience, and school*. Committee on Developments in the Science of Learning with additional material from the Committee on Learning Research and Educational Practice, & National Research Council. Washington, DC: The National Academies.

Brathwaite, B. (2006). *Sex in video games*. Newton: Charles River Media, Inc..

Brettigny, E. (2017). Critical thinking on the road of life. In M. Grosser (Ed.), *Developing critical thinking. A multi-dimensional approach for the context of South Africa* (pp. 47-66). New York: Nova Science.

- Breunig, M. C. (2009). Teaching Dewey's experience and education experientially. In B. Strema, & C. A., Bisson (Eds.), *Teaching adventure education theory: Best Practices* (pp.1-395). Portland: Human Kinetics Pub. Cengage Learning.
- Brookfield, S. D. (2012). *Teaching for critical thinking*. San Francisco: Jossey Bass.
- Brookhart, S. M. (2010). *How to assess higher-order thinking skills in your classroom*. Alexandria, Virginia: ASCD.
- Brophy-Warren, J. (2009). Resident evil 5' reignites debate about race in videogames. *Wall Street Journal*, 12. Retrieved from https://www.amren.com/news/2009/03/resident_evil_5/
- Brown, A. L. (1990). Domain-specific principles affect learning and transfer in children. *Cognitive Science*, 14(1), 107-133.
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-42.
- Brown, P. P., & Brown, C. S. (2015). Transformative learning theory in gerontology: Non-traditional students. *Educational Gerontology*, 41,136-148.
- Brown, S. (2013). *Several muslim countries ban Black Ops 2*. Retrieved from <http://www.digitalafro.com>
- Browne, M. N., & Freeman, K. (2000). Distinguishing features of critical thinking classrooms. *Teaching in Higher Education*, 5(3), 301-309.
- Brownstein, G. M. (2001). *The role of constructivism in teaching and learning of chemistry*. Retrieved from <https://yulirahmawati.id/2008/04/14/the-role-of-constructivism-in-teaching-and-learning-chemistry/>
- Bruce, C. D., Ross, J., Flynn, T., & McPherson, R. (2009). *Lesson study and demonstration classrooms: Examining the effects of two models of teacher professional development*. Retrieved from <http://www.tmerc.ca/digitalpapers/samples/WholeResearchStory.pdf>.

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, 31, 21-32.

Buchner, A. (1995). Theories of complex problem solving. In P.A. Frensch & J. Funke (Eds.), *Complex problem solving: The European Perspective* (pp. 26-63). Hillsdale, NJ: Lawrence Erlbaum Associates.

Buffington, M. L. (2007). Contemporary approaches to critical thinking and the World Wide Web. *Art Education*, 60(1), 18-23.

Burbach, M. E., Matkin, G. S., & Fritz, S. M. (2010). *Teaching critical thinking in an introductory leadership course utilizing active learning strategies: A confirmatory study*. Retrieved from http://findarticles.com/p/articles/mi_m0FCR/is_3_38/ai_n6245168

Burbules, N. C. (2016). Being critical about being critical. A response toward a transformative criticality for democratic citizenship education. *Democracy and Education*, 24(2). Retrieved from <http://democracyeducationjournal.org/home/vol24/iss2/7>

Burden, P. R., & Byrd, D. M. (2003). *Methods for effective teaching. Meeting the needs of all students* (5th ed.). London: Pearson Education.

Butler, H. A., Pentoney, C., & Bong, M. P. (2017). Predicting real-world outcomes: Critical thinking ability is a better predictor of life decisions than intelligence, *Thinking Skills and Creativity*, 25, 38-46.

Campbell, H. A., & Grieve, G. P. (Eds.). (2014). *Playing with religion in digital games*. Bloomington: Indiana University Press.

Case, R. (2005). Bringing critical thinking to the main stage. *Education Canada*, 45(2), 45-46.

Cerasoli, C. P., Alliger, G. M., Donsbach, J. S., Mathieu, J. E., Tannenbaum, S. I., & Orvis, K. A. (2014). *What is informal learning and what are its antecedents? An integrative and meta-analytic review*. Albany, New York: Group For Organizational Effectiveness.

- Chai, C. S., & Khine, M. S. (2008). Assessing the epistemological and pedagogical beliefs among pre-service teachers in Singapore. In M. S. Khine (Ed.), *In Knowing, knowledge and beliefs: Epistemological studies across diverse cultures* (pp. 287-299). Amsterdam, Netherlands: Springer.
- Chatel, R. G. (2001). Diagnostic and instructional uses of the cloze procedure. *The NERA Journal*, 37, 3-6.
- Chartrand, J., & Rose, M. (2008). *The difference between good leaders and great leaders: How to assess for critical thinkers in hiring and development*. Retrieved from http://www.pearsonpsychcorp.com.au/userfiles/Good%20and%20Great%20Leaders_Aus.pdf
- Cheng, M. H. M., & Wan, Z. H. (2017). Exploring the effects of classroom learning environment on critical thinking skills and disposition: A study of Hong Kong 12th graders in Liberal Studies. *Thinking Skills and Creativity*, 24, 152-163.
- Cheung, C. K., Rudowicz, E., Kwan, A. S. F., & Due, X. D. (2002). *Assessing university students' general and specific critical thinking*. Retrieved from <http://findarticles.com/p/articles/mi>.
- Chiu, M. M. (2004). Adapting teacher interventions to student needs during cooperative learning. *American Educational Research Journal*, 41, 365-399.
- Cobern, W. W. (2000). The nature of science and the role of knowledge and belief. *Science and Education*, 9, 219-246.
- Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). New York: Routledge.
- Colley, H., Hodgkinson, P., & Malcolm, J. (2003). Informality and formality in learning. A report for the learning and skills research centre. University of Leeds. Retrieved from <http://www.LSRC.au.uk>
- Coloroso, B. (2004). *The bully, the bullied and the bystander*. New York: Harper Collins.

- Connolly, T. M., Boye, E. A., MacArthur, E., Hailey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers and Education*, 59, 661-686.
- Coombs, P. H., Prosser, R., & Ahmed, M. (1973). *New paths to learning for rural children and youth*. New York: International Council for Educational Development.
- Costa, A. L. (2009). Describing the habits of mind. In A. L. Costa, & B. Kallick (Eds.), *Learning and leading with habits of mind. 16 Essential characteristics for success* (pp. 15-41). Victoria: Hawker Brownlow Education.
- Costa, A., Kallick, B. (2005). *Habits of mind*. Victoria: Hawker Brownlow Education.
- Costa, A. L., & Kallick, B. (2009a). Assessing habits of mind. In A. L. Costa, & B. Kallick (Eds.), *Learning and leading with habits of mind. 16 Essential characteristics for success* (pp. 190-221). Victoria: Hawker Brownlow Education.
- Costa, A. L. & Kallick, B. (2009b). Teaching habits of mind. In A. L. Costa, & B. Kallick (Eds.), *Habits of Mind across the curriculum. Practical strategies for teachers* (pp. 33-66). Alexandria, VA: ASCD (Association for Supervision and Curriculum Development).
- Cottrell, S. (2011). *Critical thinking skills. Developing effective analysis and argumentation*. London: Palgrave.
- Cranton, P., & King, K. P. (2003). Transformative learning as a professional development goal. *New Directions for Adult and Continuing Education*, 98, 31-38.
- Creswell, J. W. (2009). *Research design. Qualitative, quantitative and mixed methods approaches* (3rd ed.). California: Sage.
- Creswell, J. W. (2014). *Educational research: Planning, conducting and evaluating quantitative and qualitative research* (4th ed.). Harlow: Pearson Education Limited.
- Critical thinking company. (2013). The Cornell critical thinking test -level Z. Retrieved from <http://www.criticalthinking.com/cornell-critical-thinking-test-level-z.html>

Cumberbatch, G. (2004). *Video violence: Villain or victim. A review of the research evidence concerning media violence and its effects in the real world with additional reference to video games*. The Communications Research Group. London: Video Standards Council.

Dabbagh, N., & Kitsantas, A. (2012). Personal learning environments, social media, and self-regulated learning: A natural formula for connecting formal and informal learning. *The Internet and Higher Education*, 15(1), 3-8.

Daly, W. M. (1998). Critical thinking as an outcome of nursing education. What is it? Why is it important to nursing practice? *Journal of Advanced Nursing*, 28(2), 323-331.

Daniel, M. F. (1992). Reflections on teacher formation: When school and university enter together in a process of continuous thinking. *Analytic Teaching*, 16(2), 29-41.

Daniel, M. F. (2001). Philosophical dialogue among peers: A study of manifestations of critical thinking in preservice teachers. *Advances in Health Sciences Education*, 6, 49-67.

Daniels, D. H., Beaumont, L. J., & Doolin, C. A. (2008). *Understanding children: An interview and observation guide for teachers*. New York: McGraw-Hill.

Darby, M. L. (2007). Debate: A teaching-learning strategy for developing competence in communication and critical thinking. *Journal of Dental Hygiene*, 81(4), 78-89.

Darling-Hammond, L., & Austin, K. (2003). Lessons for life: Learning and Transfer. In B. Rossbach (Ed.), *The learning classroom: Theory into practice* (pp.189-204). Stanford: Stanford University.

Davenport, D. (2002). Anonymity on the Internet: Why the price may be too high. *Communications of the ACM*, 45(4), 33-35.

Davies, M. (2013). Critical thinking and the disciplines reconsidered. *Higher Education Research and Development*, 32(4), 529-44.

De Araujo, T. B., Silveira, F. R., Souza, D. L. S., Strey, Y. T. M., Flores, C. D., & Webster, R. S. (2015). Impact of video game genre on surgical skills development: A feasibility study. *Journal of Surgical Research*, 201(1), 235-243

De Beer, J. (2010). The teacher as a user of media. In L. Conley (Ed.), *Becoming a teacher* (pp. 124-142). Cape Town: Heinemann.

Dede, C. (2010). Comparing frameworks for 21st century skills. 21st century skills. In J. Bellanca, & R. Brandt (Eds.), *Rethinking how students learn* (pp. 51-75). Bloomington, IN: Solution Tree Press.

Delpont, C. S. L., & Fouché, C. B. (2011). Mixed methods research. In A. S. De Vos, H. Strydom, C. B. Fouché, & C. S. L. Delpont (Eds.), *Research at grass roots. For the social sciences and human service professions* (4th ed., pp. 433-448). Pretoria: Van Schaik.

Demaine, E. D., Lockhart, J., & Lynch, J. (2016). The computational complexity of Portal and other 3D games. In H. Ito, S. Leonardi, L. Pagli, & G. Precipe (Eds.), *Leibnitz international proceedings of Informatics* (pp. 19.1-19.21). Leibnitz: Dagstuhl Publishing.

DeMaria, R., & Wilson, J. L. (2003). High score!: The illustrated history of electronic games. New York: McGraw-Hill Osborne Media.

Department of Basic Education. See South Africa. Department of Basic Education.

Department of Education. See South Africa. Department of Education.

De Vos, A.S., & Strydom, H. (2011). Intervention research. In A. S. De Vos, H. Strydom, C. B. Fouché, & C. S. L. Delpont (Eds.), *Research at grass roots: For the social sciences and human service professions* (4th ed., pp. 473-490). Pretoria: Van Schaik Publishers.

DeWall, C. N., Anderson, C. A., & Bushman, B. J. (2011). The general aggression model: Theoretical extensions to violence. *Psychology of Violence*, 1(3), 245.

Dewey, J. (1910). Objects, data and existences: A reply to professor McGilvary. *The Journal of Philosophy, Psychology and Scientific methods*, 6(1), 13-21.

Dewey, J. (1922). *Human nature and conduct*. New York, USA: Henry Holt.

Dewey, J. (1933). *How we think*. New York: Prometheus Books.

Dietz, T. L. (1998). An examination of violence and gender role portrayals in video games: Implications for gender socialization and aggressive behavior. *Sex Roles*, 38(5), 425-442.

Dignath, C. & Büttner, G. (2008). Components of fostering self-regulated learning among learners. A meta-analysis on intervention studies at primary and secondary school level. *Metacognition Learning*, 3, 231-264.

DiMaggio, P. (1997). Culture and cognition. *Annual Review of Sociology*, 23, 263-287.

Dinardo J. (2010) Natural experiments and quasi-natural experiments. In S. N. Durlauf, & L. E. Blume (Eds.), *Microeconometrics. The New Palgrave Economics Collection* (pp. 139-153). London: Palgrave Macmillan.

Dirkx, J. M., Mezirow, J., & Cranton, P. (2006). Musings and reflections on the meaning, context, and process of transformative learning: A dialogue between John M. Dirkx and Jack Mezirow. *Journal of Transformative Education*, 4(2), 123-139.

Djaouti, D., Alvarez, J., & Jessel, J. P. (2011). Classifying serious games: The G/P/S model. In P. Felicia (Ed.), *Handbook of research on improving learning and motivation through educational games: Multidisciplinary approaches* (pp. 118-136). Hershey, PA: IGI Global.

Dolmans, D. H., De Grave, W., Wolfhagen, I. H., & Van Der Vleuten, C. P. (2005). Problem-based learning: Future challenges for educational practice and research. *Medical Education*, 39(7), 732-741.

Donald, D., Lazarus, S., & Lolwana, P. (2006). *Educational psychology in social context* (2nd ed.). Cape Town: Oxford University Press.

Dostál, J., & Gregar, J. (2015). *Enquiry-based instruction: Concept, essence, importance and contribution*. Olomouc: Palacký University.

Duffy, T. M., & Jonassen, D.H. (Eds.). (2013). *Constructivism and the technology of instruction: A conversation*. Abingdon, United Kingdom: Routledge.

Dufura, M. J., Parcel, T. L., & Troutman, K. P. (2013). Does capital at home matter more than capital at school? Social capital effects on academic achievement. *Research in Social Stratification and Mobility*, 31, 1–21.

Dumitru, D. E., Elen, J., Railiené, A., & Papathanasiu, I. V. (2018). *A European review on critical thinking educational practices in Higher Education*. Erasmus Programme of the European Union.

Dunn, D. S., Halonen, J. S., & Smith, R. A. (2008). *Teaching critical thinking in Psychology. A handbook for best practices*. West Sussex: Wiley.

Dunne, G. (2015). Beyond critical thinking to critical being: Criticality in higher education and life. *International Journal of Educational Research*, 71, 86-99.

Du Plessis, A., & Webb, P. (2008). Generative use of computers: Promoting critical outcomes of the South Africa curriculum. *Education as Change*, 12(1), 15-27.

Du Plessis, A., & Webb, P. (2012). Teachers' perceptions about their own and their schools' readiness for computer implementation: A South African case study. *The Turkish Online Journal of Educational Technology*, 11(3), 312-325.

Duran, M., & Dökme, I. (2016). The effect of the enquiry-based learning approach on students' critical thinking skills. *Eurasia Journal of Mathematics, Science and Technology Education*, 12(12), 2887-2908.

Duron, R., Limbach, B., & Waugh, W. (2006). Critical thinking framework for any discipline. *International Journal of Teaching and Learning in Higher Education*, 17(2), 160-166.

Eaton, S. E. (2012). *Literacy, language and leadership. 10 characteristics of informal learning*. Retrieved from <https://drsaraeaton.wordpress.com/>

Eddy, M. D. (2004). Fallible or inerrant? A belated review of the 'Constructivist's Bible'. *British Journal for the History of Science*, 37, 93–98.

- Egenfeldt-Nielsen, S., Smith, J. H., & Tosca, S. P. (2015). *Understanding video games: The essential introduction*. Abingdon, United Kingdom: Routledge.
- Elder, L., & Paul, R. W. (2007). *The thinker's guide to analytic thinking*. California: Foundation for Critical Thinking.
- Elder, L., & Paul, R. W. (2008). Critical thinking in a world of accelerating change and complexity. *Social education*, 72(7), 388-391.
- Elder, L., & Paul, R. W. (2010). *Critical thinking development: A foundation stage theory*. Retrieved from www.criticalthinking.org/pages/critical-thinking-development-a-stage-theory/483
- Elson, M., Breuer, J., Van Looy, J., Kneer, J., & Quandt, T. (2015). Comparing apples and oranges? Evidence for pace of action as a confound in research on digital games and aggression. *Psychology of Popular Media Culture*, 4(2), 112.
- Ennis, R. H. (1964). A definition of critical thinking. *The reading teacher*, 17(8), 599-612.
- Ennis, R. H. (1985). A logical basis for measuring critical thinking skills. *Educational Leadership*, 43(2), 44-48.
- Ennis, R.H. (1987). A taxonomy of critical thinking dispositions and abilities. In J. B. Baron & R. J. Sternberg (Eds.), *Teaching thinking skills: Theory and practice* (pp. 9–26). New York: Freeman.
- Ennis, R. H. (1993). Critical thinking assessment. *Theory and Practice*, 32(3), 179-186.
- Ennis, R. H. (2001). Goals for a critical thinking curriculum and assessment. In A. Costa (Ed.), *Developing minds* (3rd ed.). (pp. 44-66). Alexandria, VA: ASCA publications.
- Ennis, R. H. (2003). Critical thinking assessment. In D. Fasko (Ed.), *Critical thinking and reasoning* (pp. 293-310). Cresskill, NJ: Hampton Press.
- Ennis, R. H. (2009). Investigating and assessing multiple-choice critical thinking tests. In J. Sobocan, & L. Groarke (Eds.), *Critical thinking education and assessment: Can higher order thinking be tested?* (pp. 75-97). London & Ontario: Althouse.

Ennis, R. H., & Weir, E. E. (1985). *The Ennis-Weir critical thinking essay test: An instrument for teaching and testing*. Phoenix, Arizona: Midwest Publications.

Entertainment Software Association. (2010). *Essential facts about the computer and video game industry*. Retrieved from www.theesa.com/facts/pdfs/ESA_EF_2012.Pdf.
Date of access

Erikson, M. G., & Erikson, M. (2018). Learning outcomes and critical thinking – good intentions in conflict. *Studies in Higher Education*. Online.
doi:10.1080/03075079.2018.1486813.

Ertmer, P. A., & Newby, T. J. (1993). Behaviourism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, 6(4), 50-72.

Ertmer, P. A., & Newby, T. J. (1996). The expert student: Strategic, self-regulated, and reflective. *Instructional Science*, 24(1), 1-24.

Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, 26(2), 43-71.

Etchells, P., & Chambers, C. (2014, October 10). *Violent video games research: Consensus or confusion*. [Clipping from The Guardian]. Retrieved from <https://www.theguardian.com/science/head-quarters/2014/oct/10/violent-video-games-research-consensus-or-confusion>

Everett, A., & Watkins, C. (2008). The power of play: The portrayal and performance of race in video games. In Salen, K. (Ed.), *The ecology of games: Connecting youth, games, and learning* (pp. 141-164). The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning. Cambridge, MA: The MIT Press,

Ewoldsen, D. R., Eno, C. A., Okdie, B. M., Velez, J. A., Guadagno, R. E., & DeCoster, J. (2012). Effect of playing violent video games cooperatively or competitively on subsequent cooperative behaviour. *Cyber-Psychology, Behaviour, and Social Networking*, 15, 277-280.

Eyre, D. (2016). *High performance learning: How to become a world class school*. London: Routledge.

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction*. California: California Academic press.

Facione, P. A. (2000). The disposition toward critical thinking: Its character, measurement, and relationship to critical thinking skill. *Informal Logic*, 20(1), 64-65.

Facione, P. A. (2009). *Critical Thinking: What it is and why it counts*. Retrieved from www.insightassessment.com/pdf_files/what&why98.pdf

Facione P. A. (2011). *Think critically*. Boston, MA: Prentice Hall.

Fahim, M., & Hajimaghsoodi, A. (2014). The relationship between motivation and critical thinking ability of Iranian EFL students. *International Journal of Language Learning and Applied Linguistics World*, 5(2), 605-619.

Fahim, M., & Shakouri, N. (2012). Critical thinking in Higher Education. A Pedagogical look. *Theory and Practice in Language Studies*, 2(7), 1370-1375.

Falik, L. (2001). *Using MLE parameters to change children's behaviour: Technique for parents and childcare providers*. Retrieved from <http://www.icelp.org>

Fantin, I. (2014). *Applied problem solving: Method, applications, root causes, countermeasures, Poka-Yoke and A3*. Milan, Italy: Create Space Independent Publishing Platform.

Farr, M. J. (1987). *The long-term retention of knowledge and skills: A cognitive and instructional perspective*. New York: Springer-Verlag.

Fellick, J. M. (2001). Violence in video games. *AAP News*, 19(4), 138-152.

Ferguson, C. J. (2007). The good, the bad and the ugly: A meta-analytic review of positive and negative effects of violent video games. *Psychiatric Quarterly*, 78(4), 309-316.

- Ferguson, C. J. (2015). Pay no attention to that data behind the curtain: On angry birds, happy children, scholarly squabbles, publication bias, and why betas rule metas. *Perspectives on Psychological Science*, 10(5), 683-691.
- Ferguson, C. J., & Garza, A. (2011). Call of (civic) duty: Action games and civic behaviour in a large sample of youth. *Computers in Human Behaviour*, 27(2), 770-775.
- Ferguson, C.J., & Kilburn, J. (2009). The public health risks of media violence: A meta-analytic review. *The Journal of Pediatrics*, 154(5), 759-763.
- Ferguson, R., Faulkner, D., Whitelock, D., & Sheehy, K. (2015). Pre-teens' informal learning with ICT and Web 2.0. *Technology, Pedagogy and Education*, 24(2), 247-265.
- Feuerstein, R. (1990). The theory of structural cognitive modifiability and mediated learning experience. In R. Feuerstein (Ed.), *Feuerstein's theory and applied systems: A reader* (pp. 37-45). Jerusalem: ICELP.
- Feuerstein, R. (1997). *Research: Basic theory*. Retrieved from <http://www.icelp.com>.
- Feuerstein, R. (2007). *The Feuerstein instrumental enrichment programme (FIE). Instrumental materials: Level 1 Training*. Israel: ICELP. Workshop presented by Lilian Lomofsky, June 2008. Vanderbijlpark: North-West University.
- Feuerstein, R., & Feuerstein, F. (1991). Mediated Learning Experience: a theoretical review. In R. Feuerstein, P. S. Klein, & A. J. Tannenbaum (Eds.), *Mediated Learning Experience (MLE): theoretical, psychosocial and learning implications* (pp. 3-51). London: Freund Publishing House Ltd.
- Feuerstein, R., Feuerstein, R. S., & Falik, L. H. (2010). *Beyond smarter: Mediated learning and the brain's capacity for change*. New York: Teachers College Record.
- Feuerstein, R., Feuerstein, R.S., Falik, L.H., & Rand, Y. (2002). *The dynamic assessment of cognitive modifiability: The learning propensity assessment device: Theory, instruments and techniques*. Jerusalem: ICELP.
- Feuerstein, R., & Hoffman, M. B. (1995). *Teacher's guide to organization of dots*. Illinois: IRI/Skylight Training and Publishing.

- Field, A. (2005). *Discovering statistics using SPSS* (2nd ed.). Los Angeles: Sage.
- Fisher, A., & Scriven, M. (1997). *Critical thinking: Its definition and assessment*. Norwich: Centre for research in critical thinking.
- Fisher, R. (2001). *Critical thinking: An introduction*. New York, USA: Cambridge.
- Fling, S., Smith, L., Rodriguez, T., Thornton, D., Atkins, E., & Nixon, K. (1992). Videogames, aggression, and self-esteem: A survey. *Social Behaviour and Personality: and International Journal*, 20(1), 39-45.
- Floyd, C. B. (2011). Critical thinking in a second language. *Higher Education Research and Development*, 30(3), 289-302.
- Fraser, J. D. C. (2006). Mediation of learning. In M. M. Nieman, & R. B. Monyai (Eds.), *The educator as mediator of learning* (pp. 1-21). Pretoria: Van Schaik.
- Fraser, M. W., & Galinsky, M. J. (2010). Steps in intervention research: Designing and developing social programs. *Research on Social Work Practice*, 20(5), 459-466.
- Fraser, M. W., Rishman, J. M., Galinsky, M. J., & Day, S. H. (2009). *Intervention research*. New York: Oxford University Press.
- Freedman, J. L. (2003). Book review: Media violence and its effects on aggression: Assessing the scientific evidence. [Review of the book *Media violence and its effects on aggression: Assessing the scientific evidence*. J. L. Freedman]. *Canadian Psychology*, 44(2), 179-180.
- Freiberg, H. J. (2002). Essential skills for new teachers. *Educational Leadership*, 59(6), 56-60.
- French, B. F., Hand, B., Therrien, W. J., & Vazquez, J. A. V. (2012). Detection of sex differential item functioning in the Cornell Critical Thinking Test. *European Journal of Psychological Assessment*, 28(3), 201-207.

Funk, J. B., Baldacci, H. B., Pasold, T., & Baumgardner, J. (2004). Violence exposure in real-life, video games, television, movies, and the internet: is there desensitization?. *Journal of Adolescence*, 27(1), 23-39.

Funk, J. B., Hagan, J., Schimming, J., Bullock, W. A., Buchman, D. D., & Myers, M. (2002). Aggression and psychopathology in adolescents with a preference for violent electronic games. *Aggressive Behaviour*, 28(2), 134-144.

Furnham, A., & Yazdanpanahi, T. (1995). Personality differences and group versus individual brainstorming. *Personality and Individual Differences*, 19, 73-80.

Gabbiadini, A., Riva, P., Andrighetto, L., Volpato, C., & Bushman, B. J. (2016). Acting like a tough guy: Violent-sexist video games, identification with game characters, masculine beliefs, and empathy for female violence victims. *PLoS one*, 11(4), 152.

Gamer, R. (2007). *The definitive Space Invaders*. *Retro Gamer (Imagine Publishing)*(41). Retrieved from http://www.nowgamer.com/features/894697/the_definitive_space_invaders_part_1.html.

Gamoran, A., Secada, W. G., & Marrett, C. B. (2000). The organizational context of teaching and learning. In M. T. Hallinan (Ed.), *Handbook of the sociology of education* (pp. 37-63). New York: Kluwer Academic/Plenum Publishers.

Gardner, H. (2010). Five minds for the future. In J. Bellanca, & R. Brandt (Eds.), *21st century skills: Rethinking how students learn* (pp. 9-31). Bloomington, IN: Solution Tree Press. p. 9-31).

Garson, G.D. 2009. *Reliability analysis*. Retrieved from <http://tx.liberal.ntu.edu.tw/~purplewoo/Literature/!DataAnalysis/Reliability%20Analysis.htm>

Gee, J. P. (2003a). High score education: Games, not school, are teaching kids to think. *Wired Magazine*, 11(5). Retrieved from <http://www.wired.com/wired/archive/11.05/view.html?pg=1>

Gee, J.P. (2003b). What video games have to teach us about learning and literacy. *Computers in Entertainment*, 1(1), 20.

Gentile, D. A., & Anderson, C. A. (2003). Violent video games: The newest media violence hazard. In D. A. Gentile (Ed.), *Advances in applied developmental psychology. Media violence and children: A complete guide for parents and professionals* (pp. 131-152). Westport, CT, US: Praeger Publishers/Greenwood Publishing Group.

Gentile, D. A., Anderson, C. A., Yukawa, S., Ihori, N., Saleem, M., Ming, L. K., Shibuya, A., Liau, A. K., Khoo, A., Bushman, B. J., & Rowell Huesmann, L. (2009). The effects of prosocial video games on prosocial behaviours: International evidence from correlational, longitudinal, and experimental studies. *Personality and Social Psychology Bulletin*, 35(6), 752-763.

Gentile, D. A., Saleem, M., & Anderson, C. A. (2007). Public policy and the effects of media violence on children. *Social Issues and Policy Review*, 1(1), 15-61.

Ghadi, I., Alwi, N. H., Bakar, K. A., & Talib, O. (2012). Construct validity examination of critical thinking dispositions for undergraduate students in University Putra Malaysia. *Higher Education Studies*, 2(2), 138-145.

Gibson, J. J. (2014). *The ecological approach to visual perception: Classic edition*. Hove: Psychology Press.

Glaser, E. M. (1941). An experiment in the development of critical thinking. *Teachers College Record*, 43(5), 409-410.

Goldman, T. (2010). *College professor requires students to study Portal. The escapist*. Retrieved from <https://v1.escapistmagazine.com/forums/read/7.234661-Kids-Cant-Handle-Old-School-RPGs-Anymore>

Goldrick-Rab, S. (2010). Challenges and opportunities for improving community college student success. *Review of Educational Research*, 80(3), 437-469.

Goodwin, M., & Sommervold, C. (2012). *Creativity, critical thinking, and communication: Strategies to increase students' skills*. Maryland: Rowman & Littlefield.

Gorell, R. (2013). *Group coaching: A practical guide to optimizing collective talent in any organization*. London: Kogan Page Publishers.

Goyak, A. M. (2009). *The effects of cooperative learning techniques on perceived classroom environment and critical thinking skills*. (Dissertation – PhD). Liberty University: Virginia.

Grabe, W. (2009). *Reading in a second language: Moving from theory to practice*. New York: Cambridge University Press.

Grabove, V. (1997). The several facets of transformative learning theory and practice. *New Directions for Adult and Continuing Education*, 74, 89-96.

Granic, I., Lobel, A., & Engels, R. C. (2014). The benefits of playing video games. *American Psychologist*, 69(1), 66.

Gredler, M. E. (2004). Games and simulations and their relationships to learning. *Handbook of Research on Educational Communications and Technology*, 2, 571-581.

Greeff, M. (2005). Information collection: Interviewing. In A. S. De Vos, H. Strydom, C. B. Fouché & C. S. L. Delport (Eds.), *Research at grass roots: For the social sciences and human service professions* (3rd ed., pp. 286-313). Pretoria: Van Schaik.

Green, C.S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature*, 423(6939), 534-537.

Green, C.S., & Bavelier, D. (2012). Learning, attentional control and action video games. *Current Biology*, 22, 197-207.

Green, L., & Murrin, K. (2014). Philosophy for children. In Green, L. (Ed.), *Schools as thinking communities* (pp.121-140). Pretoria: Van Schaik.

Greene, J. A., & Yu, S. B. (2015). Educating critical thinkers. The role of epistemic cognition. *Policy Insights from the Behavioural and Brain Sciences*, 3(1), 45-53.

Greenfield, P. M. (1994). Video games as cultural artifacts. *Journal of Applied Developmental Psychology*, 15, 3-12.

- Griffith, J.L., Voloschin, P., Gibb, G. D., & Bailey, J. R. (1983). Differences in eye-hand motor coordination of video-game users and non-users. *Perceptual and Motor Skills*, 57(1), 155-158.
- Griffiths, M. (2005). Video games and health: Video gaming is safe for most players and can be useful in health care. *British Medical Journal*, 331(7509), 122-123.
- Grizzard, M., Tamborini, R., Lewis, R. J., Wang, L., & Prabhu, S. (2014). Being bad in a video game can make us morally sensitive. *Cyberpsychology, Behavior, and Social Networking*, 17(8), 499-504.
- Grosser, M. M., & Lombard, B. J. J. (2008). The relationship between culture and the development of critical thinking abilities of prospective teachers. *Teaching and Teacher Education*, 24, 1364-1375.
- Grosser, M. M., & Nel, M. (2013). The relationship between the critical thinking skills and academic language proficiency of prospective teachers. *South African Journal of Education*, 33(2), 246-262.
- Grosser, M. M., & Olivier, C. (2017). Developing critical thinking as an academic and a life skill. In M. Grosser (Ed.), *Developing critical thinking. A multi-dimensional approach for the context of South Africa* (pp. 3-34). New York: Nova Science.
- Gunter, M. A., Estes, T. H. & Mintz, S. L. (2010). *Instruction: A models approach*. Boston, Mass.: Pearson Education.
- Gutek, G. L. (2009). *New perspectives on philosophy and education*. New Jersey, USA: Pearson.
- Hadi, S. A., Susantini, E., & Augustini, R. (2018). Training of students' critical thinking skill through the implementation of a modified free enquiry model. *Journal of Physics: Conference Series*, 947. doi: 10. /1088/1742-6596/947/1/012063.
- Hager, P., & Halliday, J. (2009). *Recovering informal learning: Wisdom, judgement and community* (Vol. 7). Dordrecht, Netherlands: Springer Science & Business Media.

Halonen, J. S. (1995). Demystifying critical thinking. *Teaching of Psychology*, 22(1), 75-81.

Halpern, D. F. (1988). Assessing student outcomes for psychology majors. *Teaching of Psychology*, 15(4), 181-186.

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains: Dispositions, skills, structure training, and metacognitive monitoring. *American Psychologist*, 53(4), 449–455.

Halpern, D. F. (2003a). *Thought and Knowledge. An introduction to critical thinking*. London: Lawrence.

Halpern, D. F. (2003b). The “how” and “why” of critical thinking assessment. In D. Fasko (Ed.), *Critical thinking and reasoning: Current research, theory and practice* (pp. 34-85). Cresskill, NJ: Hampton Press.

Halpern, D. F. (2007). The nature and nurture of critical thinking. In R. Sternberg, H. L. Roediger, & D. F. Halpern (Eds.), *Critical thinking psychology* (pp. 1-12). Cambridge: Cambridge University Press.

Halpern, D. F. (2014). *Thought and knowledge* (5th ed.). NY: Psychology Press.

Halx, M. D., & Reybold, L. E. (2005). A pedagogy of force: Faculty perspectives of undergraduate critical thinking capacity. *Journal of General Education*, 54(4), 293-315.

Han, D. H., Kim, Y. S., Lee, Y. S., Min, K. J., & Renshaw, P. F. (2010). Changes in cue-induced, prefrontal cortex activity with video-game play. *Cyberpsychology, Behavior, and Social Networking*, 13(6):655-661.

Hardy, M. D. (1997). Von Glaserfeld's radical constructivism: A critical review. *Science and Education*, 6(1-2), 135-150.

Hartmann, T., & Klimmt, C. (2006). Gender and computer games: Exploring females' dislikes. *Journal of Computer Mediated Communication*, 11(4), 910-931.

Hashim, O. R. (2010). Investigation of the teaching of critical and creative thinking in Malaysia. *Jurnal Pendidikan Islam*, 1, 39-56.

Hauge, M. R., & Gentile, D. A. (2003). *Video game addiction among adolescents: Associations with academic performance and aggression*. Society for Research in Child Development Biennial Conference, Tampa, 24-27 April.

Haury, D. L. (1993). Teaching science through enquiry. *ERIC Clearinghouse for Science Mathematics and Environmental Education*.

Heijltjes, A., van Gog, T., Leppink, J., & Paas, F. (2014). Improving critical thinking: Effects of dispositions and instructions on economics students' reasoning skills. *Learning and Instruction*, 29, 31–42.

Herman, L., Horwitz, J., Kent, S., & Miller, S. (2002). The history of video games. *Gamespot*. Retrieved from <http://www.gamespot.com/video-game-history-month/>

Herz, J. C. (1997). *Joystick nation: How videogames ate our quarters, won our hearts, and rewired our minds*. Boston: Little, Brown & Co. Inc..

Heyman, G. D. (2008). Children's critical thinking when learning from others. *Current Directions in Psychological Science*, 17(5), 344-347.

Higgins, E. T. (2008). Culture and personality. Variability across universal motives as a missing link. *Social and Personality Compass*, 2, 608-634.

Higgins, E. T., Kruglanski, A. W., & Pierro, A. (2003). Regulatory mode: Locomotion and assessment as distinct orientations. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (pp. 293-344). New York: Academic Press.

Higgins, E.T., Pierro, A., & Kruglanski, A. W. (2008). Re-thinking culture and personality: How self-regulator universals create cross-cultural differences. In R. M. Sorrentino, & S. Yamaguchi (Eds.), *Handbook of motivation and cognition across cultures* (pp. 161-190). New York: Elsevier.

Hmelo-Silver, C. E., & Barrows, H. S. (2006). Goals and strategies of a problem-based learning facilitator. *Interdisciplinary Journal of Problem-Based Learning*, 1(1), 21-39.

- Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and enquiry learning: A response to Kirschner, Sweller and Clark (2006). *Educational Psychologist*, 42(2), 99-107.
- Hong, Y-y., Morris, M.W., Chiu, C-y., & Benet-Martínez, V. (2000). Multi-cultural minds. A dynamic approach to culture and cognition. *American Psychologist*, 55(7), 709-720.
- Hsieh, R. L., Lee, W. C., & Lin, J. H. (2016). The impact of short-term video games on performance among children with developmental delays: a randomized controlled trial. *PloS one*, 11(3), 149.
- Hughes, W., & Lavery, J. (2015). *Critical thinking: An introduction to the basic skills* (7th ed.). Peterborough, Canada: Broadview press.
- Hull, J. G., Brunelle, T. J., Prescott, A. T., & Sargent, J. D. (2014). A longitudinal study of risk-glorifying video games and behavioural deviance. *Journal of Personality and Social Psychology*, 107(2), 300-325.
- Hung, D. W. L. (1999). Activity, apprenticeship, and epistemological appropriation: Implications from the writing of Michael Polanyi. *Educational Psychologist*, 3, 193-205.
- Hung, P. H., Hwang, G. J., Lee, Y. H., & Su, I. H. (2012). A cognitive component analysis approach for developing game-based spatial learning tools. *Computers and Education*, 59(2), 762-773.
- Hung, W. (2011). Theory to reality: A few issues in implementing problem-based learning. *Educational Technology Research and Development*, 59(4), 529-552.
- Hwang, C. J., Chiu, L. Y., & Chen, C. H. (2015). A contextual game-based learning approach to improving students' enquiry-based learning performance in social studies causes. *Computers and Education*, 81, 13-25.
- Hyttinen, H. (2015). *Looking beyond the obvious. Theoretical, empirical and methodological insights into critical thinking* (Doctoral Thesis). University of Helsinki: Helsinki.

Imenda, S. (2014). Is there a conceptual difference between the theoretical and conceptual frameworks? *Journal of Social Sciences*, 38(2), 185-195.

Innabi, H., & ElSheikh, O. (2007). The change in mathematics teachers' perceptions of critical thinking after 15 years of educational reform in Jordan. *Educational Studies in Mathematics*, 64(1), 45-68.

Insight assessment. (2013). *The California critical thinking skills test – college level*. Retrieved from [http://www.insightassessment.com/Products/Products-Summary/Critical-Thinking-Skills-Tests/California-Critical-Thinking-Skills-Test-CCTST/\(language\)/eng-US](http://www.insightassessment.com/Products/Products-Summary/Critical-Thinking-Skills-Tests/California-Critical-Thinking-Skills-Test-CCTST/(language)/eng-US)

Irvine, M. (2008). Survey: 97 percent of children play video games. *Huffington Post*, Retrieved from http://www.huffingtonpost.com/2008/09/16/survey-97-percent-of-chil_n_126948.html

Isman, E. B., & Tzuriel, D. (2008). The mediated learning experience (MLE) in a three generational perspective. *British Journal of Developmental Psychology*, 26(4), 545-560.

Itin, C. M. (1999). Reasserting the philosophy of experiential education as a vehicle for change in the 21st century. *Journal of Experiential Education*, 22(2), 91-98.

Ivankova, N. V., Creswell, J. W., & Plano Clark, V. L. (2007). Foundations and approaches to mixed methods research. In K. Maree (Ed.). *First steps in research* (pp. 254-278). Pretoria: Van Schaik.

Jacobson, M., & Ruddy, M. (2004). *Open to outcome: A practical guide for facilitating & teaching experiential reflection*. Bethany: Wood'N'Barnes Publishing.

Johnson, S. (2006). *Everything bad is good for you: How today's popular culture is actually making us smarter*. London: Penguin Publishing.

Johnson, S., & Schelsinger, V. (2007). *This is your brain on video games: Gaming sharpens thinking, social skills, and perception*. *Discover Magazine*. Retrieved from http://discovermagazine.com/2007/brain/video-games/article_view?b_start:int=0&-C=

Johnston, P., Woodside-Jiron, H., & Day, J. (2001). Teaching and learning literate epistemologies. *Journal of Educational Psychology*, 93(1), 5-33.

Joubert, I., Bester, M., & Meyer, E. (2008). *Literacy in the Foundation Phase*. Pretoria: Van Schaik.

Joyce, B., & Weil, M. (2000). *Models of teaching: Tools for teaching* (6th ed.). Boston, Mass.: Allyn & Bacon.

Juul, J. (2007). Swap adjacent gems to make sets of three: A history of matching tile games. *Artifact*, 1(4), 205-216.

Kachchhap, S. L., & Mishika, A. (2015). Theoretical contributions to graduate research. An investigative study in the Philippines. *International Forum*, 18(2), 65-82.

Kadam, K., Sahasrabudhe, S., & Iyer, S. (2012). *Improvement of mental rotation ability using blender 3-D*. Proceedings of the 2012 IEEE Fourth International Conference on Technology for Education (pp. 60-66). Washington, DC: IEEE Computer Society.

Kaddoura, M. A. (2010). New graduate nurses' perceptions of the effect of clinical simulation on their critical thinking, learning, and confidence. *Journal of Continuing Education in Nursing*, 41, 506–516.

Kafui, S-P., & Cronjé, J. (2018). Digital device ownership and learning environment preferences of students in South Africa and Ghana. *Turkish Online Journal of Distance Education*, 19(3), 93-111.

Kember, D. (2001). Beliefs about knowledge and the process of teaching and learning as a factor in adjusting to study in higher education. *Studies in Higher Education*, 26, 205-221.

Kennedy, H. W. (2002). Lara Croft: Feminist icon or cyberbimbo? On the limits of textual analysis. *Game Studies: International Journal of Computer Games Research*, 2(2). Retrieved from <http://eprints.uwe.ac.uk/94>

Kennedy, K. J. (1991). Exploring the relationship between developmental learning and curriculum design. *Australian Journal of Reading*, 14(4), 349.

Kent, S. L. (2010). *The ultimate history of video games: From Pong to Pokemon and beyond... the story behind the craze that touched our lives and changed the world*. New York: Three Rivers Press.

Killen, R. (2015). *Teaching strategies of quality teaching and learning* (2nd ed.). Cape Town: Juta.

Kim, J. S. (2005). The effects of a constructivist teaching approach on student academic achievement, self-concept, and learning strategies. *Asia Pacific Education Review*, 6(1), 7-19.

King, P. M., & Kitchener, K. S. (2002). The reflective judgement model: twenty years of research on epistemic cognition. In B. K. Hofer, & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 37-62). New Jersey: Lawrence Erlbaum Associates.

King, P. M., & Kitchener, K. S. (2004). Reflective Judgment: Theory and research on the development of epistemic assumptions through adulthood. *Educational Psychologist*, 39, 5–18.

Kirsh, S. J. (1998). Seeing the world through mortal kombat-colored glasses: Violent video games and the development of a short-term hostile attribution bias. *Childhood*, 5(2), 177-184.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and enquiry based teaching. *Educational Psychologist*, 41, 75-86.

Klepek, P. (2011). *Intro to GLaDOS 101: A professor's decision to teach portal*. Retrieved from <https://www.giantbomb.com/articles/intro-to-glados-101-a-professors-decision-to-teach/1100-3206/>

Klein, S., Benjamin R., Shavelson, R., & Bolus, R. (2007). The collegiate learning assessment. Facts and fantasies. *Evaluation Review*, 31(5), 415– 439.

Knowles, M. S., Holton III, E. F., & Swanson, R. A. (2014). *The adult student: The definitive classic in adult education and human resource development*. London: Routledge.

Koenig, R. (2010). *Learning for keeps. Teaching strategies essential for creating independent students*. Alexandria, Virginia: ASCD.

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice-Hall.

Kompf, M., & Bond, R. (2001). Critical reflection in adult education. In T. Barer-Stein, & M. Kompf (Eds.), *The craft of teaching adults* (pp. 21–38). Toronto, ON: Irwin.

Kong, G., & Seng, A. (2006). *Enhancing the critical thinking skills and dispositions of preservice teachers*. Paper presented at the 7th National Conference of the International Association for Cognitive Education in Southern Africa, Vanderbijlpark.

Konijn, E. A., Nije Bijvank, M., & Bushman, B. J. (2007). I wish I were a warrior: the role of wishful identification in the effects of violent video games on aggression in adolescent boys. *Developmental Psychology*, 43(4), 1038-1045.

Konrath, S.H., O'Brien, E. H., & Hsing, C. (2011). Changes in dispositional empathy in American college students over time: A meta-analysis. *Personality and Social Psychology Review*, 15(2), 180-198.

Kooijmans, T. A. (2004). *Effects of video games on aggressive thoughts and behaviours during development*. Rochester Institute of Technology. Retrieved from <http://www.personalityresearch.org/papers/kooijmans.html>.

Kramer, D. (2006). *OBE Teaching Toolbox. OBE strategies, tools and techniques for implementing Curriculum 2005*. Florida Hills: Vivlia Publishers & Booksellers (Pty) Ltd.

Krashen, S., & Brown, C. L. (2007). *What is academic language proficiency? Research papers*. Retrieved from http://www.sdkrashen.com/articles/Krashen_Brown_ALP.pdf

Ku, K. Y. L. (2009). Assessing students' critical thinking performance: Urging for measurements using multi-response format. *Thinking Skills and Creativity*, 4(1), 70-76.

- Kuhn, D. (1999). A developmental model of critical thinking. *Educational Researcher*, 28(2), 16-46.
- Kuhn, D. (2005). *Education for thinking*. Cambridge, MA: Harvard University Press.
- Kuhlthau, C., Maniotes, L., & Caspari, A. (2007). *Guided enquiry: Learning in the twenty-first century*. Westport, CT: Libraries Unlimited.
- Kutner, L., & Olson, C. (2008). *Grand theft childhood: The surprising truth about violent video games and what parents can do*. New York: Simon and Schuster.
- Kwan, Y. W., & Wong, A. F. L. (2015). Effects of the constructivist learning environment on students' critical thinking ability: Cognitive and motivational variables as mediators. *International Journal of Educational Research*, 70, 68-79.
- Lah, K. (2010). *'RapeLay' video game goes viral amid outrage*. Retrieved from <https://www.cnn.com>.
- Larsson, K. (2017). Understanding and teaching critical thinking - A new approach. *International Journal of Educational Research*, 84, 32-42.
- Larstuk, T. (2011). *Portal 2: A Student Video Game Project, All Grown Up*. NPR. Retrieved from <https://www.npr.org/2011/04/19/135511250/portal-2-a-student-video-game-project-all-grown-up>.
- Laurel, B. (1991). On dramatic interaction. *Verbum*, 3(3), 6-7.
- Lave, J. (1992). *Learning as participation in communities of practice*. Paper presented at the Annual Meeting of the American Educational Research Association San Francisco, California.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Leech, N. L., Barrett, K. C., & Morgan, G. A. (2005). *SPSS for intermediate statistics: Use and interpretation* (2nd ed.). London: Routledge.

- Leedy, P. D., & Ormrod, J. E. (2005). *Practical research. Planning and design* (8th ed.). New Jersey: Pearson.
- Leedy, P. D., & Ormrod, J. E. (2013). *Practical Research: Planning and Design* (10th ed.). New Jersey: Pearson.
- Leigh, F. (2007). Platonic dialogue, maieutic method and critical thinking. *Journal of Philosophy of Education*, 41(3), 309-323.
- Leland, J. (2016). Edutainment in video games. *Computers for Everyone*, 1, 96.
- Leone, M. (2010). *Gabe Newell: Portal 2 is. The Best Game We've Ever Done*. Retrieved from <https://www.techspot.com/news/38219-valve-portal-2-is-the-best-game-weve-ever-done.html>.
- Lin, C. H., & Chen, C. M. (2016). Developing spatial visualization and mental rotation with a digital puzzle game at primary school level. *Computers in Human Behaviour*, 57, 23-30.
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic enquiry*. London: Sage.
- Liu, F. (2010). Reading abilities and strategies: A short introduction. *International Education Studies*, 3(3), 153-157.
- Lipman, M. (1991). *Thinking in education*. Cambridge: Cambridge University Press.
- Lodico, M. G., Spaulding, D. T., & Voegtle, K. H. (2010). *Methods in research. From theory to practice* (2nd ed.). San Francisco: Jossey Bass.
- Lombard, B. J. J., & Grosser, M. M. (2004). Critical thinking abilities among prospective teachers: Ideals versus realities. *South African Journal of Education*, 24(3), 212-216.
- Lombard B. J. J., & Grosser, M. M. (2008). Critical thinking: are the ideals of OBE failing us or are we failing the ideals of OBE? *South African Journal of Education*, 28, 571-579.
- Lorenzo, G., & Dziuban, C. (2006). *Ensuring the net generation is net savvy*. EDUCAUSE Learning Initiative Paper 2. Boulder, CO: EDUCAUSE. Retrieved from <http://www.educause.edu/ir/library/pdf/ELI3006.pdf>

- Loughlin, K. A. (1993). *Women's perceptions of transformative learning experiences within consciousness-raising*. San Francisco, CA: Mellen Research University Press.
- Lowood, H. (2009). Videogames in computer space: The complex history of pong. *IEEE Annals of the History of Computing*, 31(3), 5-19.
- Luckin, R., Clark, W., Graber, R., Logan, K., Mee, A., & Oliver, M. (2009). Do Web 2.0 tools really open the door to learning? Practices, perceptions and profiles of 11–16 year old students. *Learning, Media and Technology*, 34(2), 87-104.
- Lugmayr, A., Sutinen, E., Suhonen, J., Sedano, C. I., Hlavacs, H., & Montero, C. S. (2017). Serious storytelling—a first definition and review. *Multimedia Tools and Applications*, 76(14), 15707-15733.
- Lun, V. M-C., Fischer, R., & Ward, C. (2010). Exploring cultural differences in critical thinking: Is it about my thinking style or the language I speak? *Learning and Individual Differences*, 20(6), 604-616.
- Lunenburg, F. C. (2011). Critical thinking and constructivism techniques for improving student achievement. *National Forum of Teacher Education Journal*, 21(3), 1-9.
- Mahapoonyanont, N. (2010). Factors related to critical thinking abilities: A meta-analysis. *Procedia - Social and Behavioral Sciences*, 9, 986-990.
- Mahapoonyanont, N. (2012). The causal model of some factors affecting critical thinking abilities. *Procedia - Social and Behavioral Sciences*, 46, 146-150.
- Manalo, E., & Sheppard, C. (2016). How might language affect critical thinking performance? *Thinking Skills and Creativity*, 21, 41-49.
- Manalo, E., Kusumi, T., Koyasu, M., Michita, Y., & Tanaka, Y. (2013). To what extent do culture-related factors influence university students' critical thinking use? *Thinking Skills and Creativity*, 10, 121-132.
- Mardis, M. A. (2013). What it has or what it does not have? Signposts from US data for rural children's digital access to informal learning. *Learning, Media and Technology*, 38(4), 387-406.

- Maree, K., & Pietersen, J. (2016). The quantitative research process. In K. Maree (Ed.), *First steps in research* (pp. 145-153). Pretoria: Van Schaik Publishers.
- Maree, K., & Van der Westhuizen, C. (2007). Planning a research proposal. In K. Maree (Ed.), *First steps in research* (pp. 23-45). Pretoria: Van Schaik.
- Marin, L. M., & Halpern, D. F. (2011). Pedagogy for developing critical thinking in adolescents: Explicit instruction produces greatest gains. *Thinking Skills and Creativity*, 6(1), 1-13.
- Markiewicz, A., & Patrick, A. (2016). Developing monitoring and evaluation frameworks. California: Sage.
- Marr, D. (2008). *Validity of the academic profile test*. New Jersey, USA: Educational testing service. Retrieved from https://www.ets.org/s/proficiencyprofile/pdf/Validity_Academic_Profile.pdf
- Martinovic, D., Ezeife, C. I., Whent, R., Reed, J., Burgess, G. H., & Pomerlau, C. M. (2014). Critic-proofing of the cognitive aspects of simple games. *Computers and Education*, 72, 132-144.
- Mathews, S. R., & Lowe, K. (2011). Classroom environment that foster a disposition for critical thinking. *Learning Environments Research*, 14(1), 59-73.
- Maxim, G. W. (2010). *Dynamic social studies for constructivist classrooms: Inspiring tomorrow's social scientists*. Boston: Allyn & Bacon.
- McAllister, M., Billett, S., Moyle, W., & Zimmer-Gembeck, M. (2009). Use of a think-aloud procedure to explore the relationship between clinical reasoning and solution-focused training in self-harm for emergency nurses. *Journal of Psychiatric and Mental Health Nursing*, 16(2), 121-128.
- McCarthy, P. R., & McCarthy, H. M. (2006). When case studies are not enough: Integrating experiential learning into business curricula. *Journal of Education for Business*, 81(4), 201-204.

- McCarthy, R.J., Coley, S.L., Wagner, M.F., Zengel, B., & Basham, A. (2016). Does playing video games with violent content temporarily increase aggressive inclinations? A pre-registered experimental study. *Journal of Experimental Social Psychology*, 67, 13-19.
- McCaslin, M., & Hickey, D.T. (2001). Educational psychology, social constructivism, and educational practice: a case of emergent identity. *Educational Psychologist*, 36,133-141.
- McGonigal, K. (2005). Teaching for transformation: From learning theory to teaching strategies. *Newsletter on Teaching*, 14(2). The center for teaching and learning, Stanford University.
- McKee, E., Williamson, V. M., & Ruebush, L. E. (2007). Effects of demonstration laboratory on student learning. *Journal of Science Education and Technology*, 16(5), 395-400.
- McLellan, H. (2002). Virtual realities. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 461-497). Mahwah, NJ: Lawrence Erlbaum.
- McMillan, J. H., & Schumacher, S. (2006). *Research in education. Evidence-based enquiry* (6th ed.). Boston: Pearson.
- McMillan, J. H., & Schumacher, S. (2014). *Research in education. Evidence-based enquiry*. Massachusettes: Allyn & Bacon.
- McNeeley, R. S. (2007). *Theories of learning: Learning theories in the early childhood classroom environment*. Retrieved from <http://web.utk.edu/~rmcneele/classroom>
- McNeill, J., & Wiles, J. (1990). *The essentials of teaching: Decisions, places and methods*. New York: Macmillan.
- McPeck, J. E. (1981). *Critical thinking in education*. New York: St. Martin's Press.
- McPeck, J. E. (2015). *Critical thinking and education*. London: Routledge.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco: Jossey-Bass.

Merriam, S. B., Caffarella, R. S., & Baumgartner, L. M. (2012). *Learning in adulthood: A comprehensive guide*. New Jersey: John Wiley & Sons.

Merrill, M. D. (2009). First principles of instruction. *Instructional-design theories and models: Building a Common Knowledge Base*, 3, 41-56.

Mezirow, J. (1997). Transformative learning: Theory to practice. *New Directions for Adult and Continuing Education*, 74, 5-12.

Miller, D. (2002). *Reading with meaning: teaching comprehension in the primary grades*. Portland: Stenhouse Publishers.

Miller, M. (2005). *A history of home video game consoles*. Retrieved from <http://www.informit.com/articles/article.aspx?p=378141>

Miller, M. K., & Summers, A. (2007). Gender differences in video game characters' roles, appearances, and attire as portrayed in video game magazines. *Sex Roles*, 57(9-10), 733-742.

Mirolo, C., & Di Vano, D. (2013). *Welcome to Nimrod to learn CS ideas in the middle school*. In Proceedings of the 8th (Workshop in Primary and Secondary Computing Education (WiPSCE) , November, 11–13. Studenterhusfonden Konferencenter: Aarhus, Denmark.

Mittell, J. (2012). Playing for plot in the lost and portal franchises. Eludamos. *Journal for Computer Game Culture*, 6(1), 5-13.

Monyai, R. B. (2006). Teaching strategies. In M. M. Nieman, & R. B. Monyai (Eds.), *The educator as mediator of learning* (pp. 104-135). Pretoria: Van Schaik.

Moon, J. A. (2004). *A handbook of reflective and experiential learning: Theory and practice*. Hove: Psychology Press.

- Moore, T. (2004). The critical thinking debate: how general are general thinking skills. *Higher Education Research and Development*, 23, 3–18.
- Moore, T. (2013). Critical thinking: Seven definitions in search of a concept. *Studies in Higher Education*, 38, 506–522.
- Mukwambo, M., Ngcoza, K., & Chikunda, C. (2015). How researchers define and measure variables In C. Okeke, & M .Van Wyk (Eds.), *Educational research. An African approach*. (pp.186-205). Cape Town: Oxford University Press.
- Myers, B. E., & Dyer, J. E. (2006). The influence of student learning style on critical thinking skill. *Journal of Agricultural Education*, 47(1), 43.
- Nauert, R. (2013). *Video games can help boost social memory and cognitive skills*. Newburyport: Psych Central.
- Neisser, U. (2014). *Cognitive psychology: Classic edition*. London: Psychology Press.
- Nel, N. (2011). Second language difficulties in a South African context. In E. Landsberg, D. Kruger, & E. Swart (Eds.), *Addressing barriers to learning: A South African perspective* (pp. 167-184). Pretoria: Van Schaik.
- Nel, N., & Nel, M. (2012). English Language. In N. Nel, M. Nel, & A. Hugo (Eds.), Nel, N., *Student support in a diverse classroom* (pp. 79-115). Pretoria: Van Schaik.
- Nelson, C. E. (1994). Critical thinking and collaborative learning. *New Directions for Teaching and Learning*, 59, 45-58.
- Nelson, R., & Strachan, I. (2009). Action and puzzle video games prime different speed/accuracy trade-offs. *Perception*, 38(11), 1678-1687.
- Nieuwenhuis. J. (2007a). Introducing qualitative research. In K. Maree (Ed.), *First steps in research*. (pp. 46-88). Pretoria: Van Schaik.
- Nieuwenhuis, J. (2007b). Qualitative research designs and data gathering techniques. In K. Maree (Ed.), *First steps in research* (pp. 70-101). Pretoria: Van Schaik.

- Nieuwenhuis, J. (2007c). Analyzing qualitative data. In K. Maree (Ed.), *First steps in research* (pp. 107-115). Pretoria: Van Schaik.
- Nieuwenhuis, J. (2016a). Introducing qualitative research. In K. Maree (Ed.), *First steps in research* (2nd ed., pp.50-70). Pretoria: Van Schaik.
- Nieuwenhuis, J. (2016b). Qualitative research designs and data gathering techniques. In K. Maree (Ed.), *First steps in research*. (2nd ed., pp. 72-102). Pretoria: Van Schaik.
- Nieuwenhuis, J. 2016c. Analyzing qualitative data. In K. Maree (Ed.), *First steps in research*. (2nd ed., pp. 104-113). Pretoria: Van Schaik.
- Nisbett, R. E., & Norenzayan, A. (2002). Culture and cognition. In D.L. Medin (Ed.), *Steven's handbook of experimental psychology*. (3rd ed., pp. 20-140). New York: Wiley.
- Nisbett, R. E., Peng, K., Choi, I., & Norenzayan, A. (2001). Culture and systems of thought: Holistic versus analytic cognition. *Psychological Review*, 108(2), 291-310.
- Niu, L., Behar-Horenstein, L. S., & Garvan, C. W. (2013). Do instructional interventions influence college students' critical thinking skills? A meta-analysis. *Educational Research Review*, 9,114-128.
- Norris, S. P. (1985). Synthesis of research on critical thinking. *Educational Leadership*, 42(8), 40-45.
- Norris, S. P., & Ennis, R. H. (1989). *Evaluating critical thinking*. Pacific Grove, CA: Critical Thinking Press Software.
- Nourbakhsh, M. R., & Ottenbacher, K. J. (1994). The statistical analysis of single-subject data: A comparative examination. *Physical Therapy*, 74(8), 80-88.
- Novak, J. D., & Cañas, A. J. (2006). *The theory underlying concept maps and how to construct and use them*. Pensacola, Fla.: Institute for Human and Machine Cognition.
- Nunneley, S. (2011). *Core Portal 2 game is the same "whether you buy it on PS3 or 360", says Valve*. VG247. Retrieved from <https://www.vg247.com/2011/01/22/the-core-portal-2-game-is-the-same-whether-you-buy-it-on-ps3-or-360-says-valve/>

- Ognibene, L. (2007). *The cure for the common school. Effective teaching methods for the 21st century*. Boston: Universe Lincoln.
- Olivier, C. (2012). *The DNA of great teachers. Learning designs*. Pietermaritzburg, South Africa: Intrepid Printers.
- Olson, C. K. (2010). Children's motivations for video game play in the context of normal development. *Review of General Psychology*, 14(2), 180.
- Osana, H. P., & Seymour, J. R. (2004). Critical thinking in preservice teachers: A rubric for evaluating argumentation and statistical reasoning. *Educational Research and Evaluation: An International Journal on Theory and Practice*, 10(4), 473-498.
- Papp, K. K., Huang, G. C., Clabo, L. M. L., Delva, D., Fischer, M., Konopasek, L., Schwartzstein, R. M., & Gusic, M. (2014). Milestones of critical thinking: A developmental model for medicine and nursing. *Academic Medicine*, 89(5), 715-720.
- Pascarella, E. T., Blaich, C., Martin, G. L., & Hanson, J. M. (2011). How robust are the findings of academically adrift? *Change: The Magazine of Higher Learning*, 43, 20–24.
- Passmore, J. (Ed.). (2015). *Excellence in coaching: The industry guide*. London: Kogan Page Publishers.
- Paton, M. (2005). Is critical analysis foreign to Chinese students? In E. Manalo & G. Wong-Toi (Eds.), *Communication skills in university education: The international dimension* (pp. 1-11). Auckland: Pearson Education.
- Paul, R. W. (1985). Bloom's taxonomy and critical thinking intervention. *Educational Leadership*, 42(8), 36-39.
- Paul, R. W. (1988). Critical thinking in the classroom. *TEACHING K-8*, 18, 49-51.
- Paul, R. W. (1990). *Critical thinking*. Rohnert Park, CA: Sonoma State University.
- Paul, R. W. (1992). *Critical thinking: Basic questions and answers*. Rohnet Park, CA: Foundation for Critical Thinking.

- Paul, R. W., & Elder, L. (1997). Critical Thinking: Implications for Instruction of the Stage Theory. *Journal of Developmental eEducation*, 20(3), 34-35.
- Paul, R. W., & Elder, L. (2005a). Critical thinking... and the art of substantive writing, part I. *Journal of Developmental Education*, 29(1), 40.
- Paul, R. W., & Elder, L. (2005b). *Critical thinking: Tools for taking charge of your learning and life* (2nd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Paul, R. W., & Elder, L. (2006). *The miniature guide to critical thinking concepts and tools*. California: The Foundation for Critical Thinking.
- Paul, R. W., & Elder, L. (2007). *The miniature guide to critical thinking: concepts and tools. Foundations for critical thinking*. Retrieved from <http://www.criticalthinking.org>
- Paul, R. W., & Elder, L. (2008a.) *The miniature guide to critical thinking: concepts and tools* (5th ed.). California: Foundation for Critical Thinking Press.
- Paul, R. W. & Elder, L. (2008b). Critical thinking: Strategies for improving student learning. Part II. *Journal of Developmental Education*, 32(2), 1-35.
- Paul, R. W., & Elder, L. (2014). *Critical thinking tools for taking charge of your professional and personal life*. New Jersey, NJ: Pearson Education.
- Paul, S. A. (2011). Assessment of critical thinking: A Delphi study. *Nurse Education Today*, 34(11), 1357-1360.
- Pavlov, I. P., & Anrep, G. V. (2003). *Conditioned reflexes*. Chelmsford, Massachusetts: Courier Corporation.
- Perkins, D. N., & Salomon, G. (1992). Transfer of learning. *International Encyclopaedia of Education*, 2, 6452-6457.
- Perry (Jr.) W. G. (1999). *Forms of intellectual and ethical development in the college years: A scheme*. San Francisco: Jossey-Bass Publishers, San Francisco.

- Phan, H. P. (2008). Predicting change in epistemological beliefs, reflective thinking and learning styles: a longitudinal study. *British Journal of Educational Psychology*, 78, 75–93.
- Philpott, J. (2009). *Captivating your class. Effective teaching skills*. New York: Continuum International Publishing Group.
- Pho, A., & Dinscore, A. (2015). *Game-based learning. Tips and Trends*. Spring Publications, Washington DC.
- Piaget, J. (2013). *The construction of reality in the child*. Abingdon, Oxon: Routledge.
- Pienaar, G. E. (2001). Teaching critical thinking skills in the language classroom. *Tydskrif vir Taalonderrig*, 35(2 & 3), 125-137.
- Pietersen, J., & Maree, K. (2007a). Statistical analysis II: Inferential statistics. In K. Maree (Ed.), *First steps in research* (p. 197-213). Pretoria: Van Schaik.
- Pietersen, J., & Maree, K. (2007b). Overview of statistical techniques. In K. Maree (Ed.), *First steps in research* (pp. 224-252). Pretoria: Van Schaik.
- Pietersen, J. & Maree, K. 2007c. The quantitative research process. In K. Maree (Ed.), *First steps in research* (pp. 145-153).
- Pink, D. (2006). *A whole new mind: Moving from the information age to the conceptual age*. New York, NY: Riverhead Books.
- Pintrich, P. R., & Schunk, D. H. (2002). *Motivation in education. Theory, research and applications* (2nd ed.). Upper Saddle River, NJ: Merrill Prentice Hall.
- Pithers, R. T., & Soden, R. (2000). Critical thinking in education: A review. *Educational research*, 42(3), 237-249.
- Pittman, C. (2013). Teaching with portals: The intersection of video games and physics education. *LEARNing Landscapes*, 6(2), 341-360.
- Posso, A. (2016). Internet usage and educational outcomes among 15-year old Australian students. *International Journal of Communication*, 10, 26.

Powell, K. C., & Kalina, C. J. (2009). *Cognitive and social constructivism: Developing tools for an effective classroom*. Retrieved from <https://www.questia.com/library/journal/1G1-216181184/cognitive-and-social-constructivism-developing-tools>

Powell, K. C., & Kalina, C. J. (2011). Cognitive and social constructivism: Developing tools for an effective classroom. *Education*, 130(2), 241-250.

Prayogi S., Yuanita. L., & Wasis. (2018). Critical enquiry-based learning: Model of learning to promote critical thinking ability of pre-service teachers. *Journal of Physics: Conference Series*, 947. doi: 10.1088/1742-6596/947/1/012013.

Prensky, M. (2012). *From digital natives to digital wisdom: Hopeful essays for 21st century learning*. Thousand Oaks, CA: Corwin Press.

Pressley, M., & Allington, R. L. (2014). *Reading instruction that works: The case for balanced teaching*. New York City, New York: Guilford Publications.

Primack, B. A., Carroll, M. V., McNamara, M., Klem, M. L., King, B., Rich, M., Chan, C. W., & Nayak, S. (2012). Role of video games in improving health-related outcomes: A systematic review. *American Journal of Preventive Medicine*, 42(6), 630-638.

Prince, M., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of Engineering Education*, 95(2), 123-138.

Profetto-McGrath, J. (2003). The relationship of critical thinking skills and critical thinking dispositions of baccalaureate nursing students. *Journal of Advanced Nursing*, 43(6), 569-577.

Przybylski, A. K., Deci, E. L., Rigby, C. S., & Ryan, R. M. (2014). Competence-impeding electronic games and players' aggressive feelings, thoughts, and behaviours. *Journal of Personality and Social Psychology*, 106(3), 441.

Qing, Z., Jing, G., & Yan, W. (2010). Promoting preservice teachers' critical thinking skills by enquiry-based chemical experiment. *Procedia – Social and Behavioural Sciences*, 2(2), 4597-4603.

Rabin, S. (Ed.). (2005). *Introduction to game development* (2nd ed.). Boston: Cengage Learning.

Ramadge, A. (2011). *GLaDOS, the greatest video game villain of all time, is back for more cake and chaos in Portal 2*. Retrieved from <https://www.news.com.au/technology/home-entertainment/glados-the-greatest-video-game-villain-of-all-time-back-for-cake-and-chaos-in-portal-2/news-story/4d7c1cf>

Ramani, E., & Joseph, M. (2008). Achieving academic excellence through higher-order cognition in an African language: students researching “small talk” in Sesotho sa Leboa. *Perspectives in Education*, 26, 42-56.

Rath, R. (2015). Game criticism as tangential learning facilitator: The case of Critical Intel. *Journal of Games Criticism*, 2(1),1-9.

Reddy, P., & Lantz, C. (2010). Myths, maths and madness – Misconceptions around psychology. In D. Upton & A Trapp (Eds.), *Teaching psychology in Higher Education* (pp. 54–81). Chichester: Blackwell.

Regoniel, P. (2010). *What is the difference between the theoretical and conceptual framework?* Retrieved from <https://college.knoji.com/what-is-the-difference-between-the-theoretical-framework-and-the-conceptual-framework/>

Reigeluth, C.M. (Ed.). (2013). *Instructional design theories and models: An overview of their current status*. Abingdon, UK:Routledge.

Reynolds, M. (2011). Critical thinking and systems thinking: Towards a critical literacy for systems thinking in practice. In C. P. Horvath, & J. M. Forte (Ed.). *Critical thinking* (pp. 37-68). New York, USA: Nova Science Publishers.

Rhodes, L. K., & Bellamy, G. T. (1999). Choices and consequences in the renewal of teacher education. *Journal of Teacher Education*, 50(1), 17-26.

Rice, J. 2007. Assessing higher order thinking in video games. *Journal of Technology and Teacher Education*, 15(1), 87-100.

Richet, J. L. (2013). *Laundering money online: A review of cybercriminals methods*. United Nations Office on Drugs and Crime (UNODC).

Riley-Tillman, T. C., & Burns, M. (2009). *Evaluating educational interventions: Single-case designs for measuring response to intervention*. New York: Guilford Press.

Rogers, A. (2014). The classroom and the everyday: The importance of informal learning for formal learning. *Investigar em Educação*, 11(1), 7-34.

Rogoff, B. (2009). Apprenticeship in thinking: Cognitive development in social context. *Korean Journal of Medical Education*, 21(2), 197-198.

Rollings, A., & Adams, E. (2006). *Game design and development: Fundamentals of game design*. Upper Saddle River, New Jersey: Prentice Hall.

Rosenberg, B. H., Landsittel, D., & Averch, T. D. (2005). Can video games be used to predict or improve laparoscopic skills? *Journal of Endourology*, 19(3), 372-376.

Rothstein, R. (2000). *When culture affects how we learn*. Retrieved from <http://www.asianam.org>

Roy, A., & Machiette, B. (2005). Debating the issues: A tool for augmenting critical thinking skills of marketing students. *Journal of Marketing Education*, 27(3), 264-276.

Ruger, H. A. (1910). *The psychology of efficiency: An experimental study of the processes involved in the solution of mechanical puzzles and in the acquisition of skill in their manipulation*. Canberra: Science Press.

Russell, D. (1943). Critical thinking in childhood and youth. *The School*, 31(9), 744-750.

Russell, T. L. (1999). *The No Significant Difference Phenomenon (NSDP)*. Raleigh, NC: North Carolina State University.

Rüütman, T., & Kipper, H. (2011). *Teaching strategies for direct and indirect instruction in teaching Engineering*. Paper presented at the 14th International Conference on interactive collaborative learning, Piešťany, Slovakia, 21-23 September 2011. Retrieved from www.icl-conference.org/dl/proceedings/2011/.../contribution122_a.pdf

Ryan, M-L. (2001) *Beyond myth and metaphor. The case of narrative in digital media. Game Studies*, 1, 1. Retrieved from www.gamestudies.org/0101/ryan

Sadeck, O., & Cronjé, J. (2017). A continuum of teachers' e-learning practices. *The Electronic Journal of e-Learning*, 15(5), 396-409.

Saleem, M., Anderson, C. A., Gentile, D. A. (2012). Effects of prosocial, neutral, and violent video games on children's helpful and hurtful behaviors. *Aggressive Behavior*, 38(4), 281-287.

Santanen, E., Briggs, R. O., & De Vreede, G-J. (2004). Causal relationships in creative problem solving: Comparing facilitation interventions for ideation. *Journal of Management Information Systems*, 20(4), 167-198.

Sauer, J. D., Drummond, A., & Nova, N. (2015.) Violent video games: The effects of narrative context and reward structure on in-game and postgame aggression. *Journal of Experimental Psychology: Applied*, 21(3), 205-214.

Savery, L. K. (1994). The influence of the perceived styles of leadership on a group of workers on their attitudes to work. *Leadership and Organization Development Journal*, 15(4), 12-18.

Schacter, D. L., Gilbert, D. T., & Wegner, D. M. (2009). *Psychology* (2nd ed.). New York: Worth Publishers.

Schilling, M. A. (2003). Technological leapfrogging: Lessons from the US video game console industry. *California Management Review*, 45(3), 6-32.

Schiller, N. (2008). A portal to student learning: What instruction librarians can learn from video game design. *Reference Services Review*, 36(4), 351-365.

Schmidt, H. G., Rotgans, J. I., & Yew, E. H. (2011). The process of problem-based learning: What works and why. *Medical Education*, 45(8):792-806.

Scholten, H., Malmberg, M., Lobel, A., Engels, R. C., & Granic, I. (2016). A randomized controlled trial to test the effectiveness of an immersive 3D video game for anxiety prevention among adolescents. *PloS one*, 11(1), 22-26.

- Schraw, G., & Olafson, L. (2003). Teachers' epistemological world views and educational practices. *Journal of Cognitive Education and Psychology*, 3(2), 178-235.
- Schulzke, M. (2009). Moral decision making in fallout. *Game Studies*, 9(2), 4-6.
- Schunk, D. H. (2000). Coming to terms with motivation constructs: *Contemporary Educational Psychology*, 25, 116–119.
- Schwartz, D. L., Bransford, J. D., & Sears, D. (2005). *Efficiency and innovation in transfer. Transfer of learning from a modern multidisciplinary perspective*. Greenwich: Information Age Publishing.
- Sessoms, D. (2008). Interactive instruction: Creating interactive learning environments through tomorrow's teachers. *International Journal of Technology in Teaching and Learning*, 4(2), 86-96.
- Shamir, A., Tzuriel, D., & Rosen, M. (2006). Peer mediation: The effects of program intervention, maths level, and verbal ability on mediation style and improvement in maths problem solving. *School Psychology International*, 27(2):209-231.
- Shavelson, R. J. (2010). *Measuring college learning responsibly: Accountability in a new era*. Stanford, CA: Stanford University Press
- Shaw, A. (2015). *Gaming at the edge: Sexuality and gender at the margins of gamer culture*. Minnesota: University Of Minnesota Press.
- Sheff, D. (2011). *Game over: How Nintendo conquered the world*. New York City, New York: Penguin Random House.
- Shepard, J., & Greene, R. W. (2003). *Sociology and you*. Ohio: Glencoe McGraw-Hill.
- Sherry, J. L. (2001). The effects of violent video games on aggression. *Human Communication Research*, 27(3), 409-431.
- Sherry, J. L. 2007. Violent video games and aggression: Why can't we find effects? *Mass Media Effects Research: Advances through Meta-Analysis*, 12, 245-262.

Shute, V. J., Ventura, M., & Ke, F. (2015). The power of play: The effects of Portal 2 and Lumosity on cognitive and noncognitive skills. *Computers and Education*, 80, 58-67.

Sibbett, L. A. (2016). Toward a transformative criticality for democratic citizenship education. *Democracy and Education*, 24(2). Retrieved from <http://democracyeducationjournal.org/home/vol24/iss2/1>

Siegel, H. (1988). Educating reason rationality, critical thinking and education. *Teaching Philosophy*, 11(2), 165-168.

Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology*, 64, 489-528.

Skinner, B. F. (2011). *About behaviourism*. New York: Vintage.

Smith, G. G., & Middleton, J. A. (2003). Interactive versus observational learning of spatial visualization of geometric transformation. *Australian Educational Computing*, 18(1), 3-10.

Snowman, J., McCown, R., & Biehler, R. (2011). *Psychology applied to teaching* (12th ed.). Boston, MA: Houghton.

Sola, E., Hoekstra, R., Fiore, S., & McCauley, P. (2017). An investigation of the state of creativity and critical thinking in engineering undergraduates. *Creative Education*, 8, 1495-1522.

South Africa. Department of Basic Education. (2011). *Curriculum and Assessment Policy Statement*. Pretoria: Government Printer.

South Africa. Department of Education. (1997). *Curriculum 2005. Lifelong learning for the 21st century*. Pretoria: Government Printer.

South Africa. Department of Education. (2002). *Overview of Revised National Curriculum Statement, Grades R-9 (Schools)*. Pretoria: Sol Plaatjie House.

South African Institute for Distance Education. (2012). *Getting practical. A guide to teaching and learning*. (3rd ed.). Cape Town: Oxford University Press.

Spence, L. D. (2001). *Problem-based learning: Lead to learn, learn to lead*. Retrieved from <https://www.studygs.net/pblhandbook.pdf>

Squire, K. (2003). Video games in education. *International Journal of Intellectual Games and Simulation*, 2(1), 49-62.

Squire, K., & Jenkins, H. (2003). Harnessing the power of games in education. *Insight*, 3(1), 5-33.

Staff, E. (2007). The 30 defining moments in gaming. Retrieved from <http://www.edge-online.com/features/the-30-defining-moments-in-gaming>

Sternberg, R. J. (2007). A systems model of leadership: WICS. *American Psychologist*, 62(1), 34.

Sternheimer, K. (2003). *It's not the media: The truth about pop culture's influence on children*. New York: Basic Books.

Stes, A., Min-Leliveld, M., Gijbels D., & Van Petegem, P. (2010). The impact of instructional development in higher education: The state-of-the-art of the research. *Educational Research Review* 5, 25-49.

Steyn, H. S. (2005). *Handleiding vir bepaling van effekgrootte-indekse en praktiese betekenisvolheid* [Manual for the determination of effect size indices and practical significance]. Potchefstroom: Statistical Consultation Service, North-West University.

Stoddard, J. D. (2010). The roles of epistemology and ideology in teachers' pedagogy. *Teachers and Teaching*, 16(1):153-171.

Strydom, H. (2002). Information collection: Participant observation. In A. S. De Vos, H. Strydom, C. B. Fouché, & C. S. L. Delport (Eds.), *Research at grass roots. For the social sciences and human service professions* (2nd ed., pp. 278-290). Pretoria: Van Schaik.

Strydom, H. (2011). Sampling in the quantitative paradigm. In A. S. De Vos, H. Strydom, C. B. Fouché, & C. S. L. Delport (Eds.), *Research at grass roots. For the social sciences and human service professions* (4th ed., pp. 222-234). Pretoria: Van Schaik.

Strydom, H., & Delport, C. S. L. (2011). Sampling and pilot study in qualitative research. In A. S. De Vos, H. Strydom, C. B. Fouché, & C. S. L. Delport (Eds.), *Research at grass roots. For the social sciences and human service professions* (4th ed., pp. 390-396). Pretoria: Van Schaik.

Stupnisky, R. H., Renaud, R. D., Daniels, L. M., Haynes, T. L., & Perry, R. P. (2008). The interrelation of first-year college students' critical thinking disposition, perceived academic control, and academic achievement. *Research in Higher Education*, 49(6), 513–30.

Sumner, W. G. (1906). *Folkways: A study of the sociological importance of usages, manners, custom or morals*. Boston: The Athenaeum Press.

Sumner, W. G. (1979). *Folkways: A study of the sociological importance of usages, manners, customs, mores and morals*. Redditch, Worcestershire: Read Books Ltd.

Svingby, G., & Nilsson, E. M. (2011). Research review: Empirical studies on computer game play in science education. In P. Felicia (Eds.), *Handbook of research on improving learning and motivation through educational games: Multidisciplinary approaches* (pp. 118-136). Hershey, PA: IGI Global.

Swanepoel, J.W.H., Swanepoel, C.J., Van Graan, F.C., Allison, J.S., Weideman, H.M., & Santana, L. (2006). *Elementêre statistiese metodes* [Elementary statistical methods]. Potchefstroom: Platinum Press.

Swann, J. (2012). *Learning, teaching and education research in the 21st century: An evolutionary analysis of the role of teachers*. London: Bloomsbury Publishing.

Teichler U. (2005). Research on higher education in Europe. *European. Journal of Education*, 40(4), 447-469.

Ten Dam, G., & Volman, M. (2004). Critical thinking as a citizenship competence: teaching strategies. *Learning and Instruction*, 14(4), 359-379.

Thayer-Bacon, B. J. (2000). *Transforming critical thinking: Thinking constructively*. New York: Teachers College Press.

Theron, L. C., & Grosser, M. M. (2010). *Qualitative research: Data analysis and interpretation*. FOER 611 Lecture, 10 March 2010. Vanderbijlpark: North-West University.

Thinyane, H. (2010). Are digital natives a world-wide phenomenon? An investigation into South African first-year students' use and experience with technology. *Computers and Education*, 55, 406-414.

Thompson, J. (2007). *Video games getting deeper*. *The Star*. Retrieved from https://www.thestar.com/life/2007/06/15/video_games_getting_deeper.html

Thorpe, S. A. (1996). *African traditional religions. An introduction*. Pretoria: University of Pretoria.

Thorsen, T. (2003). *Haitian-Americans protest Vice City*. Retrieved from <http://www.gamespot.com/pc/action/grandtheftautovicecity/news.html?sid=608445>.

Thorsen, T. (2005). *Confirmed: Sex Minigame in PS2 San Andreas*. Retrieved from www.gamespot.com/articles/confirmed-sex-minigame-in-ps2-san-andreas/1100-6129301/

Thyer, B. (2014). *Workshop: Quasi experimental research*. Vanderbijlpark: Optentia Research Focus Area.

Tight M. (2003). *Researching higher education*. Berkshire: Society for research into Higher Education & Open University Press

Tobias, S., & Duffy, T.M. (Eds.). 2009. *Constructivist instruction: Success or failure?*. London: Routledge.

- Toner, J., & Moran, A. (2016). On the importance of critical thinking: A response to Wulf's (2015) commentary. *Psychology of Sport and Exercise*, 22, 339-340.
- Tournaki, N. (2003). The differential effects of teaching addition through strategy instruction versus drill and practice to students with and without learning disabilities. *Journal of Learning Disabilities*, 36(5), 449-458.
- Tremblay, K., Lalancette, D., & Roseveare, D. (2012). *AHELO Feasibility Study Report. Volume 1 –Design and Implementation*. Organization for Economic Co-operation and development (OECD). Retrieved from <http://www.oecd.org/edu/skills-beyondschool/AHELOFSReportVolume1.pdf>
- Trilling, B., & Fadel, C. (2009). *21st century skills: Learning for life in our times*. New Jersey: John Wiley & Sons.
- Trybus, J. (2010). *Game-based learning: What it is, why it works, and where it's going. NMI White Paper*. New York: New Media Institute.
- Tuovinen, J. E., & Sweller, J. (1999). A comparison of cognitive load associated with discovery learning and worked examples. *Journal of Educational Psychology*, 91(2), 334-341.
- Turan, H. (2016). Comparison of critical thinking dispositions of prospective teachers. *Educational Research and Review*, 11(8), 867-876.
- Turner, J. C. (1995). The influence of classroom contexts on young children's motivation for literacy. *Reading Research Quarterly*, 30(3), 410-441.
- Tzuriel, D. (2001). *Dynamic assessment of young children*. New York: Kluwer Academic/Plenum.
- Tzuriel, D. (2013). Mediated learning experience and cognitive modifiability. *Journal of Cognitive Education and Psychology*, 12(1), 59-80.
- Umar, I. N., & Ahmad, N. H. (2010). Trainee teachers' critical thinking in an online discussion forum: A content analysis. *Malaysian Journal of Learning and Instruction*, 7, 75-91.

UNESCO. (2012). *UNESCO guidelines for the recognition, validation and accreditation of the outcomes of non-formal and informal learning*. Hamburg, Germany: UNESCO Institute for Lifelong Learning.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin*, 139, 352-402.

Valve Software [Firm] (2007). *Portal The Orange Box* [Video Game], Bellevue, WA: Valve Software.

Vandermensbrugghe, J. (2004). The unbearable vagueness of critical thinking in the context of the Anglo-Saxonisation of education. *International Education Journal*, 5(3), 17-422.

Van Der Silk, F., & Weideman, A. (2008). Measures of improvement in academic literacy. *Southern African Linguistics and Applied Language Studies*, 26, 363-378.

Van Der Silk, F., & Weideman, A. (2009). Revisiting test stability: Further evidence relating to the measurement of difference in performance on a test of academic literacy. *Southern African Linguistics and Applied Language Studies*, 27:253-263.

Van Rooyen, H. G., & Van der Merwe, C. (2008). Teaching-learning media. In M. Jacobs, N. C. G. Vakalisa, & N. Gawe (Eds.), *Teaching-learning dynamics. A participative approach for OBE* (pp. 228-266). Sandton: Heinemann Publishers.

Ventura, M., Shute, V., & Zhao, W. (2013). The relationship between video game use and a performance-based measure of persistence. *Computers and Education*, 60, 52-58.

Von Glasersfeld, E. (1984). An introduction to radical constructivism. In P. Watzlawick, (Ed.), *The invented reality* (pp. 17-40). New York: Norton.

Von Salisch, M., Vogelgesang, J., Kristen, A., & Oppl, C. (2011). Preference for violent electronic games and aggressive behaviour among children: The beginning of the downward spiral? *Media Psychology*, 14(3), 233-258.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Harvard: Harvard University Press.

Wagner, R. (2012). Religion in video games. *Understanding Religion and Popular Culture*, pp.118-140.

Wallace, B., Ross, A., Davies, J.B., & Anderson, T. (Eds.). (2007). *The mind, the body and the world: Psychology after cognitivism*. London: Imprint Academic.

Walling, A. D. (2002). Do video games lead to violent behavior in children?. *American Family Physician*, 65(7), 1436-1438.

Wang, Y., & Chiew, V. (2010). On the cognitive process of human problem solving. *Cognitive systems research*, 11(1), 81-92.

Warburton, N. (2006). *The basics of essay writing*. London: Routledge.

Watson, D. (2015). Is *critical thinking a western concept*? Retrieved from <https://www.britishcouncil.org/voices-magazine/critical-thinking-western-concept>

Watson, G., & Glaser, E. M. (2002a). *Watson-Glaser Critical Thinking Appraisal UK Edition*. The Psychological Corporation. London: Pearson.

Watson, G., & Glaser, E. M. (2002b). *Watson-Glaser Critical Thinking Appraisal – UK Edition. Manual*. The Psychological Corporation. London: Pearson.

Watson, J. B. (2013). *Behaviourism*. Worcestershire, UK: Read Books Limited.

Wechsler, S. M., Saiz, C., Rivas, S. F., Vendramini, C. M. M., Almeida, L. S., Mundim, M. C., & Franco, A. (2018). Creative and critical thinking: Independent or overlapping components. *Thinking Skills and Creativity*, 27, 114-122.

Weinert, F. E., & Helmke, A. (1995). Learning from wise mother nature or big brother instructor: The wrong choice as seen from an educational perspective. *Educational Psychologist*, 30(3), 135-142.

Wells, S., Warelou, P., & Jackson, K. (2009). Problem based learning (PBL): A conundrum. *Contemporary Nurse*, 33(2), 191-201.

- Wertsch, J.V., Del Rio, P., & Alvarez, A. (1995). *Sociocultural studies of mind*. Cambridge: Cambridge University Press.
- Wertsch, J. V., & Toma, C. (1995). Discourse and learning in the classroom: A socio-cultural approach. In L. P. Steffe, & J. Gale (Eds.), *Constructivism in education* (pp. 159–175). Hillsdale, NJ: Erlbaum.
- Westwood, P. S. (2008). *What teachers need to know about teaching methods*. Camberwell, Victoria: Australian Council for Educational Research.
- Whittaker, J. (2004). *The cyberspace handbook*. London, UK: Psychology Press.
- Wilhelm, J. D., & Wilhelm, P. J. (2010). Inquiring minds learn to read, write, and think: Reaching all students through enquiry. *Middle School Journal*, 41(5), 39-46.
- Williams, J. P., & Smith, J. H. (Eds.). (2007). *The players' realm: Studies on the culture of video games and gaming*. Jefferson, N.C.: McFarland & Co.
- Williams, R. (2005). Targeting critical thinking within teacher education: The potential impact of society. *The Teacher Educator*, 40(3), 163-187.
- Willingham, D. T. (2008). Critical thinking: Why is it so hard to teach? *Art Education Policy Review*, 109(4), 21-32.
- Willingham, D. T., Hughes, E. M., & Dobolyi, D. G. (2015). The scientific status of learning styles theories. *Teaching of Psychology*, 42(3), 266-271.
- Winch, C. (2006). *Education, autonomy, and critical thinking*. London: Routledge.
- Wolf, M. J. P. (2008). *The video game explosion: A history from PONG to PlayStation and beyond*. Westport, CT: Greenwood Press.
- Woolfolk, A. (2010). *Educational psychology* (11th ed.). Upper Saddle River: Pearson.
- Wouters, P., Van Nimwegen, C., & Van der Spek, E.D. (2013). A meta-analysis of the cognitive, and motivational effects of serious games. *Journal of Educational Psychology*, 105(2), 249-265.

Wouters, P., & Van Oostendorp, H. (2017). Overview of instructional techniques to facilitate learning and motivation of serious games. In P. Wouters, & H. Van Oostendorp (Eds.), *Instructional techniques to facilitate learning and motivation of serious games* (pp. 1-16). New York: Springer.

Yamasaki, L. J. (2016). *Portal still alive and Portal 2: Lessons from critical narrative gaming pedagogy* (Thesis - PhD). Univeristy of Los Angeles: California.

Yang, Y. T. C., Newby, T. J., & Bill, R. L. (2005). Using Socratic questioning to promote critical thinking skills through asynchronous discussion forums in distance learning environments. *The American Journal of Distance Education*, 19(3), 163-181.

Yasunaga, M. (2014). *Non-formal education as a means to meet learning needs of out-of-school children and adolescents* (Background paper for “Fixing the broken promise of education for all: Findings from the global initiative on out-of-school children”). Montreal, Canada: UNESCO Institute for Statistics.

Yew, E. H., & Schmidt, H. G. (2012). What students learn in problem-based learning: A process analysis. *Instructional Science*, 40(2), 371-395.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, California: Sage.

Zascavage, V. (2010). Critical thinking skills and the intervention specialist. *Journal of Border Education Research*, 8, 71-80.

Zhao, C., Pandian, A., & Singh, M. K. M. (2016). Instructional strategies for the development of critical thinking in EFL classrooms. *English Language Teaching*, 9(10), 14-21.

APPENDIX A

PROOF OF LANGUAGE EDITING



Faculty of Education
School of Languages for Education

Tel: (016) 910-3071

DECLARATION

This is to certify that the undersigned has done the language editing for the following candidate:

SURNAME and INITIALS: BUNT, BJ

TITLE: Potential benefits of a Puzzle Video Game - Cognitive Enrichment Programme for the development of critical thinking among first-year BEd students

DEGREE: PhD thesis

A handwritten signature in black ink, which appears to read 'Rhelda Krügel', is written over a horizontal line.

RHELDA KRÜGEL

22 February 2019

DATE

NOTE WELL: The language editor does not accept any responsibility for post-editing, re-typing or re-computerising of the content.

APPENDIX B

ETHICS CLEARANCE



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
VAAL TRIANGLE CAMPUS

PO Box 1174, Vanderbijlpark
South Africa, 1900

Basic and Social Sciences Research Ethics
Committee

Tel: +27(16) 910-3483

Web: <http://www.nwu.ac.za>

Email: Charmaine.lekonyane@nwu.ac.za

2 March 2017

Dear Mr Byron Bunt and Prof Mary Grosser

ETHICS APPLICATION: NWU-HS-2017-0020

**Potential benefits of a Puzzle Video Game - Cognitive Enrichment Programme (PVG-CEP)
for the development of critical thinking among first year B.Ed. Students**

Risk Level: Low

PhD: Education Sciences

Thank you for a well-presented application and additional material!

At the meeting of the Basic and Social Sciences Research Ethics Committee (BaSSREC) held on 16 February 2017, the committee ratified the approval of the above ethics application in view of the additional information submitted. There is an adequate risk/benefit ratio and the protocol is acceptable.

A certificate will be issued for the duration of the applicant's period of study, with a maximum period of 3 years and communication will be kept for progress tracking purposes.

Congratulations and best of wishes with the completion of your study.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'Jaco Hoffman'.

Prof Jaco Hoffman
BaSSREC – Chairperson

Ethics Expiry Date: 3 March 2020



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONFI-BOPHIRIMA
NOR OREWE-JUNIWEIT

Private Bag X6001, Potchefstroom,
South Africa, 2520

Tel: (018) 299-4900
Faks: (018) 299-4910
Web: <http://www.nwu.ac.za>

Institutional Research Ethics Regulatory Committee

Tel: +27 18 299 4849
Email: Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF STUDY

Based on approval by the Basic and Social Sciences Research Ethics Committee (BaSSREC) on 03/03/2017 after being reviewed at the meeting held on 16/02/2017, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby approves your study as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Project title:																															
Potential benefits of a Puzzle Video Game - Cognitive Enrichment Programme (PVG-CEP) for the development of critical thinking among first year B.Ed. Students																															
Project Leader/Supervisor: Prof Mary Grosser																															
Student: Byron Bunt																															
Ethics number:	<table border="1"> <tr> <td>N</td><td>W</td><td>U</td><td>-</td><td>HS</td><td>-</td><td>2</td><td>0</td><td>1</td><td>7</td><td>-</td><td>0</td><td>0</td><td>2</td><td>0</td> </tr> <tr> <td colspan="4">Institution</td> <td colspan="4">Year</td> <td colspan="7">Project Number</td> </tr> </table>	N	W	U	-	HS	-	2	0	1	7	-	0	0	2	0	Institution				Year				Project Number						
N	W	U	-	HS	-	2	0	1	7	-	0	0	2	0																	
Institution				Year				Project Number																							
Application Type: Single Study																															
Commencement date: 2017-03-03	Expiry date: 2020-03-03																														
Risk:	Low																														

Special conditions of the approval (if applicable):

- Translation of the Informed consent document to the languages applicable to the study participants should be submitted to the BaSSREC (if applicable).
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the BaSSREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- The project leader (principle investigator) must report in the prescribed format to the NWU-IRERC via BaSSREC:
 - annually (or as otherwise requested) on the progress of the study, and upon completion of the project
 - without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
 - Annually a number of projects may be randomly selected for an external audit.
- The approval applies strictly to the proposal as stipulated in the application form. Would any changes to the proposal be deemed necessary during the course of the study, the study leader must apply for approval of these changes at the BaSSREC. Would there be deviation from the study proposal without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC via BaSSREC and new approval received before or on the expiry date.
- In the interest of ethical responsibility the NWU-IRERC and BaSSREC retains the right to:
 - request access to any information or data at any time during the course or after completion of the study;
 - to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.
 - withdraw or postpone approval if:
 - any unethical principles or practices of the project are revealed or suspected,
 - it becomes apparent that any relevant information was withheld from the BaSSREC or that information has been false or misrepresented,
 - the required annual report and reporting of adverse events was not done timely and accurately,
 - new institutional rules, national legislation or international conventions deem it necessary.
- BaSSREC can be contacted for further information or any report templates via Charmaine.Lekonyane@nwu.ac.za or 018 210 3483.

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC or BaSSREC for any further enquiries or requests for assistance.

Yours sincerely

Prof LA

Du Plessis

Prof Linda du Plessis

Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

Digitally signed by
Prof LA Du Plessis
Date: 2017.08.23
07:34:17 +02'00'

APPENDIX C

CONSENT: RESEARCH DATA GATEKEEPER COMMITTEE

NWU RDGC PERMISSION GRANTED / DENIED LETTER

Based on the documentation provided by the researcher specified below, on 19/01/2018 the NWU Research Data Gatekeeper Committee (NWU-RDGC) hereby grants permission for the specific project (as indicated below) to be conducted at the North-West University (NWU):

Project title: Potential benefits of a Puzzle Video Game - Cognitive Enrichment Programme (PVG-CEP) for the development of critical thinking among first year B.Ed. students.	
Project leader/Supervisor:	Prof Mary Grosser
Student:	Mr B bunt
NWU-RDGC reference no: NWU-GK-2017-0048	
NWU Ethics reference no: NWU-HS-2017-0020	
Approval date: 19/01/2018	Expiry date: 18/01/2019
Permission granted for the following in terms of recruitment and invitation of participants:	
- The recruitment of students will only commence after registration of their academic programme. - As part of the recruitment process students should be given the opportunity to give consent whether their personal information (including the test result) should be shared with the researcher or any other external party.	
Specific Conditions:	
Written approval should be provided by the role players of the TAG/TALL tests and ICELDA (Proff. Gustav Butler & Tobie van Dyk) to make use of the results of the TAG/TALL tests, and ensure compliance with the external providers of the TAG and TALL tests as well as ICELDA.	

General Conditions of Approval:

- The NWU-RDGC will not take the responsibility to recruit research participants or to gather data on behalf of the researcher. This committee can therefore not guarantee the participation of our relevant stakeholders.
- Any changes to the research protocol within the permission period (for a maximum of 1 year) must be communicated to the NWU-RDGC. Failure to do so will lead to withdrawal of the permission.
- The NWU-RDGC should be provided with a report or document in which the results of said project are disseminated.

Please note that under no circumstances will any personal information of possible research subjects be provided to the researcher by the NWU RDGC. The NWU complies with the Promotion of Access to Information Act 2 of 2000 (PAIA) as well as the Protection of Personal Information Act 4 of 2013 (POPI). For an application to access such information please contact Ms Amanda van der Merwe (018 299 4942) for the relevant enquiry form or more information on how the NWU complies with PAIA and POPI.

The NWU RDGC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the NWU RDGC for any further enquiries or requests for assistance.

APPENDIX D
CONSENT: SCHOOL OF LANGUAGES



Postal box 1174, Vanderbijlpark
South Africa 1900

Tel: 016 910-3111
Fax: 016 910-3116
Web: <http://www.nwu.ac.za>

School of Languages
Tel: 016 910-3480
E-mail: gustav.butler@nwu.ac.za

17 January 2018

Dear sir/madam

We hereby give permission that Byron Bunt (student number: 20172672) may make use of the TALL/TAG results of 2018 at the Vaal Triangle Campus of North-West University for the purposes of selecting participants for his PhD study titled: *The potential benefits of a Puzzle Video Games - Cognitive Enrichment Program (PVG-CEP) on the development of critical thinking and problem solving abilities of first year university students.*

Kind regards

Prof. Tobie van Dyk

Chairperson: ICELDA (Deputy Director: School of Languages, Potchefstroom Campus)

Prof. Gustav Butler

Director – NWU: ICELDA (Director: School of Languages)

APPENDIX E

INFORMED CONSENT LETTER: STUDENTS



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
VAAL TRIANGLE CAMPUS

PO Box 1174, Vanderbijlpark
South Africa, 1900
Web: <http://www.nwu.ac.za>

DATE: 8 January 2017

BaSSREC Stamp

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR FIRST-YEAR B.ED. STUDENTS

TITLE OF THE RESEARCH PROJECT: Potential benefits of a Puzzle Video Game - Cognitive Enrichment Programme (PVG-CEP) for the development of critical thinking among first-year B.Ed. students

REFERENCE NUMBERS:

PRINCIPAL INVESTIGATOR/RESEARCHER: Mr Byron Bunt

ADDRESS: SCHOOL OF EDUCATION SCIENCES, NORTH-WEST UNIVERSITY,
HENDRICK VAN ECK BOULEVARD 100, VANDERBIJLPARK

CONTACT NUMBER: 016 910 3126/076 751 3079

You are invited to take part in a research project that forms part of my (the researcher's) study for a doctoral degree (PhD) in Education. Please take some time to read the information presented here, which will explain the details of this project. Please ask the independent person, Mr. Grantt Gouws, who will explain the research to you, any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied and that you clearly understand what this research is about and how you could be involved. In addition, your participation is **entirely voluntary** and you are free to decline participation. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part. You may also ask me to delete information/data about you that I collected. If you are 18 and younger, your parents/guardians will also give consent that you may take part in the study. You need to know that even if your parents/guardians give consent for you to take part, you still have the choice to decide if you want to take part in the research or not.

This study has been approved by the **Humanities and Health Research Ethics Committee (HHREC) of the Faculty of Humanities of the North-West University (NWU.....)** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki and the ethical guidelines of the National Health Research Ethics Council. It might be necessary for the research ethics committee or relevant authorities to inspect the research records to make sure that we (the researchers) are conducting research in an ethical manner.

What is this research study all about?

I am Mr Byron Bunt, the researcher and a lecturer, who would like to involve you in my research project, which I am completing for a Doctoral Degree. My research project will be conducted at the North-West University, Vaal Triangle Campus in Vanderbijlpark.

This research links well with the present teaching and learning situation in South African schools, where it is expected of teachers to teach learners the skills to identify and solve problems by means of critical and creative thinking. My study will specifically focus on critical thinking. In my study, critical thinking will mean that the research participants must be able to:

Draw inferences, in which respondents have to evaluate inferences drawn from a series of factual statements (skill);

Recognize assumptions (skill), where respondents are required to identify unstated assumptions in a series of statements;

Make deductions (skill), where respondents have to determine whether certain conclusions necessarily follow from information in given statements;

Do interpretations (skill), where evidence is weighted to decide if generalizations based on data are warranted; and

Evaluate arguments (skill), where respondents are required to distinguish between strong, relevant arguments and weak irrelevant arguments.

In addition, the research will also focus on the following critical thinking dispositions: Accuracy, persistence and systematic working ways, as well as the following intellectual standards for reasoning: Clarity, relevance and logic.

The main objectives of the study are:

To determine how sophisticated first-year B.Ed. students are in the application of critical thinking, and based on the findings;

To establish how a PVG-CEP can support the development of critical thinking among first-year B.Ed. students.

The researcher noticed that the cited international and national studies in the paragraph above approached the development of critical thinking from either a quantitative or qualitative perspective and only involved the perspectives of teachers, and mainly focused on the development of critical thinking skills and strategies, without paying attention to the development of the critical thinking dispositions and the universal standards of reasoning that also comprise effective critical thinking. This study wishes to extend the present research by combining a quantitative and qualitative research design that will focus on the development of all the elements of critical thinking, and will involve students' perspectives on the development of their critical thinking

abilities through puzzle video games. Therefore, it can be stated that this approach taken by the study will also address a methodological gap within the field.

The researcher would like to include all the first-year B.Ed.-students in the research for the pretest and posttest. The researcher will recruit the research participants by obtaining permission from the Director of the School of Education Sciences, Prof. J.E. Fourie, who will act as a gatekeeper to gain entry to the participants. This group of students will be a new group of students who have not yet been exposed to, or overburdened by research at the university.

Why have you been invited to participate?

It will be important to do the research with you, as the researcher is a lecturer at the North West University Vaal Triangle Campus and would like to use a new strategy to firstly improve the quality of teaching practice, and to establish whether it holds advantages for developing critical thinking, which is an important skill at Higher Education level. Secondly, the researcher was a teacher for many years, and knows that teachers do not know about teaching strategies that they could use to develop the critical thinking skills of learners. Doing the research with first-year student teachers will give the researcher the chance to teach a strategy to a group of teachers which they could use to possibly nurture critical thinking more effectively at school-level, when they start teaching.

In summary, you have been selected to take part in the research because:

You are a first-year, male or female B.Ed.-student from any ethnic and language group at the North-West University, Vaal Triangle Campus in Vanderbijlpark.

You are a first-year BEd-student who has passed the compulsory computer literacy course.

Participants will not be involved in the study if they are a second, third or fourth year B.Ed. student at the North-West University, Vaal Triangle Campus in Vanderbijlpark or any other university.

What will your responsibilities be?

The researcher will make use of an independent person, Mr. Grantt Gouws, who will recruit the participants for the research project. The researcher will train him for this purpose. Mr. Gouws is a qualified school teacher and works at the North-West University. An independent observer, Ms. Aldine Oosthuyzen, who knows the study well, as she will be the independent statistician who will capture the data and assist with the analysis of data, will assist him. Moreover, Ms. Oosthuyzen is a member of the Ethics Committee of the School of Economic Sciences and IT at the NWU, Vaal Triangle Campus, with a good understanding of ethical research principles, who will be able to oversee that the work of Mr. Gouws is in line with good ethical practice. Neither Mr. Gouws nor Ms. Oosthuyzen will have any relationship with the students.

The recruitment will involve a short one-hour presentation about the study in a lecture venue at the university, to all the B.Ed. 2018 first-year students, after which the independent person will hand the informed consent forms to the participants. The independent person will explain the information to the participants and request them to take the forms home where they have privacy to complete the form at their own time. The recruitment will take place at the beginning of the year during an hour period on the timetable before classes commence. In advance, the researcher will request the BEd Programme Manager, Dr. Elize Küng, to accommodate a period on the timetable for first-year students. The researcher could then utilize this period for other administrative issues

related to the research, such as receiving the informed consent, the writing of pretests and posttests, giving participants the opportunity to share their views about the research and to receive feedback about the research. The researcher will allow one week to pass between the recruitment and the obtaining of informed consent, to give participants time to think about the study and whether they want to take part or not. After one week, the independent researcher will meet with the participants during a register period in a lecture venue and collect the informed consent forms. The participants who decide to take part in the research will receive a number, which they will use when writing the different tests.

If you take part in the research, you will be part of an experiment that will run for thirteen weeks (2 hours per week per participant) each during the second semester (January to June). The participants of the control group will not take part in the experiment. The experimental group will consist of approximately 4 participants. The participants of the experimental and control group will be determined by the independent person, who will divide the participants by keeping a balanced and equal division in terms of gender, language, ethnic group etc. based on their TAG/TALL test results (A test written on entry to the university to establish academic preparedness).

The experimental group will be the group of participants where the researcher will use the new Puzzle Video Game - Cognitive Enrichment Programme for a period of thirteen weeks to see if the strategy will help the participants to develop critical thinking. An additional four students that will form part of a control group will not receive the intervention programme, but will simply write the two pre and posttests.

Based on the pretest results, the researcher will develop the Puzzle Video Game - Cognitive Enrichment Programme to address the problems with critical thinking that the researcher noted in the pretest results. If the pretests should indicate that the participants do not experience problems with the critical thinking skills, the researcher will still apply the strategy to determine if it could improve on their present application of the critical thinking skills.

Upon conclusion of the Puzzle Video Game - Cognitive Enrichment Programme, a posttest will be written to see if the Puzzle Video Game - Cognitive Enrichment Programme assisted you to develop or improve your critical thinking or problem solving skill. In total, you will write a posttest of 30 minutes.

The pre- and posttests will take the form of the Watson-Glaser Critical Thinking Appraisal which consists of five types of tests, designed to find out how well a person is able to reason logically and analytically.

The WGCTA-UK comprises five subtests containing 80 multiple-choice test items with one correct answer, with 16 items per sub-test that each measure different but interdependent aspects related to the execution of critical thinking. A total score of 80 can be achieved (16 marks per sub-test). The focus of the general scenarios in the sub-tests include neutral topics and controversial issues. The neutral topics include issues that do not expect people to have strong feelings, such as the weather or scientific facts. The controversial issues, on the other hand, focus on political and social matters that elicit definite and strong feelings (Watson & Glaser, 2002b: 2.2, 2.3). The developers suggest that the test be used as a test of power, rather than as a test of speed. The time for administering the test is indicated to be 60 minutes: 50 minutes for completion by participants

and between five to ten minutes for dealing with administrative matters, such as explaining the test procedures. An example of how the questions will be asked follows below.

Statement One:

Although it is agreed that China is rapidly modernizing its army, there is some doubt surrounding the exact amount it is spending. The research institute 'PIPPi', submits that the annual Chinese defense spending has risen from almost \$31 billion in 2000 to over \$120 billion in 2010. This figure is almost double the official figure published by the Chinese government, who fail to include other areas such as research and development in the official figure each year. In 2010, the United States government spent around \$400 billion on military defense. Based on the current level of military growth, statistics suggest that China's defense spending could overtake America's by 2030. In addition to military spending, China's army continues to enjoy the largest number of people within the ranks of its army than any other country.

Inference 1: The official figures published by the Chinese government in relation to their military spending are thought to be misleading.

True

Probably True

More Information Required

Probably False

False

At the end of the research, the researcher will compare the pretest and posttest results of all the participants to see whether the Puzzle Video Game - Cognitive Enrichment Programme assisted the participants to develop their critical thinking and problem solving skills. As suggested by the independent statistician who will assist the researcher with the data analysis, comparisons of the test results of individual students will also be done, as it could be that individual participants benefit more from the new strategy than the group of participants. For this purpose, each participant will receive a number that they will use throughout the research on their pretests and posttests so that it will be possible for the researcher to do comparisons with the different numbers. No comparison will, however, be linked to a participant's name.

Opportunities for participants to share their opinions about the research, as well as opportunities for feedback about the research will be scheduled.

In summary, your involvement will entail the following: (Exact dates and times to be provided)

Invitation and explanation of informed consent (1 hour and 20 minutes)
Completing informed consent (At home, 1 week)
Submit informed consent.
Selection to take part in the research based on the TAG/TALL test results.
Writing pretests (50 minutes) before taking part in the intervention.
The implementation of the PVG-CEP strategy for thirteen weeks, 2 hours per week, during which observations with the assistance of a co-observer will be compiled and video recorded.
Writing posttests (50 minutes) after the implementation of the intervention.
Attending one interview session to obtain feedback from students regarding their experiences and perspectives surrounding the intervention programme and its benefits.

Will you benefit from taking part in this research?

The direct benefits for you as participant will probably be the following:

You might acquire critical thinking skills with the Puzzle Video Game – Cognitive Enrichment Programme to enable you to think critically and solve problems more effectively.

The Puzzle Video Game – Cognitive Enrichment Programme is also a learning strategy that could assist you to learn and study better and possibly improve your academic performance in any subject.

Another benefit would be that you would probably possess an effective strategy that you could use when you start teaching.

The indirect benefit will probably be that:

Researchers at other universities could be informed about the possible benefits of a Puzzle Video Game - Cognitive Enrichment Programme to develop critical thinking skills and conduct further studies in other contexts to prove the benefits of the strategy for developing critical thinking skills on a larger scale.

The research findings could be used to make recommendations to the Department of Education, regarding the possible improvement of the teaching practices of teachers.

The teaching practice of the greater population of student teachers could benefit if the Puzzle Video Game - Cognitive Enrichment Programme holds merits for developing critical thinking, and the message will be communicated to Schools of Education Sciences at Universities who could incorporate training in the use of the strategy into the teacher-training curriculum.

Are there risks involved in your taking part in this research and how will these be managed?

The possible risks in this study, and how the researcher will manage them, are summarised in the table below:

Probable/possible risks/discomforts	Strategies to minimize risk/discomfort
Conflict of interest and the power relationship because the researcher will also be a lecturer at North West University Vaal Campus.	The researcher acknowledges that the group of participants will be a vulnerable group due to the conflict of interest and hierarchical lecturer-student relationship that will exist, because he will be a lecturer at North West University Vaal Campus. However, the use of an independent person (Mr Grantt Gouws) to do the recruitment of the participants and obtain informed consent, will avoid that participants feel coerced to take part in the research, and avoid them being influenced by the lecturer-student relationship. Vulnerability could be reduced in this way. The independent person will not know or have any contact with the participants and will not teach any of the participants. This will ensure that the participants will not be forced to do something against their will, or be threatened, pressurized or persuaded with force to take part in the study to please their lecturer. The researcher will avoid including students in the sample that he lectures. Tests will be translated into Afrikaans if there are Afrikaans-speaking students in the sample.
Completing a test and taking part in an intervention programme might cause anxiety and stress, and inconvenience.	The independent person, who will do the recruitment, obtain informed consent and collect the data, will explain the following to the participants. They do not need to prepare or study for the completion of the test or the intervention. The data collection with the test will take place at times convenient to the participants, preferably during a period on the timetable where all students have a free period to avoid additional traveling to complete the test. Refreshments will be provided after the completion of the test. The intervention will take place during times that are suitable for the participants for approximately two hours per week. The test and intervention will not influence the participants' passing or failing their studies. The data will only be used for research purposes only. Data collection will not overburden the participants. The test completion will not exceed 60 minutes, and not disturb teaching time. Refreshments will be given after the completion of the test. The intervention will take place during times convenient for the participants, for no longer than an hour at a time.
Complete anonymity cannot be guaranteed	In order to identify which participants are experts or novices in terms of the development of critical thinking, and the use of video recordings and interviews, this will mean that the researcher cannot guarantee complete anonymity.

The researcher has planned for appropriate measures to minimize research-related risks, so that the participants could experience the benefits that the research could hold, as noted above. The risks appear to be reasonable in relation to the importance of skills to be gained that can possibly improve teaching and learning.

Who will have access to the data?

Your test results will not be linked to your name. You will not write your name on the test, but will be identified by a number (1, 2 etc.). All results that will be reported will be linked to a number. You will remain anonymous to the researcher, and your name will not be mentioned in the findings that will emanate from the research. The researcher assures you that we will protect the information we have about you. All information regarding the research will be stored on a password-protected computer and the completed tests will be locked up in a cupboard in the researcher's office. The researcher is the only person who has a key to unlock the cupboard.

Apart from the independent researcher, only two other people will have access to the data, namely the independent statistician who will assist me with the capturing of the data, and my promoter who will check and verify that my research findings are correct. The independent statistician is Ms. Aldine Oosthuyzen who is a qualified and experienced statistician. The researcher will store the data for a minimum of five years. The independent person, study leader and the independent statistician will sign a written agreement at the beginning of the study that they will keep all information about the study and the findings of the study confidential, and not talk about it.

What will happen to the data?

The researcher assures you that the information obtained via the research will be used for research purposes only, and no information about you will be made known in reporting about the study (for example your name, your address or your parents'/guardians' name or an address). The data from this study will be reported in the following ways: (i) The researcher will report the findings in the form of a thesis that will be submitted to examiners at other universities for examination purposes, (ii) The researcher also intends to write about the research in articles and book chapters, and speak about the research at conferences.

This is a once-off study, so the data will not be re-used in any other studies, which the researcher may do in future.

Will you be paid/compensated to take part in this study and are there any costs involved?

You will not be paid/compensated to take part in the study, but refreshments will be given to you after the completion of each test. This will serve as a token of appreciation that you were willing to become part of the research. The writing of the tests and the intervention programme will take place during periods on the normal timetable. You do not have to arrange for additional traveling to participate. No costs will be involved in taking part in the study.

How will you know about the findings?

The general findings of the research will be shared with you via email or post (please include your address below) by the researcher who will compile a short report about the findings that will be provided to all the research participants during a specified period. All questions about the report can be directed to the researcher at the contact details below. Alternatively, you are welcome to schedule an appointment with the researcher to discuss your questions.

Is there anything else that you should know or do?

You can contact Mr Byron Bunt at 076 751 3079 or 20172672@nwu.ac.za or his study leader, Prof. Mary Grosser at 083 490 0501 or mary.grosser@nwu.ac.za, if you have any further queries or encounter any problems.

You can contact the chair of the BaSSREC Research Ethics Committee (Prof Jaco Hoffmann) jaco.hoffmann@nwu.ac.za if you have any concerns or complaints that have not been adequately addressed by the researcher.

If you have difficulty in following and understanding the explanation of the research, please contact the researcher or the independent person at the details below, and they will arrange a time with you to meet with the researcher to explain what is problematic to you.

You will receive a copy of this information and consent form for your own records.

Declaration by participants

By signing below, I, agree that I will take part in a research study entitled: **Potential benefits of a Puzzle Video Game - Cognitive Enrichment Programme (PVG-CEP) for the development of critical thinking among first-year B.Ed. students**

I declare that:

I have read and understood this information and consent form and it is written in a language with which I am fluent and comfortable.

I have had a chance to ask questions to both the person obtaining consent, as well as the researcher (if this is a different person), and all my questions have been adequately answered. I understand that taking part in this study is **voluntary** and I have not been pressurised to give consent that my son/daughter may take part.

I understand that my test results could be reproduced publically and/or quoted, but without reference to me or my parents'/guardians' personal identity.

I may choose to leave the study at any time and will not be penalised or prejudiced in any way. I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) on (*date*) 20....

.....
Signature of participant

.....
Signature of witness

You may contact me again

☐ **Yes** ☐ **No**

I would like a summary of the findings of this research

☐ **Yes** ☐ **No**

The best way to reach me is:

Name & Surname: _____

Postal Address: _____

Email: _____

Phone Number: _____

Cell Phone Number: _____

In case the above details change, please contact the following person who knows me well and who does not live with me and who will help you to contact me:

Name & Surname: _____

Phone/ Cell Phone Number /Email: _____

Declaration by person obtaining consent

I (*name*) declare that:

I explained the information in this document to

I encouraged him/her to ask questions and took adequate time to answer them.

I am satisfied that he/she adequately understands all aspects of the research, as discussed above

I did not use an interpreter.

The best way to reach me is:

Name & Surname:

Postal Address:

Email:

Phone Number:

Cell Phone Number:

Signed at (*place*) on (*date*) 20....

.....
Signature of person obtaining consent

.....
Signature of witness

Declaration by researcher

I (*name*) declare that:

I explained the information in this document to

I encouraged him/her to ask questions and took adequate time to answer them.

I am satisfied that he/she adequately understands all aspects of the research, as discussed above

I did/did not use a interpreter.

Signed at (*place*) on (*date*) 20....

.....
Signature of independent person

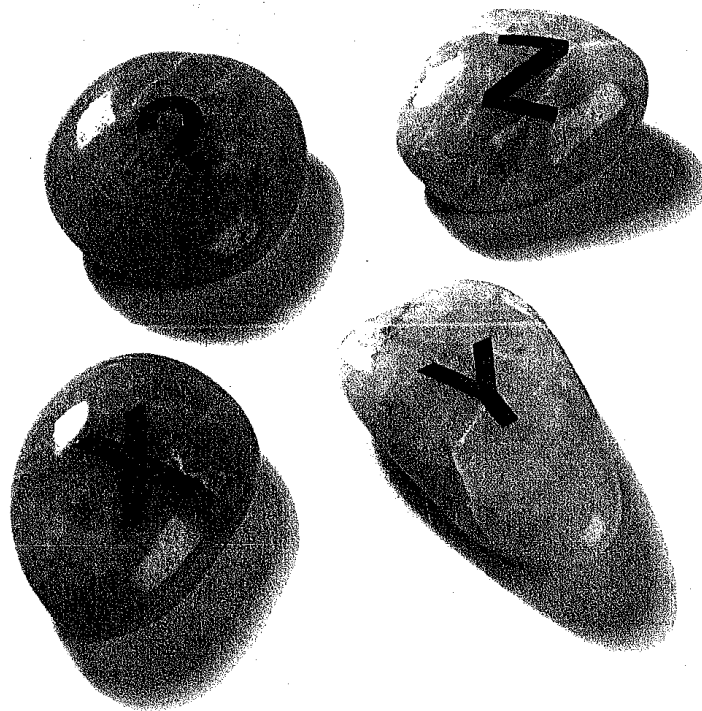
.....
Signature of witness

APPENDIX F

W-GCTA TEST (UK)

Goodwin Watson – Edwin Glaser

Critical Thinking Appraisal – UK Edition Test Booklet



 **Harcourt
Assessment**
The Psychological Corporation



DIRECTIONS

- This booklet contains five types of test designed to find out how well you are able to reason analytically and logically.
- *Each test has separate directions that should be read carefully.*
- All answers are to be marked on the separate Record Form. Use a sharp pencil. If you wish to change an answer, make sure that you erase your old answer completely.
- Make sure that you have filled in the details requested on the Record Form.
- **DO NOT TURN THIS PAGE UNTIL THE EXAMINER TELLS YOU TO.**



Published by Harcourt Assessment, 32 Jamestown Road, London, NW1 7BY.
Copyright © 2002, 2001, 2000, 1990, 1980, 1964 by Harcourt Assessment.
Adapted by permission.

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording or any retrieval system, without permission in writing from the publisher.

Printed in England.

ISBN: 0 7491 0761 8

Test 1: Inference

DIRECTIONS

An inference is a conclusion that a person can draw from certain observed or supposed facts. For example, if the lights are on in a house and music can be heard coming from the house, a person might infer that someone is at home. But this inference may or may not be correct. It is possible that the people of the house did not turn the lights and the radio off when they left the house.

In this test, each exercise begins with a statement of facts that you are to regard as true. After each statement of facts you will find several possible inferences i.e., conclusions that some persons might draw from the stated facts. Examine each inference separately, and make a decision as to its degree of truth or falsity.

For each inference you will find spaces in the Record Form labelled T, PT, ID, PF and F. For each inference put a cross on the Record Form under the appropriate heading as follows:

T if you think the inference is definitely TRUE; that it properly follows beyond a reasonable doubt from the statement of facts given.

PT if, in the light of the facts given, you think the inference is PROBABLY TRUE; that it is more likely to be true than false.

ID if you decide that there are INSUFFICIENT DATA; that you cannot tell from the facts given whether the inference is likely to be true or false; if the facts provide no basis for judging one way or the other.

PF if, in the light of the facts given, you think the inference is PROBABLY FALSE; that it is more likely to be false than true.

F if you believe the inference is definitely FALSE; that it is wrong, either because it misinterprets the facts given, or because it contradicts the facts or necessary inferences from those facts.

Sometimes, in deciding whether an inference is probably true or probably false, you will have to use certain commonly accepted knowledge or information that practically every person has. This will be illustrated in the example that follows.

Now look at the example below; the correct answers are indicated in the box at the right.

In the exercises that follow, more than one of the inferences from a given statement of facts may be true (T), or false (F), or probably true (PT), or probably false (PF), or have insufficient data (ID) to warrant any conclusion. Thus you are to judge each inference independently.

EXAMPLE

Statement:

Two hundred school students in their early teens voluntarily attended a recent weekend student conference in Leeds. At this conference, the topics of race relations and means of achieving lasting world peace were discussed, since these were problems that the students selected as being most vital in today's world.

Proposed Inferences:

1. As a group, the students who attended this conference showed a keener interest in broad social problems than do most other people in their early teens. (PT, because, as is common knowledge, most people in their early teens do not show so much serious concern with broad social problems. It cannot be considered definitely true from the facts given because these facts do not tell how much concern other young teenagers may have. It is also possible that some of the students volunteered to attend mainly because they wanted a weekend outing.)
2. The majority of the students had not previously discussed the conference topics in the schools. (PF, because the students' growing awareness of these topics probably stemmed at least in part from discussions with teachers and classmates.)
3. The students came from all parts of the country. (ID, because there is no evidence for this inference.)
4. The students discussed mainly industrial relations problems. (F, because it is given in the statement of facts that the topics of race relations and means of achieving world peace were the problems chosen for discussion.)
5. Some teenage students felt it worthwhile to discuss problems of race relations and ways of achieving world peace. (T, because this inference follows from the given facts; therefore it is true.)

Test 1

	T	PT	ID	PF	F
1	☐	☒	☐	☐	☐
2	☐	☐	☐	☒	☐
3	☐	☐	☒	☐	☐
4	☐	☐	☐	☐	☒
5	☒	☐	☐	☐	☐

EXERCISES

Statement:

A teacher of English arranged for the students in one of her classes to see the film made from Charles Dickens' *Great Expectations*, while the students in all of her other English classes studied the book itself, without seeing the picture. She wanted to know whether films could be used effectively in the teaching of literature. Tests to check on appreciation and understanding of the story were given immediately after each type of instruction. On all tests, the class that saw the film did better. This class became so interested in *Great Expectations* that before the term was over, most of the students in the class chose to read the book entirely on their own initiative. The teacher felt that her experiment was a success.

Proposed inferences:

1. The tests given in this experiment were intended to measure more than just recall of facts about a book.
2. The students who were taught with the aid of the film were required to read the book at the beginning of the term.
3. Other teachers of English trying this experiment with their students would get similar results.
4. The teacher who conducted the study will continue to use films as a teaching strategy when it is feasible and suitable to do so.
5. There was no evidence that the class that saw the film understood or appreciated *Great Expectations* more than the classes that read the book without seeing the film.
6. Students can learn more about most subjects from films than they can from books.

Statement:

The first newspaper in France, edited by Pierre Lebrun, appeared in Orléans on September 25, 1690, and was banned the same day by Justice Georges Bonet. The editor's subsequent long fight to continue to publish his paper and print what he wished marks an important episode in the continuing struggle to maintain a free press.

Proposed inferences:

7. The editor of the first French newspaper died within a few days after his paper was banned on September 25, 1690.
8. Information about the first issue of Pierre Lebrun's newspaper promptly came to Justice Bonet's attention.
9. The editor of this paper wrote articles criticising Justice Bonet.
10. Pierre Lebrun persisted in holding to some of his aims.
11. Justice Bonet objected to some of the items published in Pierre Lebrun's paper.

Statement:

Thirty years ago, the American town of Westfield began taking title to farms lost by their owners as a result of nonpayment of taxes. To date the town has set out some 3,600 acres of community forest on some of this land. The pine trees have grown well. The town forest yielded the equivalent of £100,000 net profit on pulpwood last year and £95,000 the year before. Local authorities believe that the net profit on the pulpwood will continue to grow and eventually reach £300,000 a year from just the present 3,600 acres.

Proposed inferences:

12. The town spends more to cut and sell the pulpwood than it gains from the sales.
13. If the individual owners had planted trees just before losing their farms, they would have made enough profit immediately from those trees to pay their back taxes and retain their farms.
14. The Westfield community forest contains many varieties of marketable trees.
15. Under certain conditions, the town of Westfield has the legal authority to take title to land on which there has been a tax default.
16. The Westfield community forest will yield an annual net profit of £300,000 from the present 3,600 acres within two or three years.

Test 2: Recognition of Assumptions

DIRECTIONS

An assumption is something presupposed or taken for granted. When you say, 'I'll be a qualified solicitor in two months', you take it for granted that you will be alive in two months, that you will pass the relevant examinations, and similar things.

Below are a number of statements. Each statement is followed by several proposed assumptions. You are to decide for each assumption whether a person, in making the given statement, is really making that assumption i.e., taking it for granted, justifiably or not.

If you think that the given assumption is taken for granted in the statement, mark 'YES' under 'Assumption Made' in the proper place on the Record Form. If you think the assumption is not necessarily taken for granted in the statement, mark 'NO' in the space under 'Assumption Made'. Remember to judge each assumption independently. Below is an example. The box at the right shows how these items should be marked on the Record Form.

EXAMPLE

Statement:

'We need to save time in getting there so we'd better go by plane.'

Proposed assumptions:

1. Going by plane will take less time than going by some other means of transportation. (YES, it is assumed in the statement that the greater speed of a plane over the speeds of other means of transportation will enable the group to reach its destination in less time.)
2. There is a plane service available to us for at least part of the distance to the destination. (YES, this is necessarily assumed in the statement as, in order to save time by plane, it must be possible to go by plane.)
3. Travel by plane is more convenient than travel by train. (NO, this assumption is not made in the statement – the statement has to do with saving time, and says nothing about convenience or about any other specific mode of travel.)

Test 2	
Assumption made	
YES	NO
1	☒ ☐
Assumption made	
YES	NO
2	☒ ☐
Assumption made	
YES	NO
3	☐ ☒

EXERCISES

Statement:

'There is not enough of everything to give all people what they want.'

Proposed Assumptions:

17. The supply of things that people want is not equal to the demand for all those things.

18. People should not expect to get something for nothing.

Statement:

'As more and more school students plan to go on to university, many new university buildings must be constructed.'

Proposed Assumptions:

19. The number of university buildings that will be needed in the future depends on the plans of school students regarding higher education.

20. Existing university buildings are already overcrowded.

21. If students are to attend university, buildings must be available for them.

Statement:

'Many new sources of energy will be discovered, preventing future energy shortages.'

Proposed Assumptions:

22. Producing energy from new energy sources will not consume more energy than the sources yield.

23. The number of new energy sources is unlimited.

24. Once new sources of energy have been discovered, demand for energy will not exceed supply.

Statement:

'There is greater progress in science, environmental protection and education when nations cooperate rather than work alone.'

Proposed Assumptions:

25. If nations cooperate in these areas, they will avoid military conflicts.

26. Ethnic and political differences among peoples will not necessarily prevent them from working together on concerns common to all humanity.

27. International cooperation in scientific and educational programmes will lead from tyranny to free societies.

Statement:

'If you don't believe me, I'll prove it to you logically.'

Proposed Assumptions:

28. Logical proof will cause you to alter your belief about the matter under discussion.

29. What I present as logical proof will influence your thinking.

30. Some matters of belief cannot be proven by logic.

Statement:

'A wise man will save some money each week.'

Proposed Assumptions:

31. No fools have sense enough to save some money each week.

32. A person needs to be wise in order to save some money each week.

Test 3: Deduction

DIRECTIONS

In this test, each exercise consists of several statements (premises) followed by several suggested conclusions. *For the purpose of this test, consider the statements in each exercise as true without exception.* Read the first conclusion beneath the statements. If you think it *necessarily* follows from the statements given, mark 'YES' under 'Conclusion follows' in the proper place on the Record Form. If you think it is *not a necessary conclusion* from the statements given mark 'NO' under 'Conclusion follows', even though you may believe it to be true from your general knowledge. Similarly, read and judge each of the other conclusions. Try not to let your prejudices influence your judgement – just stick to the given statements (premises) and judge whether each conclusion *necessarily* follows.

The word 'some' in any of these statements means an indefinite part of quantity of a class of things. 'Some' means *at least* a portion, and perhaps *all* of the class. Thus, 'Some holidays are rainy' means *at least* one, possibly more than one, and perhaps even *all* holidays are rainy.

Study the example carefully before starting the test.

EXAMPLE

Statement:

Some holidays are rainy. All rainy days are boring. Therefore:

Proposed Conclusions:

1. No clear days are boring. (NO, the conclusion does not follow. You cannot tell from the statements whether or not clear days are boring. Some may be.)
2. Some holidays are boring. (YES, the conclusion necessarily follows from the statements as, according to them, the rainy holidays must be boring.)
3. Some holidays are not boring. (NO, the conclusion does not follow, even though you may know that some holidays are very pleasant.)

Test 3	
Conclusion follows	
YES	NO
1	☐ ☒
Conclusion follows	
YES	NO
2	☒ ☐
Conclusion follows	
YES	NO
3	☐ ☒

EXERCISES

Statement:

An opinion not based on conviction is likely to give way before the slightest argument. Many of our opinions are not based on conviction but are carelessly adopted. Therefore:

Proposed Conclusions:

- 33. It is likely that we can be argued out of many of our opinions.
- 34. Many of our opinions are likely to give way before the slightest argument.
- 35. If a person's opinion was easily swayed by an argument, the opinion was not held with conviction.

Statement:

All great novels are works of art. All great novels capture our imagination. Therefore:

Proposed Conclusions:

- 36. Whatever captures our imagination is a work of art.
- 37. If Tolstoy's *War and Peace* is a great novel, it will capture our imagination.
- 38. Our imagination can be captured by many kinds of art forms.

Statement:

In a certain town in 1987, every person who contracted a serious case of measles was under ten years of age. No resident of the town who received measles vaccine developed a serious case of measles that year. Therefore:

Proposed Conclusions:

- 39. Some children under ten years of age did not receive measles vaccine.
- 40. Measles vaccine is more effective for adults than for children under ten years of age.
- 41. Some people under ten years of age received measles vaccine that year.

Statement:

Some people who favour higher budgets for schools are opposed to a national curriculum. Only genuine friends of education are in favour of higher budgets for schools. Therefore:

Proposed Conclusions:

- 42. Some genuine friends of education are not in favour of a national curriculum.
- 43. Some persons who favour a national curriculum are not genuine friends of education.
- 44. A person can't oppose a national curriculum and be a genuine friend of education.

Statement:

All radicals are members of small minor political parties. No patriotic citizen is a radical. Therefore:

Proposed Conclusions:

- 45. No member of a small minor political party is a patriotic citizen.
- 46. No radical is either a patriotic citizen or a member of a major political party.
- 47. No patriotic citizen is a member of a small minor political party.
- 48. Some members of small minor political parties are unpatriotic citizens.

Test 4: Interpretation

DIRECTIONS

Each of the following exercises consists of a short paragraph followed by several suggested conclusions.

For the purpose of this test, assume that everything in the short paragraph is true. The problem is to judge whether or not each of the proposed conclusions logically follows beyond a reasonable doubt *from the information given in the paragraph*. If you think that the proposed conclusion follows beyond a reasonable doubt (even though it may not follow absolutely and necessarily), mark 'YES' under 'Conclusion follows' in the proper place on the Record Form. If you think that the conclusion does *not* follow beyond a reasonable doubt from the facts given, mark 'NO' under 'Conclusion follows'.

Remember to judge each conclusion independently.

Look at the example below; the block at the right shows how the answers should be marked on the Record Form.

EXAMPLE

Statement:

A study of vocabulary growth in children from eight months to six years old shows that the size of spoken vocabulary increases from 0 words at age eight months to 2,562 words at age six years.

Proposed Conclusions:

1. None of the children in this study had learned to talk by the age of six months. (YES, the conclusion follows beyond a reasonable doubt since, according to the statement, the size of the spoken vocabulary at eight months was 0 words.)
2. Vocabulary growth is slowest during the period when children are learning to walk. (NO, the conclusion does not follow as there is no information given that relates growth of vocabulary to walking.)

Test 4	
Conclusion follows	
YES	NO
1	☒ ☐
Conclusion follows	
YES	NO
2	☐ ☒

EXERCISES

Statement:

A salesperson for Brown's Lotion claimed that this product would promptly soothe sore muscles in the body by penetrating the affected parts. The salesperson poured ten drops of the lotion on a thick piece of shoe leather, and the lotion quickly soaked through the leather.

Proposed Conclusions:

- 49. The salesperson demonstrated the healing powers of the product.
- 50. The salesperson was implying that if the lotion could penetrate a thick piece of leather, it could penetrate sore muscles.
- 51. The salesperson's demonstration was good evidence for the claim that the lotion would promptly soothe sore muscles in the body.

Statement:

Of the 90,000 year 10 and year 11 GCSE students in the country's secondary schools during a certain year, only 27,000 were studying Design and Technology and only 18,000 Information Technology.

Proposed Conclusions:

- 52. In some secondary schools, Design and Technology and Information Technology were not compulsory for all year 10 and 11 students during that year.
- 53. One major reason for the fact that about half of that year's year 10 and 11 students did not study Information Technology or Design and Technology at school is that they would be studying them during their first and second years at college.
- 54. Some year 10 and 11 students in the country's secondary schools during the year in question were studying neither Information Technology nor Design and Technology.

Statement:

A national weekly magazine published a series of articles criticising one of the country's largest political groups for its position on birth control, divorce, and the status of women. The magazine was promptly banned from the school libraries of a London borough by the local council.

Proposed Conclusions:

- 55. The council members believe that censorship is justified in some situations.
- 56. The magazine should not have published the series of articles.

Statement:

A sleeping woman was awakened by a dream that she had suffered a painful fall. Later that night her husband returned from a fishing trip that he had taken alone in a rowing boat some miles away. His arm had been broken as the result of a fall in his boat. The husband and wife discovered that the accident and the dream had happened at exactly the same time.

Proposed Conclusions:

- 57. No ordinary form of communication could account for the occurrence of the wife's dream and the husband's accident at the same time.
- 58. The exact time that the wife was awakened by her dream was noted.
- 59. The dream was a chance coincidence that was not really influenced by the accident.

Statement:

A Manchester newspaper made a survey of the number of male and female drivers involved in all car accidents in the Greater Manchester area during a given period of time. They found that male drivers were involved in 1,210 accidents while female drivers were involved in only 920 accidents. Twenty per cent of the drivers in the survey were under twenty years of age.

Proposed Conclusions:

- 60. In a typical car accident in Manchester during the time covered by the survey, the driver was more likely to be male than female.
- 61. In the Manchester survey, male teenage drivers had more accidents than female teenage drivers.

Statement:

At the end of term, the students in Mrs Green's class averaged 10 marks higher than the students in Mr Walter's class on the same geometry test. Mrs Green and Mr Walter used a somewhat different method of teaching geometry.

Proposed Conclusions:

- 62. Mrs Green and Mr Walter taught in the same school.
- 63. The students in Mrs Green's class were brighter as a group than the students in Mr Walter's class.
- 64. The method of teaching used by Mrs Green was superior to the method used by Mr Walter.

Test 5: Evaluation of Arguments

DIRECTIONS

In making decisions about important questions, it is desirable to be able to distinguish between arguments that are strong and arguments that are weak, as far as the question at issue is concerned. *For an argument to be strong, it must be both important and directly related to the question.*

An argument is weak if it is not directly related to the question (even though it may be of great general importance), or if it is of minor importance, or if it is related only to trivial aspects of the question.

Below is a series of questions. Each question is followed by several arguments. *For the purpose of this test, you are to regard each argument as true.* The problem then is to decide whether it is a *strong* or a *weak* argument.

Mark 'STRONG' on the Record Form under 'Argument' if you think the argument is strong, or 'WEAK' if you think the argument is weak. Judge each argument separately on its own merit. *Try not to let your personal attitude toward the question influence your evaluation of the argument, since each argument is to be regarded as true.*

In the example, note that the argument is evaluated as to how well it supports the side of the question indicated.

When the word 'should' is used as the first word in any of the following questions, its meaning is, 'Would the proposed action promote the general welfare of the people in the United Kingdom?'

EXAMPLE

Statement:

Should all young people in the United Kingdom go on to higher education?

Proposed Arguments:

1. Yes; college provides an opportunity for them to wear college scarves. (WEAK, this would be a silly reason for spending years in college.)
2. No; a large percentage of young people do not have enough ability or interest to derive any benefit from college training. (STRONG. If it is true, as the directions require us to assume, it is a weighty argument against all young people going to college.)
3. No; excessive studying permanently warps an individual's personality. (WEAK, this argument, although of great general importance when accepted as true, is not directly related to the question, because attendance at college does not necessarily require excessive studying.)

Test 5	
Argument	
STRONG	WEAK
1 ☐	☒
Argument	
STRONG	WEAK
2 ☒	☐
Argument	
STRONG	WEAK
3 ☐	☒

EXERCISES

Statement:

Is it possible to develop a controllable death ray that will, under certain conditions, kill living organisms on which it is focused as far as five miles or more distant?

Proposed Arguments:

- 65. No; some physicists have already tried to develop a controllable death ray and have not been able to do so.
- 66. No; if such a ray is ever developed, countermeasures to reduce or offset its effects will also be developed.
- 67. Yes; experiments have shown that certain kinds of energy waves are capable of killing plants, insects and small animals at distances of up to half a mile.

Statement:

Should the government take over all the major industries in the country?

Proposed Arguments:

- 68. No; having such a powerful government would undermine our personal and political freedom.
- 69. Yes; the government already operates or controls roads, armed forces and public health services.
- 70. Yes; the government would then be able to control inflation, which can threaten to bring about a severe national economic depression.

Statement:

Should the government subsidise farmers for soil conservation practices on their own land?

Proposed Arguments:

- 71. No; farmers have historically been a powerful pressure group on Parliament but today most of the population lives in cities.
- 72. No; soil conservation practices are in the farmers' own long term interest and are likely to more than repay farmers for their investment by increasing the value of their land.
- 73. No; government money is taxpayers' money, and people are already taxed too heavily.

Statement:

Should high standards of purity for the country's air and water be maintained, even though the result is higher prices to the consumer for electricity and manufactured goods?

Proposed Arguments:

- 74. Yes; lowering air and water purity standards will inevitably lead to loss of human life.
- 75. No; a slight lowering of air and water purity standards will have few ill effects, but further inflation of prices for electricity and manufactured products will prove disastrous.
- 76. Yes; those who demand lower purity standards are concerned mainly with their own short-term profits.

Statement:

Should the government be limited to spending no more than its income from various sources during any given year?

Proposed Arguments:

- 77. Yes; being required to live within our means is the only way to curb serious inflation, which in turn dilutes the purchasing power of our money and reduces employment.
- 78. Yes; it would be good for people to learn to make sacrifices and stop the needless waste brought about by our way of living.
- 79. No; such rigid restriction against even prudent borrowing would seriously limit our growth as a nation and create an economic depression.
- 80. No; such a requirement would dangerously restrict the ability of the government to deal adequately with national or local emergencies.

STOP
you may now go back and check your work

APPENDIX G

ANECDOTAL RECORDS

Participant 1 Anecdotal records

Date: 19 February 2018 Time: 08:00 am Participant: 1 Week: 1 Activity: Introduction to Portal	Observer: Byron Bunt
Participant 1 started playing the game with confidence. He was uncertain of the controls at first, but picked it up quickly. The portal dynamics threw him off at first, with statements like “What is this orange hole? Must I go through it?” and “Where must I go now?”. The mechanisms were easily mastered, such as the box and button mechanic. The participant was asked to convey his thoughts in words when playing, but started out by mumbling a few words here and there, which negatively impacted on the relevancy and clarity criteria. Participant 1 did not clearly express his thoughts, which negatively impacted on relevancy, with statements like <i>“I can see a camera in front of me”</i>. The participant only seldom evaluated his performance, by only mentioning that he was struggling with the puzzles, and not looking at how to solve them. The participant was also provided with the GROW model to consult during the playing of the game, but only vaguely consulted it and did not work with a system in mind. The application of logic was problematic for the participant in terms of not being able to logically conclude that the two portals are connected.	
Date: 26 February 2018 Time: 08:00 am Participant: 1 Week: 2 Activity: Portal 1 chamber 0 -9	Observer: Byron Bunt
Participant 1 started chamber 0 confidently and managed to not make any mistakes throughout the first 3 chambers. The logical application of critical thinking was evident, as correct conclusions and inferences were drawn. However, from chamber 4, participant 1 began to struggle as the game got more difficult and complex and he struggled and still made incorrect assumptions about the puzzles. The participant was able to recognise that later test chambers no longer made use of cubes and he had to adapt to this new mechanism. He asked the researcher for some assistance more than once, which negatively impacted on the persistence criteria. The portal dynamics threw him off at first, with statements like “Where must I go now?” Statements like <i>“I can’t find the box”</i> or <i>“I can’t shoot a portal here”</i> were made, showing some issues with deductive reasoning and accuracy. He tended to make frequent mistakes, such as opening portals on incorrect surfaces repeatedly. Participant 1 was still not able to	

properly evaluate his arguments, by only highlighting when he made mistakes, and not reflecting on them. Again, he did not clearly express his thoughts, which negatively impacted on clarity and relevancy. Evidence for clarity seldom emerged and the participant only sometimes articulated reflections and communicated with precision regarding his actions and thoughts, such as when faced with the laser redirection mechanic, the participant would only state that he was struggling. Participant 1 did not clearly express his thoughts, which negatively impacted on relevancy, with statements like *"I am in a room"*. The GROW model was still only vaguely implemented. The participant could not perform simple logical steps when trying to solve a problem, such as redirecting laser beams into receptacles.

Date: 5 March 2018

Time: 08:00 am

Participant: 1

Week: 3

Activity: Portal 1 chamber 10 -19

Observer: Byron Bunt & Grantt Gouws

Background information:

Participant 1 started positively, remembering some of the skills from the previous weeks. This did however not manifest completely, as he struggled drawing the correct inferences, and still making incorrect assumptions about the puzzles. His conclusions regarding turrets and how they can be used through portals was less advanced, as the participant was frequently shot by the turrets. Participant 1 was still not able to properly evaluate his arguments, and again only vaguely made use of the GROW model, scoring low for systemic working ways. He struggled drawing the correct inferences about the puzzles, such as concluding incorrectly that portals will always open on any surface. Participant 1 was still not able to effectively evaluate his arguments, performing at a mediocre level, by only sometimes reflecting on mistakes, such as when placing portals on wrong surfaces. However, he showed no signs of giving up, and persisted fairly confidently, only once asking for help, in the statement *"Sir, I think I need your help here"*. Participant 1's accuracy dropped slightly during this week, as he was making more mistakes this round. Participant 1 did however show some clarity in his feedback, making clear statements regarding his intentions, which were sometime irrelevant, thus scoring low for relevancy. Participant 1 did not clearly express his thoughts, which negatively impacted on relevancy, with statements like *"I can see the exit"*. Logic was not properly applied when the laser beams were being redirected through the portals, as the participant sometimes kept on trying to reposition the portals incorrectly.

Date: 12 March 2018 Time: 08:00 am Participant: 1 Week: 4 Activity: Portal 2 Chapter 1	Observer: Byron Bunt
Participant 1 started off week 4 with much more enthusiasm, with a marked improvement in drawing inferences correctly as well as recognizing assumptions. The participant correctly assumed that turrets were hostile and needed to be avoided. This is evident in statements like <i>"I know that this button needs a box"</i>. Deductive reasoning also saw marginal improvement, whereas doing interpretations remained on the same level as in the previous week. The participant was seen repeatedly trying to open portals on wrong surfaces within the early test chambers. Participant 1 could marginally evaluate his own arguments during weeks 4, by stating that he was making a mistake, but now adding some reflections, like <i>"Maybe I should try to move this box here"</i>. Participant 1 started making greater use of the GROW model this time around, leading to a higher score for systemic working ways. Participant 1 once again showed great persistence, not requiring help from the researcher as often as before, also showing mediocre levels of accuracy whilst performing the puzzle solutions. The researcher was impressed with Participant 1's logic, as the participant appeared to become more abled, and could perform simple logical steps when trying to solve a puzzle such as directing lasers into portals. The statements made by Participant 1 were very clear and relevant, scoring high in those categories as well. The participant's feedback was more relevant, scoring moderately in this category, with statements like <i>"I can see this door is locked"</i>.	
Date: 19 March 2018 Time: 08:00 am Participant: 1 Week: 5 Activity: Portal 2 Chapter 2	Observer: Byron Bunt
Participant 1 scored the same as before with regards to drawing inferences and recognizing assumptions. Deductions were being made on the same level as previous weeks, the same could be said for doing interpretations. Deductive reasoning saw marginal improvement in terms of deducing the correct manner in which to use the box and button mechanic. This was evident in statements like <i>"There's a button here. I must find a box"</i>. Participant 1 could marginally evaluate his own arguments during weeks 4, by stating that he was making a mistake, but now adding some reflections, like <i>"Maybe I should try to redirect this laser"</i>. Participant 1 could marginally evaluate	

his own arguments, and did consult the GROW model, but only on occasion. Correct conclusions were drawn from the momentum jump mechanic as well as the laser redirection mechanic, as the correct redirected beam allowed the participant to unlock doors. The participant could interpret the testing environments that if you fell into the water that you would die. Participant 1 showed high levels of persistence, once more not requiring much assistance from the researcher. Participant 1 was working accurately, and his comments were clear and relevant. The participant still made mistakes in terms of how the portals could change the laser's direction, showing slightly limited logic. Clarity remained at the same level when it comes to the quality of the feedback, giving statements made such as: *"I am lost, what now?"* implying that he was not clear in terms of what he saw or his thinking. The participant's thoughts and ideas that were verbalised started making some sense when compared to the actual task at hand, including statements like *"I'm not sure how to open this door"*.

Date: 26 March 2018

Time: 08:00 am

Participant: 1

Week: 6

Activity: Portal 2 Chapter 3

Observer: Byron Bunt

Week 6 saw fairly similar inferences being drawn and assumptions being recognised for Participant 1 in comparison to previous weeks. A slight improvement was noticed regarding Participant 1's deductive reasoning, while interpretations remained on a similar level to previous weeks. Improvement was noticed regarding participant 1's deductive reasoning, with improvements in correct portal placement on white surfaces. The participant seemed to be abler to deduce solutions for the box and button mechanic even when boxes were not immediately apparent. The participant could interpret the testing environments that the water hazards could kill you if touched. Evaluation of arguments saw a rise in performance, as Participant 1 was able to correctly judge his arguments as valid or not. Systemic working ways saw a dip, as Participant 1 consulted GROW far less than on previous occasions. Persistence levels were high as usual, whereas accuracy took a slight increase according to the co-observer. The participant made fewer mistakes as previously, however repeating some mistakes, like not redirecting the laser in the correct direction. Participant 1's feedback was still clear and relevant. Participant 1's feedback was still moderately relevant in relation to the box and button puzzle, with statements like *"I can see this button, but I can't find the box"*

Date: 7 May 2018 Time: 08:00 am Participant: 1 Week: 7 Activity: Portal 2 Chapter 4	Observer: Byron Bunt
Week 7 saw no improvement for Participant 1 regarding drawing inferences, but did see a spike in performance for recognizing assumptions. Assumptions about the laser redirection were not recognised, with frequent mistakes in terms of placing lasers through portals still requiring practice. Week 7 also saw a dip in performance for making deductions and a steady performance for doing interpretations. The scrutinisation of specific puzzle situations were of a higher standard as he could deduce potential solutions to the laser redirection more effortlessly. Participant 1 scored the same again for evaluating arguments and saw an increase in use of the GROW model, leading to improved systematic working ways. The participant for example working out step by step how to do a momentum portal jump. Persistence and accuracy remained the same compared to previous weeks, as Participant 1 did not require a lot of assistance from the researcher. Clarity remained on the same level when it comes to the quality of the feedback, but the relevancy saw a dip, as some irrelevant statements were being made, such as “This game is getting difficult” when the participant faced the first momentum jump mechanic. The participant could perform advanced logical steps such as redirecting the energy pellet through portals to knock down turrets when trying to solve a puzzle.	
Date: 14 May 2018 Time: 08:00 am Participant: 1 Week: 8 Activity: Portal 2 Chapter 5	Observer: Byron Bunt
Week 8 saw an increase for drawing inferences and recognizing assumptions, as Participant 1 was able to move through the puzzle chambers more effortlessly. Week 8 also saw great improvement for making deductions and doing interpretations, as Participant 1 was more skilfully finding the solutions to the puzzles. Participant 1 was able to move through the puzzle chambers more effortlessly, drawing correct conclusions regarding turrets and how they can be moved through portals. The participant was able to interpret using portals in relation to momentum jumping. Participant 1 also improved on evaluation of arguments, and started making more use of GROW, leading to improved systematic working ways. The participant being able to state upfront that he made a mistake when doing a momentum jump. Week 8 also	

saw a rise in persistence and accuracy, as Participant 1 did not require assistance at all and was accurately performing mid-air portal placements. The participant would consult the GROW model and try to find a new solution, and also providing reasons for each of the steps followed during the solving of a problem. The feedback from Participant 1 was also quite clear and very relevant, leading to similar scores as in previous weeks, with relevancy increasing. The participant still struggled with some more complex procedures, such as mid-air portal placements, showing errors in logic. Participant 1's feedback was clear over the course of weeks 8 -11, as he stated "<i>I need to open this door</i>". Participant 1 was more relevant with statements like "<i>This laser can go through the portals</i>".	
Date: 21 May 2018 Time: 08:00 am Participant: 1 Week: 9 Activity: Portal 2 Chapter 6	Observer: Byron Bunt
Week 9 saw a perfect display of drawing inferences, leading to a maximum score. The participant was able to draw correct conclusions based on very complex portal manoeuvres, such as mid-air portal placement. Participant 1 was able to move through the puzzle chambers more effortlessly. Recognizing assumptions was performed on a high standard, but just missing maximum performance. Making deductions was still not being done on a high standard, but doing interpretations saw an increase during Week 9. The participant correctly interpreted the need to redirect lasers into receptacles. Evaluation of arguments was successfully carried out, with the GROW model being regularly used as a systematic working way, leading to high scores. The participant stated that he made a mistake with the laser redirection mechanic. Week 9 saw high levels of persistence and accuracy once again from Participant 1, as he did not request help from the researcher. Week 9 saw similar levels of relevancy and clarity from Participant 1's feedback, with high levels being displayed. Participant 1's feedback was clear over the course of weeks 8 -11, as he stated "<i>Maybe this red beam can open it</i>". Participant 1 was also relevant with statements like "<i>If I jump through here, I should come out at this other side</i>".	
Date: 28 May 2018 Time: 08:00 am Participant: 1 Week: 10 Activity: Portal 2 Chapter 7	Observer: Byron Bunt

Week 10 saw high levels of drawing inferences and recognizing assumptions being performed by Participant 1. Participant 1 was able to successfully state his assumptions up front regarding portal placements by stating that portals can only be opened on white surfaces, for momentum usage through portals by stating that he had to fall through the one to come out of the other with speed, as well as turret and laser redirection by stating that turrets could be thrown through portals. The participant's ability to adapt to new situations in later puzzles in which past assumptions were altered, such as when using portals to redirect lasers into multiple portals, saw improvement. Making deductions was still performed at an average level while doing interpretations was carried out at a high level, just not enough to meet optimal levels. Making deductions was performed at an average level, with issues relating to manipulation of the energy pellet into receptacles showing deductive errors, such as knowing when to open another portal for the energy pellet to bounce through. The participant could interpret how momentum was conserved when falling through portals, but could not perform the more complex double jump. Participant 1 scored very high for evaluating arguments, and worked with the GROW model very well, scoring high for systematic working ways. The participant would frequently evaluate minor mistakes and try to adapt them, such as with the momentum jumps. Persistence and accuracy levels were also quite high, similar performance compared to previous weeks. Week 10 saw Participant 1's feedback improves in terms of relevancy, while still retaining high levels of clarity. Participant 1's feedback was clear over the course of weeks 8 -11, as he stated *"This thing shoots at me, I need to avoid it"*. Some steps in solving problems were illogical, in relation to advanced mid-air portal placement.

Date: 4 June 2018

Time: 08:00 am

Participant: 1

Week: 11

Activity: Portal 2 Chapter 8

Observer: Byron Bunt

Week 11 saw a sharp improvement for drawing inferences for Participant 1, showing optimal performance. The same is true for recognizing of assumptions. Making deductions and doing interpretations were both performed at high levels, just missing optimal performance. The participant could deduce how to work with momentum jumps by falling through portals the first time he tried it. Participant 1 performed the making of deductions at high levels, just missing optimal performance by correctly deducing how advanced momentum jumps and mid-air portal placements work. The participant was able to successfully navigate through the chambers with ease and not getting stuck with specific puzzle mechanisms, being able to piece together the solutions by observing the environment of the game. The participant successfully

interpreted the need to use boxes to avoid being shot at by turrets. Participant 1 evaluated his arguments on optimal levels, and performed the GROW model at high levels as well, scoring high for systematic working ways. Participant 1 evaluated his arguments at optimal levels, as he could state upfront when making a mistake when getting shot at by turrets. Participant 1 scored very high for both persistence and accuracy once more, not requiring aid from the researcher and solving the puzzles very accurately. Participant 1's feedback was again clear and also very relevant. He was mostly transparent, clearly articulating reflections most of the time and communicating with precision his actions and thoughts, with statements like *"Maybe if I jump down into this portal, it might make me fly out this one"*. Relevant statements like *"This platform is moving so slowly. Maybe if I jump at the right time I can fall on top of it"* were made. Other statements such as *"Where must this box go?"* were made. The task expected him to use the box as a weapon against turrets, by dropping it through a portal onto a turret.

Date: 11 June 2018

Time: 08:00 am

Participant: 1

Week: 12

Activity: Portal 2 Chapter 9

Observer: Byron Bunt

Week 12 saw extremely high levels of drawing inferences as well as recognition of assumptions from Participant 1. Participant 1 correctly concluded the solutions to very advanced mechanics, such as timed platform manoeuvres. Making deductions and doing interpretations were done on optimal levels as well, a significant increase from previous weeks. The participant interpreted correctly the very advanced procedure of redirecting the energy pellet through portals to knock down turrets. Participant 1 was optimally evaluating his arguments as well as working systematically, fully consulting the GROW model. Persistence and accuracy were also optimally performed in week 12, as the participant did not require any assistance. Feedback was also optimal, being extremely clear and relevant, being extremely clear with statements like *"I can maybe get passed this turret if I drop a box on it"*. Participant 1's application of logic was at the highest level, as he could logically apply the solution of knocking turrets over with the energy pellet and performing complex timed procedures. Feedback was also optimal, being extremely relevant in terms of statements like *"This energy ball, maybe it can bounce on those turrets over there"*.

Overall, extremely positive performance for Participant 1.

Date: 18 June 2018 Time: 08:00 am Participant: 1 Week: 13 Activity: Portal 2 Co-op	Observer: Byron Bunt
Week 13 saw optimally high levels of drawing inferences as well as recognition of assumptions from Participant 1. His conclusions drawn during timed platform manoeuvres were excellent. The participant was able to conclude that turrets can be dropped through portals. Making deductions and doing interpretations were done on optimal levels as well, continuing from the previous week. Deductions were, similar to the previous week, done at optimal levels regarding the advanced mid-air portal placements. The participant again interpreted correctly the need to knock down turrets using the energy pellet. Participant 1 was optimally evaluating his arguments as well as working systematically, fully consulting the GROW model and working step by step. The participant could formulate own rules and strategies to guide task completion, such as by first looking completely around the room and listing objects. Persistence and accuracy were also optimally performed in week 12, as the participant did not need any help from the researcher. Feedback was also ideal, being exceptionally clear and relevant. The participant made statements that showed some confusion, such as <i>"This laser, what must I do with this now?"</i> Generally, exceedingly positive performance for Participant 1. Feedback was also ideal, being exceptionally clear, with statements like <i>"This ball of light keeps bouncing. Maybe I can bounce it on top of these turrets"</i>. Participant 1's application of logic was at the highest level, as he could logically apply the solution of knocking turrets over with the energy pellet and performing complex timed procedures. Week 13 showed optimal relevancy levels, with statements like <i>"This lift is taking me to the fire. I need to figure out how to get over to that side before I burn"</i>.	

Participant 2 Anecdotal records

Date: 21 February 2018 Time: 11:00 am Participant: 2 Week: 1 Activity: Introduction to Portal	Observer: Byron Bunt
Participant 2 began anxiously, struggling with the controls, mostly trying to move the mouse to the centre of the screen. This assumption that the view must always be centred would mean that the player could not look around to see if there were objects	

or surfaces on the ceiling or floor. The participant was unable to deduce how to accurately make momentum jumps, and failed to understand that she needs to fall through the portal to be flung out the other portal. The participant seemed to be unable to interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how the portals only open on specific surfaces. She did ask the researcher for help often, negatively impacting on the persistence criteria. Basic puzzle mechanics were picked up slowly, but eventually mastered, such as the box and button mechanism. Mistakes were prevalent however, leading to lower scores for deductions, inferences and logic. The participant failed to draw correct conclusions regarding the two-way nature of the portals, coming in and out of each other. The participant also did not work systematically, even though the GROW model had been outlined. Participant 2 had extremely inaccurate work that lead to multiple mistakes being made with the simple box and button mechanic, such as dropping the box or not placing it correctly on the button. The participant was unable to apply simple logic steps towards using the box and button mechanic, as the participant could not logically deduce that the box must be placed on top of the button. Participant 2 seldom spoke, only stating what she saw, and not evaluating or reflecting on her actions or thoughts, leading to low scores on relevancy and clarity. Statements such as "Wow, this game is difficult", or "I'm stuck, please help me sir" indicate that she struggled. The participant failed to clearly articulate her actions and thoughts during game play.

Date: 28 February 2018

Time: 11:00 am

Participant: 2

Week: 2

Activity: Portal 1 Chambers 0 - 9

Observer: Byron Bunt

Participant 2 really struggled in Week 2, scoring very low for drawing inferences and recognition of assumptions, as conclusions drawn about the box and button mechanic were incorrect. She therefore struggled to adapt when the box was removed entirely, in which a new solution was needed. Deductive reasoning was not applied at all during this week, while interpretations were not made. The participant made errors when redirecting lasers and hurting herself. The participant seemed to be unable to interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how boxes can be placed on buttons. The GROW model was ignored leaving no room for working systematically, while arguments were never evaluated. Participant 2 constantly asked for assistance and worked extremely inaccurately, leading to low persistence and accuracy scores. The participant also did not work systematically, even though the GROW model had been outlined. Participant 2 had extremely inaccurate work that lead to multiple mistakes being made with the simple box and button mechanic, such as placing the box correctly on the button. The

participant was unable to apply simple logic steps towards using the box and button mechanic, as the participant could not logically deduce that the laser needed to be redirected. Participant 2 barely spoke a word the entire time aside for asking for assistance, meaning no clear or relevant feedback was given, scoring low for those 2 criteria as well. Overall, a weak performance for Participant 2. Minimal feedback was witnessed, and when it did occur it was not clear or relevant to the situation happening in the puzzle video game, such as <i>“What is going on here?”</i>	
Date: 7 March 2018 Time: 11:00 am Participant: 2 Week: 3 Activity: Portal 1 chambers 10 - 19	Observer: Byron Bunt
Week 3 saw a slight rise in both drawing inferences and recognition of assumptions for Participant 2, with average levels of performance, as conclusions drawn on correct portal placement saw improvement, thus confirming the observation of the researcher. The participant could recognise assumptions relating to how momentum can be carried through portals. Participant 3 could not successfully make deductions when solving the puzzles, but did slightly improve when it came to doing interpretations. The participant seemed to be unable to interpret the various mechanisms presented within the puzzle test chambers, such as being able to redirect laser beams into receptacles. Participant 2 also did not improve on evaluating her arguments and did not consult the GROW model at all, leaving low scores for systematic working ways. Participant once again asked for assistance from the researcher, almost on a continual basis, leaving little room for persistence or working accurately, with statements like <i>“Sir I need your help with this one”</i>. Once again, no feedback was given, seeing as the participant mostly worked in silence, despite being informed to try to say what she is thinking, leaving minimal scores for clarity and relevancy criteria. Feedback was not clear and not specific to the situation in the puzzle video game, such as <i>“I do not know where to go now”</i>.	
Date: 14 March 2018 Time: 11:00 am Participant: 2 Week: 4 Activity: Portal 2 Chapter 1	Observer: Byron Bunt
Week 4 saw another dip for both drawing inferences and recognition of assumptions, performing minimally for both, as she could not correctly conclude the solution for the laser redirection mechanic. Assumptions were not recognised, given the more	

complex laser redirection that involved more than one laser. Participant 2 failed to make any meaningful deductions and dipped in doing interpretations as well. The participant seemed to be unable to interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how momentum jumps work. Turrets were also incorrectly deduced to be a threat, seemingly walking right in front of them. Participant 2 also did not successfully evaluate her arguments, and ignored the GROW model, leaving minimal scores for systematic working ways. Persistence and accuracy were once again low, showing the biggest trend of negative performance, constantly needing assistance from the researcher lowered these criteria and making frequent portal placement mistakes. The participant was unable to apply simple logic steps towards using the box and button mechanic, as the participant could not logically deduce that the turrets should be avoided. Minimal feedback was witnessed, and when it did occur it was not clear or relevant to the situation happening in the puzzle video game. Feedback was not clear and not specific to the situation in the puzzle video game, such as *"I am lost now, this game is hard!"*. Minimal feedback was witnessed, and when it did occur it was not clear or relevant to the situation happening in the puzzle video game, such as *"I need some help"*.

Date: 21 March 2018

Time: 11:00 am

Participant: 2

Week: 5

Activity: Portal 2 Chapter 2

Observer: Byron Bunt

Participant 2 once more did not exceed expectations regarding drawing inferences, as the same low performance was observed for another consecutive week. Week 5 saw a slight increase in recognition of assumptions, but only marginally. The researcher noted some growth, probably because assumptions regarding the use of momentum jumps were tested more often, with which the participant became familiar. No deductions were made and interpretations were minimally done, scoring low for both those criteria. Week 5 saw no attempt at evaluating of arguments, but did see an attempt to work with the GROW model, scoring marginally higher for systematic working ways. She could systematically approach the momentum jumps by breaking down the steps, like first jumping and falling through one portal, and flinging out the other. Another week demonstrated more of the same in terms of persistence and accuracy, with the participant still needing a lot of help from the researcher and making frequent portal placement mistakes. The participant was unable to apply simple logic steps towards using the box and button mechanic, as the participant could not logically deduce that the momentum of a fall is maintained through portals. Week 5 also saw a slight improvement in the feedback given, with it being marginally clearer than in the past, but the relevancy was still quite low. This week saw a slight improvement in the

feedback given, with it being clearer than in the past, comprising statements like: <i>“Sir, this box, I can’t move it. What must I do?”</i>	
Date: 28 March 2018 Time: 11:00 am Participant: 2 Week: 6 Activity: Portal 2 Chapter 3	Observer: Byron Bunt
Week 6 saw a slight improvement when it came to drawing inferences as well as the recognition of assumptions, which is a positive result for Participant 2. Week 6 saw a slight improvement when it came to drawing inferences surrounding the moving platforms and timing to jump through a portal to land on them. Participant 2 began to test assumptions regarding momentum jumping with greater success. It also saw a marginal improvement in making deductions but no improvement in doing interpretations, which was a similar outcome compared to previous weeks. No deductions were made at all regarding how momentum can be carried through portals. The participant could not make basic interpretations about the puzzle dynamics, constantly getting stuck in places, such as when falling from high places with misplaced portals. Participant 2 did not evaluate her arguments, which saw a low score for that criteria, but did show consistent reference on a small scale of the GROW model, leading to an average score for systematic working ways. Participant 2 did try to consult the GROW model on occasion, but did not try to implement it fully as she stopped when identifying the objects but not following through with a way forward. Week 6 saw a slight improvement in persistence, as the researcher felt he did not have to assist as much, but the accuracy of the puzzle solutions left much to be desired, and making frequent portal placement mistakes. The researcher noted highly inaccurate statements being made such as: <i>“I need to move this box, but it won’t fit in the portal”</i> or <i>“Sir, this jumping thing I can’t do it properly”</i>. The participant was able to apply logic in order to solve the laser redirection mechanic, as the logical solution would entail directing the laser through one portal and out of the other one. The feedback once more was of a poor to non-existent standard, with minimal clarity and relevancy evident. This week saw a slight improvement in the feedback given, with it being clearer than in the past, comprising statements like: <i>“This red light, I think it must move over here”</i>.	
Date: 9 May 2018 Time: 11:00 am Participant: 2 Week: 7 Activity: Portal 2 Chapter 4	Observer: Byron Bunt

Week 7 saw a dip in performance for drawing inferences as well as recognition of assumptions, to a minimal level. The conclusions drawn by the participant for the momentum jumps, were incorrect. The participant was unable to recognise the assumptions based on portals only open on specific surfaces. Participant 2's deductions were also made poorly, and the interpretations made were incorrect, resulting on low scores. No deductions were made at all regarding how turrets could be disabled using falling boxes. The participant could not make basic interpretations about the puzzle dynamics, constantly getting stuck in places, such as when constantly getting killed by the lasers. Evaluation of arguments was not performed, but participant 2 still showed resolve in moderately following the GROW model, resulting in a slightly higher score for systematic working ways. Participant 2 did try to consult the GROW model on occasion, but did not try to implement it fully as she stopped when identifying the objects but not following through with a way forward, in terms of errors made when doing momentum jumps. Week 7 showed a slight improvement in terms of persistence, where the researcher felt that he did not need to assist the participant as much as usual. However, the accuracy of the puzzle solutions was still poor. According to the researcher, the participant was unable to apply logic to perform the mid-air portal placement, influencing the observation score negatively. Feedback remains the poorest part of Participant 2's performance, still playing mostly in silence and not putting into words what she is seeing and thinking, thus resulting in low scores for relevancy and clarity. Feedback remained poor, and the participant played the game in silence most of the time, not putting into words what she was seeing and thinking. She only made statements in relation to how hard the game is.

Date: 16 May 2018

Time: 11:00 am

Participant: 2

Week: 8

Activity: Portal 2 Chapter 5

Observer: Byron Bunt

Week 8 saw another poor performance from Participant 2 when it came to drawing inferences and recognition of assumptions, as conclusions drawn surrounding the laser redirection mechanic lead to frequent mistakes, as the participant incorrectly concluded that the beam was not harmful. The participant was unable to recognise the assumptions based on lasers needed to be redirected. Participant 2 struggles to make any notable deductions involving the puzzles in question, and could not make basic interpretations about the puzzle dynamics, constantly getting stuck in places. No deductions were made at all regarding how aerial faith plates require timing to jump. The participant could not make basic interpretations about the puzzle dynamics, constantly getting stuck in places such as when failing to build momentum for the longer jumps. She also did not evaluate her arguments sufficiently, and did not try to

consult the GROW model, scoring low for systematic working ways. Participant 2 did try to consult the GROW model on occasion, but did not try to implement it fully as she stopped when identifying the objects but not following through with a way forward, in terms of errors in turret avoidance. Participant 2 still asks the researcher for assistance and does not work accurately at all, making frequent portal placement mistakes. No feedback was evident in this observation, scoring low for relevancy and clarity. Feedback remained poor, and the participant played the game in silence most of the time, not putting into words what she was seeing and thinking. She only made statements in relation to how hard the game is.

Date: 23 May 2018

Time: 11:00 am

Participant: 2

Week: 9

Activity: Portal 2 Chapter 6

Observer: Byron Bunt

Participant 2 once more did not exceed expectations regarding drawing inferences, as the same low performance was observed for another consecutive week, as seen in the multiple re-attempts on the mid-air portal placement. The participant was unable to recognise the assumptions based on turrets should be avoided. Week 9 saw a slight increase in recognition of assumptions, but only marginally. No deductions were made and interpretations were minimally done, scoring low for both those criteria. The participant could not make basic interpretations about the puzzle dynamics, constantly getting stuck in places such as when avoiding turrets. Week 9 saw no attempt at evaluating of arguments, but did see an attempt to work with the GROW model, scoring marginally higher for systematic working ways. Participant 2 did try to consult the GROW model on occasion, but did not try to implement it fully as she stopped when identifying the objects but not following through with a way forward, in terms of errors made with laser redirection. Another week demonstrated more of the same in terms of persistence and accuracy, with the participant still needing a lot of help from the researcher, and making frequent portal placement mistakes. Week 9 also saw a slight improvement in the feedback given, with it being marginally clearer than in the past, but the relevancy was still quite low. Feedback remained poor, and the participant played the game in silence most of the time, not putting into words what she was seeing and thinking. She only made statements in relation to how hard the game is.

Date: 30 May 2018 Time: 11:00 am Participant: 2 Week: 10 Activity: Portal 2 Chapter 7	Observer: Byron Bunt
Participant 2 struggled once more in Week 10, scoring very low for drawing inferences and recognition of assumptions, as seen in the multiple re-attempts on momentum jumps. She assumed that the mid-air portal jump manoeuvre would remain static, whereas it became more complex while trying to fire upside down. When the box was removed the participant was able to recognise her assumptions and try a new solution. Without the box, another mechanism is needed to unlock the chamber door, which may involve the player standing on the button and shooting a portal through the now opened door. As soon as the player steps off the button the door will close, but now the portal has already been placed behind the door, allowing entry. Deductive reasoning was not applied at all during this week, while interpretations were not made for any puzzles. The participant struggled to deduce how to solve the laser redirection mechanic. The participant could not make basic interpretations about the puzzle dynamics, constantly getting stuck in places, such as when confronted with the energy pellet puzzle. The GROW model was ignored leaving no room for working systematically, while arguments were never evaluated. Participant 2 regularly asked for assistance and worked exceedingly inaccurately, leading to low persistence and accuracy scores. According to the researcher, the participant was unable to apply logic to perform the momentum jumps, influencing the observation score negatively. Participant 2 barely spoke a word the entire time aside for asking for help, meaning no clear or relevant feedback was given, scoring low for those 2 criteria as well. Minimal feedback was given, even though the participant was asked to provide feedback. The feedback to some extent related to the game, such as: <i>"Sir, I need some help with this one, this box won't move"</i>. Overall, a weak performance for Participant 2.	
Date: 6 June 2018 Time: 11:00 am Participant: 2 Week: 11 Activity: Portal 2 Chapter 8	Observer: Byron Bunt
Participant 2 continued to underperform in week 11, only managing to draw inferences and recognize assumptions on a mediocre level, as seen in the multiple re-attempts on the laser redirections. The participant could not adapt when the box was removed from the box and button mechanic, thus she needed to recognise that a new solution	

is needed to unlock the door. Her ability to make deductions as well as do interpretations was extremely low, as she struggled even more with the puzzles as they got more difficult. The participant struggled to deduce how to solve the complex mid-air portal placement. The participant could not make basic interpretations about the puzzle dynamics, constantly getting stuck in places such as when the aerial faith plate jumps were not timed correctly. She was only marginally able to evaluate her arguments, with statements like *"I've got to get up there. But there is no place to make a portal. Maybe if I jump up here there might be a spot"*. She did not attempt this week to work with the GROW model, scoring low for systematic working ways. Participant 2 did show a small amount of persistence this week by not asking the researcher for as much help, but it was still not positive, the same can be said for accuracy, as she was making frequent portal placement mistakes. According to the researcher, the participant was unable to apply logic to perform turret avoidance manouvers, influencing the observation score negatively. Once more, no feedback was given, even though the participant was asked to provide it, thus scoring low for relevancy and clarity. No relevant feedback in relation to thoughts and feelings about the task at hand, but only in relation to difficulty, for example: *"This is impossible"*.

Date: 13 June 2018

Time: 11:00 am

Participant: 2

Week: 12

Activity: Portal 2 Chapter 9

Observer: Byron Bunt

Week 12 saw another dip in performance for drawing inferences and recognition of assumptions, a very poor performance possibly due to the increase in difficulty level of the puzzle, which included advanced use of the energy pellet to knock turrets off of their pedestals. The same low level was observed for making deductions and doing interpretations. The participant struggled to deduce how to solve the energy pellet manipulation puzzles. The participant was incorrectly interpreting what to do with the energy pellet and not using it to knock off turrets. Participant 2 evaluated her arguments marginally well, she got stuck and did not try to use a systematic model, GROW, in order to help her progress. Persistence and accuracy were once more low, continuously asking the researcher for help, to the point that the researcher felt that he was solving all of the puzzles. No feedback given, low scores for clarity and relevancy. No relevant feedback in relation to thoughts and feelings about the task at hand, but only in relation to difficulty, for example: *"These things keep shooting me!"*.

Date: 20 June 2018 Time: 11:00 am Participant: 2 Week: 13 Activity: Portal 2 Co-op	Observer: Byron Bunt
The final week saw one of the worst performances yet for Participant 2. All around scores were very low, for making deductions, evaluating arguments, doing interpretations, drawing inferences. The final puzzle incorporated all previous puzzle mechanics, in which she incorrectly concluded the procedures to tackle each segment. The participant seemingly forgot all of the past assumptions from previous mechanics and fumbled and made multiple errors. The last chamber involved all of the previous mechanics, and the participant was unable to interpret the correct sequence to start the solution. She did not evaluate her arguments for failing to start the complex procedure of timing the energy pellet to bounce on the turrets and knock them off. No systematic working model was used, the participant constantly asked for help. No feedback given, low scores for relevancy and accuracy. According to the researcher, the participant was unable to apply logic to perform the energy pellet manipulation puzzle, influencing the observation score negatively. No relevant feedback in relation to thoughts and feelings about the task at hand, but only in relation to difficulty, for example: <i>“This bouncing thing, I can’t get it into the portal!”</i> .	

Participant 3 Anecdotal records

Date: 22 February 2018 Time: 09:30 am Participant: 3 Week: 1 Activity: Introduction to Portal	Observer: Byron Bunt
Participant 3 struggled tremendously from the onset, constantly asking the researcher for assistance, which negatively impacted on persistence. The participant could not complete the tasks, and eventually gave up and opted out due to the difficulty experienced with the button and box mechanic. She made incorrect assumptions and drew the wrong conclusions frequently, making similar mistakes repeatedly. The participant struggled to adapt her play, when past assumptions no longer applied in new contexts within the portal test chambers. The participant made incorrect deductions regarding surfaces upon which the portals could open. She was not able to interpret the various mechanisms present within the puzzle test chambers, with the most basic one being the box and button mechanic. She did not try to explain her	

mistakes when confronted with the box and button mechanic. Basic logic could not be applied even to the simplest puzzles. Fortunately, the basic mechanics were eventually mastered after great trial and error. The participant could not perform logical steps when trying to solve a problem in relation to redirecting laser beams into receptacles. This participant did not work systematically, even though the GROW model was provided as a framework. This student played the game in absolute silence, except when asking the researcher for help, thus negatively impacting on relevancy and accuracy criteria. The participant made the same basic errors repeatedly, for example: Constantly opening portals on the wrong surfaces. Limited feedback provided by the participant, supported by statements like *"I don't know where I am going"*.

Date: 1 March 2018

Time: 09:30 am

Participant: 3

Week: 2

Activity: Portal 1 chambers 0 - 9

Observer: Byron Bunt

Week 2 saw a slight improvement for drawing inferences, but saw similar low scores for recognition of assumptions. The participant made better conclusions regarding portal placement, which supports the researcher's observation at level 2. This week saw poor performance for making deductions but saw a slight improvement for doing interpretations. The participant made incorrect deductions regarding surfaces upon which the portals could open. The participant was able to interpret the environment and successfully navigated the first few test chambers. Participant 3 performed poorly for evaluation of arguments as well as systematic working ways, not consulting the GROW model once. She did not try to explain her mistakes when confronted with the box and button mechanic. Week 2 saw slight improvement in terms of persistence, as the participant required less assistance. Accuracy however was still performed at a very low level. The participant made the same basic errors repeatedly, for example: not placing boxes correctly on buttons. Week 2 saw a slight increase in terms of clarity in the feedback given, but the relevancy criteria were very low, implying very little feedback from participant 3. The participant made some effort to reflect on her thoughts when dealing with the momentum jumps. She stated *"I know I have to fall through this portal, then I will come out of that one and jump over there"*. The participant could perform simple logical steps during the solving of the puzzles, such as when confronted with the momentum jumps, the participant could logically deduce that if she jumped into the one portal she would fly out of the other. Limited feedback provided by the participant, supported by statements like *"I don't know where I am going"*.

Date: 8 March 2018 Time: 09:30 am Participant: 3 Week: 3 Activity: Portal 1 chambers 10 -19	Observer: Byron Bunt
Week 3 revealed once more that participant 3's inferential skills were lacking, while her ability to recognize assumptions was still at the lowest level of performance. Conclusions drawn regarding portal placement were still problematic, as the participant frequently made errors while trying to place portals. This week saw a 3-week trend of poor performance when it came to making deductions, while disparity between the researcher and co-observer was seen for doing interpretations, although not a significant difference. The participant made incorrect deductions regarding surfaces upon which the portals could open. She appeared to be abler to interpret how the portals only open on specific surfaces. This week saw poor performance for a 3rd week in a row for evaluation of arguments, but participant 3 did start consulting the GROW model, but only sporadically, earning her a slightly higher score for systematic working ways. She did not try to explain her mistakes when confronted with the box and button mechanic. Week 3 saw disparity between researcher and co-observer in terms of assistance, whereas accuracy was uniformly scored at the lowest level. The participant made the same basic errors repeatedly, for example: not gaining sufficient momentum to make jumps. Week 3 saw very low levels of feedback, therefore scores for relevancy and clarity were very poor. The participant applied sufficient logic to redirect laser beams into receptacles. There was a lack of communication from the participant's side about thoughts and action. Limited feedback provided by the participant, supported by statements like <i>"I don't know where I am going"</i>.	
Date: 15 March 2018 Time: 09:30 am Participant: 3 Week: 4 Activity: Portal 2 chapter 1	Observer: Byron Bunt
Week 4 saw the same performance for drawing inferences, while participant 3's recognition of her assumptions rose slightly, with statements like "I remember this box, I must put it somewhere", or "I can go through this hole, just like last time" proving this. Week 4 saw an improvement when it came to making deductions, while the same disparity once again was seen for doing interpretations. Week 4 saw an improvement when it came to making deductions, as the participant could deduce solutions in relation to the basic box and button mechanic, by placing the box on top of the button	

and unlocking the chamber door. She appeared to be able to interpret how the portals only open on specific surfaces. Week 4 saw an increase for evaluation of arguments, but a dip for systematic working ways, as she never consulted GROW. She started to explain her errors when confronted with the laser redirection mechanic. Week 4 saw average persistence scores, with another week of low accuracy levels. The participant utilised coping mechanisms throughout the task such as trying to observe the environment more closely and listing objects and complete puzzles without giving up. She struggled with the laser redirection puzzle, more than once asking for assistance. The participant made the same basic errors repeatedly, for example: avoiding turrets. This week revealed slightly higher levels of clarity, with the relevancy remaining low. Irrelevant statements such as: *"This is difficult". What must I do?"*, were noted. Reflections about actions and thoughts were sometimes articulated. Participant 3 only gave limited feedback at times, which was not too clear. The participant applied sufficient logic to redirect laser beams into receptacles.

Date: 22 March 2018

Time: 09:30 am

Participant: 3

Week: 5

Activity: Portal 2 Chapter 2

Observer: Byron Bunt

Participant 3 performed much better when it came to drawing inferences in week 5, with the recognition of assumptions remaining at the same level compared to previous weeks. She appeared to be able to draw correct conclusions based on laser redirection most of the time. Week 5 saw disparity between researcher and co observer for making deductions, while doing interpretations was performed on an average level. The participant could deduce solutions to the laser redirection mechanic more effortlessly than previously, the researcher felt that her performance could be classified as able. Week 5 continued with above average performance for evaluating arguments with some disparity among researcher and observer, and an increase for systematic working ways. The participant put in a greater effort to consult the GROW strategy to work more systematically. Week 5 saw disparity between the researcher and co-observer, as the researcher believed that persistence levels had increased to above average. The participant was now trying harder to do things herself, especially when it came to the momentum jumps. Week 5 also saw disparity, as the researcher believed that accuracy levels had increased to average. The participant could accurately redirect lasers without making mistakes frequently. This week saw clarity remain at the same average level, while relevancy rose to average scores as well. Reflections about actions and thoughts were sometimes articulated. Participant 3 only gave limited feedback at times, which was not too clear. The participant was able to perform simple logical steps when trying to solve a puzzle, but struggled with

advanced procedures for example, when performing the multi-faceted momentum jumps. The participant was required to fall through one portal and fling out the other, but was unable to get the timing of the action right. The quality of the feedback provided did not improve, and was done sporadically.	
Date: 29 March 2018 Time: 09:30 am Participant: 3 Week: 6 Activity: Portal 2 Chapter 3	Observer: Byron Bunt
Week 6 saw continual performance on the same level as in previous weeks for drawing inferences as well as recognition of assumptions. She appeared to be able to draw correct conclusions based on turret avoidance most of the time. Week 6 saw similar levels of performance for making deductions and for doing interpretations. The participant could deduce solutions to the laser redirection mechanic more effortlessly than previously, the researcher felt that her performance could be classified as able. Week 6 continued the average performance for evaluation of arguments for participant 3, as well as systematic working ways. She evaluated her actions when making mistakes, such as when she misfired in mid-air trying to do an advanced momentum jump, putting in a greater effort to consult the GROW strategy to work more systematically. Week 6 saw a dip in terms of persistence, as the participant required more help than in the previous week. The participant sometimes had to ask for some help, probably influencing the observation of the co-observer at able level. Accuracy levels remained average. Week 6 saw average scores for both relevancy and clarity. The participant applied advanced logical steps when trying to solve a puzzle, but struggled with some more complex procedures, especially with the laser redirection. Logic is required to manipulate the laser through a portal at an angle placed on a wall. Both observers concluded their observations of the participant's performance in relation to logic at skilled level.	
Date: 10 May 2018 Time: 09:30 am Participant: 3 Week: 7 Activity: Portal 2 Chapter 4	Observer: Byron Bunt
This week continued a trend of similar performance for drawing inferences and recognition of assumptions. She appeared to be able to draw correct conclusions based on momentum jumps most of the time. She could correctly conclude that falling with speed meant that she would fly out with speed of the other portal. As the puzzles	

get more difficult, it is positive to note that participant 3 continues to perform at similar levels. This week continued the average trend for making deductions, whereas disparity existed for doing interpretations, with the researcher scoring participant 3 higher. The participant seldom deduced solutions on the first attempt she made to solve problems, for instance in relation to the momentum jumps. The participant became more successful at interpreting the laser redirection mechanic, as she could successfully connect the laser through both portals, effectively unlocking the chamber door. Week 7 saw the continuation of the trend of evaluating arguments, with slight disparity between researcher and co-observer for systematic working ways. The participant was able to evaluate her mistakes, for example when she made incorrect portal placements. The participant incorporated the GROW strategy more often during the completion of the puzzle problems, and followed the steps in the strategy more closely. Week 7 saw an increase for persistence levels, and continued the average performance for accuracy criteria. The participant did not set the box down accurately, so the chamber door would remain locked, causing frustration. Week 7 continued the trend of average performance in terms of clarity and relevancy, as the feedback had not improved tremendously and was done sporadically. Reflections about actions and thoughts were sometimes articulated. Participant 3 only gave limited feedback at times, which was not too clear. The participant could however verbalise some sensible ideas and thoughts in relation to the task at hand, such as *“This red beam, I think it should go into this hole. Maybe this door will open then”*.

Date: 17 May 2018

Observer: Byron Bunt

Time: 09:30 am

Participant: 3

Week: 8

Activity: Portal 2 Chapter 5

Week 8 saw a dip in performance for drawing inferences, but continued to perform on an average level when it came to recognition of assumptions. The more complicated momentum jumps distracted her as she could not conclude correctly that multiple portal placements were needed to traverse a larger chamber. Week 8 continued the average trend for making deductions, as well as for doing interpretations, but on a higher level of performance. The participant seldom deduced solutions on the first attempt she made to solve problems, for instance in relation to turret avoidance. The participant only made a few errors in interpreting more advanced momentum jumps. Week 8 once more showcased average performance for evaluation of arguments, but showcased a dramatic increase for systematic working ways, as the participant continued to consult the GROW model more frequently. The participant was able to evaluate her mistakes, for example when she incorrectly timed momentum jumps. She could also provide reasons for each of the steps followed during the solving of a

problem. Week 8 saw a dip for persistence levels, revealing inconsistency with participant 3 requiring assistance from week to week. Accuracy levels were once again scored as average. The researcher noted more accurate attempts at solving puzzles, such as when trying to place the portals more accurately when redirecting the lasers into receptacles. Participant 3 only gave limited feedback at times, which was not too clear. Week 8 continued a 5-week trend of average performance in terms of clarity and relevancy for the feedback given. Logic is required when directing the boxes to fall on top of the turrets to disable them. This was also applied throughout.

Date: 24 May 2018

Time: 09:30 am

Participant: 3

Week: 9

Activity: Portal 2 Chapter 6

Observer: Byron Bunt

This week saw an improvement for drawing inferences as well as recognition of assumptions for participant 3. The participant was able to recognise the assumptions of the momentum jumps, by correctly concluding that speed was needed when coming out of the other portal. Week 9 once again showcased participant 3's ability to perform making deductions adequately, while doing interpretations were above average. The participant seldom deduced solutions on the first attempt she made to solve problems, for instance in relation to energy pellet manipulation. She could interpret how to manipulate turrets through portals after a few tries. Week 9 saw similar levels of evaluating arguments. The participant was able to evaluate her mistakes, for example when she incorrectly redirected lasers. With systematic working ways scoring above average, with frequent consultation of the GROW model. The participant also started to spontaneously apply and transfer what was taught/modelled by the researcher in terms of using the GROW model within the game context. This week saw another increase for persistence to above average levels, showcasing some independence on the part of participant 3. Accuracy was scored the same as in previous weeks. The researcher noted more accurate attempts at solving puzzles, such as when trying to place the portals more accurately when redirecting the lasers into receptacles. Week 9 saw some disparity between the researcher and co-observer in terms of the feedback given, with the co-observer feeling that the clarity and relevancy criteria were scored lower. Reflections about actions and thoughts were sometimes articulated. No communication about actions were given.

Date: 31 May 2018 Time: 09:30 am Participant: 3 Week: 10 Activity: Portal 2 Chapter 7	Observer: Byron Bunt
Week 10 saw the same above average performance for participant 3 in both drawing inferences and recognition of assumptions. The participant was able to manipulate portals to overcome turrets. She could recognise successfully the assumptions pertaining to the energy pellet and how it could be used as a weapon to knock of the turrets. Week 10 once more continued the trend of average performance for making deductions and above average performance for doing interpretations. The participant seldom deduced solutions on the first attempt she made to solve problems, for instance in relation to the aerial faith plate timed jumps. Week 10 saw a sharp increase for participant 3 when it came to evaluating arguments, whereas systematic working ways took a dip in terms of consulting the GROW model. The participant could now begin to evaluate her performance properly by looking at where she went wrong with the momentum jumps. The participant suddenly did not consult the GROW strategy when solving the puzzle problems. Accuracy was scored higher, as the participant started working more accurately when solving the puzzles. The participant frequently ensured that she was doing the correct thing when trying to solve the puzzles in the various test chambers. Persistence levels were high once again for participant 3. This week saw average feedback presented by participant 3, with relevancy and clarity criteria scoring on level 2. The participant was seldom transparent about her actions and thoughts. More advanced logic was also required to perform the timed aerial faith plate jumps in order to catch a box in mid jump. This was witnessed as well. The participant provided some relevant feedback about her game play, with statements like <i>"Maybe if I jump into this portal. Maybe I can get to that side"</i>.	
Date: 7 June 2018 Time: 09:30 am Participant: 3 Week: 11 Activity: Portal 2 Chapter 8	Observer: Byron Bunt
Week 11 continues a 3-week trend of above average performance for participant 3 when it comes to drawing inferences and recognising assumptions. The participant was able to manipulate portals to manipulate the energy pellet to knock down turrets. She could recognise successfully the assumptions pertaining to the energy pellet and how it could be used as a weapon to knock of the turrets. The same applied for doing	

interpretations, whereas making deductions was still performed on an average level. The participant seldom deduced solutions on the first attempt she made to solve problems, for instance in relation to laser redirection. The researcher felt that the participant's application of interpretations during the game play of Portal, in particular the interpretations relating to how to do momentum jumps and mid-air portal placement, were sufficient. Week 11 continued the high performance for evaluating arguments as well as the average performance of working systematically. The participant could now begin to evaluate her performance properly by looking at where she went wrong with turret avoidance. The participant suddenly did not consult the GROW strategy when solving the puzzle problems. Week 11 saw high levels of persistence displayed on the part of participant 3, with accuracy being scored on high levels as well. The participant frequently ensured that she was doing the correct thing when trying to solve the puzzles in the various test chambers. This week saw continuing levels of average feedback as clarity remained the same, as well as relevancy, with the co-observer scoring lower here. Reflections about actions and thoughts were sometimes articulated. The participant was seldom transparent about her actions and thoughts. Some relevance in statements like: *"This laser needs to go through this portal"*.

Date: 14 June 2018

Time: 09:30 am

Participant: 3

Week: 12

Activity: Portal 2 Chapter 9

Observer: Byron Bunt

This week saw a dip in performance for drawing inferences as well as recognition of assumptions, presumably due to the final puzzles' difficulty level. Incorrect conclusions made by the participant in relation to the mid-air portal jumps, as she could not correctly time the portal placements as she struggled to conclude that she could shoot multiple times. This week saw a dip in performance for recognition of assumptions, presumably due to the final puzzles' difficulty level, as it involved a culmination of all skills learnt up until this point, including every mechanic in the game and requiring skill in terms of timing. Week 12 marked an increase for participant 3 when it came to making deductions as she performed at above average level, with complicated mid-air portal jumps being performed well, but a dip for doing interpretations was noted. The participant could not complete the very complex mid-air portal jumping successfully at first. Week 12 saw above average performance for both evaluating arguments as well as systematic working ways. The participant could now begin to evaluate her performance properly by looking at where she went wrong with the energy pellet manipulation. Week 12 saw improvement again, with greater effort by the participant to work closely with the GROW strategy to solve the puzzle problems.

This week marked a dip in terms of persistence levels, with more assistance being required. Accuracy levels continued a 3-week trend of high levels of performance. The participant frequently ensured that she was doing the correct thing when trying to solve the puzzles in the various test chambers. Week 12 saw another average performance in terms of clarity, but relevancy criteria rose sharply, as participant 3 started to give higher quality feedback, such as “I wonder if I can’t shoot a portal behind that fence.”, or “I can drop a box from this high up and it will fly through the portal”. The most advanced logic was required in order to manipulate the energy pellet through portals in order to knock over turrets, which this participant could manage to do.

Date: 21 June 2018

Observer: Byron Bunt

Time: 09:30 am

Participant: 3

Week: 13

Activity: Portal 2 Co-op1

The final week saw average performance of drawing inferences while recognition of assumptions scored slightly higher, as the participant could recall all of the old assumptions about mechanics used in past chambers to correctly navigate the final chamber. This last week ended on a high note with making deductions and doing interpretations both performed on an above average level, as she performed at above average level, with complicated mid-air portal jumps being performed well. The participant successfully interpreted the advanced chambers in which the energy pellet had to be used to knock down turrets. This week saw above average performance for both evaluation of arguments as well as systematic working ways. Week 13 saw improvement again, with greater effort by the participant to work closely with the GROW strategy to solve the puzzle problems. This week showed higher levels of persistence compared to previous weeks, with accuracy still being performed at high levels. She completed tasks autonomously, without giving up. The final week once more showcased average performance for clarity criteria, and above average for relevancy criteria. Reflections about actions and thoughts were sometimes articulated. The participant was seldom transparent about her actions and thoughts. Relevant statements like “*This bouncing ball, maybe I can use it to hit that turret on top there*” were made.

Participant 4 Anecdotal records

Date: 22 February 2018 Time: 11:00 am Participant: 4 Week: 1 Activity: Introduction to Portal	Observer: Byron Bunt
Participant 4 was very quick to master the basic controls of Portal. His inferences and deductions were spot on, and he managed to make connections regarding the mechanisms of the game quite quickly. He managed to distinguish between past assumptions that existed in the context of the portal activity, such as knowing how the button and box work together, as well as adapting when past assumptions no longer apply in new contexts within the portal test chambers. His interpretations were above average, with statements such as: <i>"There is something missing here, I need to find a box"</i>. He applied the GROW model very seldom, but did have a system for working the puzzles. The participant was able to provide reasons for doing momentum jumps, as he said <i>"I need to get over this gap. That portal over there is on the floor, the other one is up there. Maybe if I jump"</i>. Participant 4 did not require the researcher's assistance once, and also completed the introduction by himself, showing great levels of persistence. The participant made an attempt to work accurately and only made a few mistakes in terms of portal placement. He did try to explain his actions and what he saw, but he did not reflect on those actions and did not clearly state his thinking, merely only stating what he saw, such as <i>"I am in the elevator"</i>, <i>"I can see a camera in front of me"</i>, or <i>"There is a box here"</i>. This negatively impacted on the relevancy and clarity criteria. The participant got stuck frequently in test chambers, without being able to identify ways to solve the problem, scoring low for logic.	
Date: 1 March 2018 Time: 11:00 am Participant: 4 Week: 2 Activity: Portal 1 chambers 0 - 9	Observer: Byron Bunt
Week 2 saw a rise for participant 4 when it came to drawing inferences, and a continuation of above average performance when it came to recognition of assumptions. His inferences were close to correct, and he managed to make connections regarding the mechanisms of the game quite quickly after repeating the mechanics after a few tries. The participant adapted assumptions when faced with the button and box mechanic, once the box was removed, implying that the puzzle needed something else to be placed on the button. When it came to making deductions, participant 4 performed on a mediocre level, while his interpretations were above average, as is evident in statements like <i>"This hole, if I go through this one I</i>	

come out the other one". This week also saw a rise for evaluation of arguments but not for systematic working ways, as Participant 4 only seldom referred to the GROW model. Regarding persistence, participant 4 improved considerable in week 2, only once asking for assistance, while also improving on his accuracy tremendously. The participant consulted GROW model to ensure that he persists with solving of problems. The participant made minor errors in terms of laser redirection, in which the participant had to reattempt directing the laser through two portals. In terms of clarity and relevancy, in week 2 participant 4 scored fairly high, as his feedback was consistent and clear. His feedback was consistent and clear, stating his intentions and what he was observing in the test chambers. Logical reasoning became more evident in the participant's ability to make fewer mistakes in terms of puzzle mechanics, as he was able to apply a step-by-step approach when solving the puzzles, such as first observing his surroundings and listing all of the objects.

Date: 8 March 2018

Observer: Byron Bunt

Time: 11:00 am

Participant: 4

Week: 3

Activity: Portal 1 chambers 10 - 19

Week 3 saw a slight dip for participant 4 for drawing inferences, but continued the above average performance for recognition of assumptions. His inferences were close to correct, and he managed to make connections regarding the mechanisms of the game quite quickly after repeating the mechanics after a few tries. This week continued the mediocre performance for making deductions, and also saw a slight dip in doing interpretations, as the puzzles got more difficult. The participant was distracted by the box and button mechanic as he struggled to deduce at first what the box was for, and failed to understand that it is needed to unlock the chamber. As the puzzles got more difficult, for example when faced with the laser redirection mechanic, the participant kept on getting hit by the laser. Week 3 saw steady performance from participant 4 for evaluation of arguments and systematic working ways, although the co-observer felt that participant 4 did not consult GROW enough and scored a 1. He could provide reasons for each of the steps followed during the solving of a problem, for example when doing the momentum jumps, with statements like *"If I fall through this one, I will fly out of that one"*. The participant started working without any plan of action, did not consult the GROW strategy, and was in need of assistance from the researcher/mediator to complete actions successfully. Another week of high levels of persistence and accuracy. In terms of his feedback, participant 4 scored lower this week, as he still only spoke about what he saw, not what he was thinking. In terms of participant 4's feedback, he scored lower as he only spoke about what he saw, and not about what he was thinking, for example: *"This room has a locked door"*. The participant's feedback about his thoughts was more transparent and clear, mentioning the following: *"This door is locked. There must be something I can use"*. Logical reasoning became more evident as he was able to apply a step-by-step approach

when solving the puzzles, such as first observing his surroundings and listing all of the objects. Feedback was still clear, involving statements like: <i>"This portal can only open on this type of wall"</i>.	
Date: 15 March 2018 Time: 11:00 am Participant: 4 Week: 4 Activity: Portal 2 chapter 1	Observer: Byron Bunt
Week 4 saw another excellent performance for drawing inferences as well as recognition of assumptions, with the latter being steady over the last few weeks. The participant appeared to be effective at drawing conclusions regarding the box and button mechanics, and successfully managed to solve the laser redirection puzzles. Once more mediocre performances for making deductions as well as doing interpretations. The participant was distracted by the box and button mechanic as he struggled to deduce at first what the box was for, and failed to understand that it is needed to unlock the chamber. As the puzzles got more difficult, for example when facing turrets, the participant would be shot at very often. This week once again had the same levels of performance for evaluating arguments and systematic working ways, as participant 4 only seldom consulted GROW. The participant could provide reasons for the steps followed during problem solving for example, when doing momentum jumps. Continuous high levels of persistence were evident as the participant only needed minimal aid, with accuracy once more very highly evident. The participant was able to navigate the test chambers without the researcher's assistance. The participant made minor errors in terms of laser redirection, in which the participant had to reattempt directing the laser through two portals. Week 4 saw similar scores for clarity and relevancy compared to the previous week. In terms of participant 4's feedback, he scored lower as he only spoke about what he saw, and not about what he was thinking, for example: <i>"There is a red beam in front of me"</i>. Feedback was still clear, involving statements like: <i>"This box must be placed on a button"</i>.	
Date: 22 March 2018 Time: 11:00 am Participant: 4 Week: 5 Activity: Portal 2 chapter 2	Observer: Byron Bunt
Week 5 saw the same high level of performance for participant 4 when it came to drawing inferences and recognizing assumptions. The conclusions drawn in these weeks resulted in minor mistakes early on, such as failing to understand that lasers hurt the character, as the participant would constantly walk in front of them. The	

participant was able to adapt to new situations even though the assumptions based on previous mechanics no longer applied, for example when the box was no longer available and the participant had to figure out a new solution to unlock the chamber. This week saw a spike in making deductions, as the participant was able to apply his deductive reasoning while solving the puzzles, whereas doing interpretations saw some disagreement between the researcher and co-observer, with the performance still positive. The participant was able to apply his deductive reasoning while solving the puzzles, and for example deduced that the portals could be used to manipulate the turrets. The participant could interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how the portals only open on specific surfaces. Week 5 saw a continuing trend in participant 4's ability to evaluate his arguments, being the same level for 4 weeks in a row. The participant continued to provide plausible reasons for each of the steps followed during the solving of a problem. This week saw a rise in systematic working ways, as the participant consulted the GROW model more often. Week 5 saw more of the same regarding high persistence levels and accuracy on the part of participant 4. Week 5 saw an improvement for clarity, as participant 4 gave more clear feedback, as well as highly relevant feedback. The participant gave clearer feedback, with statements like *"This box can go on this button"*. Logical reasoning became more evident in the participant's ability to make fewer mistakes in terms of puzzle mechanics, as he was able to apply a step-by-step approach when solving the puzzles. Feedback was still clear, involving statements like: *"This beam can go through portals"*.

Date: 29 March 2018

Time: 11:00 am

Participant: 4

Week: 6

Activity: Portal 2 chapter 3

Observer: Byron Bunt

Week 6 saw another steady performance for participant 4 when it came to drawing inferences, but saw some disparity between researcher and co-observer for recognition of assumptions, although the performance can still be considered good on average. In particular, with the momentum jumps, the participant could provide reasons for why he needed to jump into the one portal in order to fling out of the other. This week saw a dip in performance for making deductions as well as for doing interpretations, due to increasing difficulty of the puzzles which possibly influenced the participant's ability to make proper deductions, for example when he was faced with the difficult momentum jumps in which he made multiple mistakes in terms of not jumping high enough to provide enough momentum to fly out of the other portal. The participant appeared to become less able to interpret the various mechanisms presented within the puzzle test chambers, such as the laser redirection puzzle. Week 6 continued the trend of evaluating arguments at the same level, while systematic working ways fell down a point during this week. The participant continued to provide plausible reasons for each of the steps followed during the solving of a problem. Week

6 saw the same performance for persistence and accuracy from participant 4 compared to previous weeks. The participant made minor errors in terms of laser redirection, in which the participant had to reattempt directing the laser through two portals. Week 6 saw another dip for clarity criteria, as the participant was mostly referring to what he saw, whereas relevancy was still fairly high. The participant was seldom transparent, and did not communicate with precision regarding his actions and thoughts, examples include a statement like *"I'm not sure what to do with this box"*. Logical reasoning became more evident in the participant's ability to make fewer mistakes in terms of puzzle mechanics, as he was able to apply a step-by-step approach when solving the puzzles, such as first observing his surroundings and listing all of the objects. Feedback was still clear, involving statements like: *"If I fall through this one, I will fly out of that one over there"*.

Date: 10 May 2018

Time: 11:00 am

Participant: 4

Week: 7

Activity: Portal 2 chapter 4

Observer: Byron Bunt

Week 7 saw another consecutive week of steady performance for drawing inferences, with once more slight disagreement for recognition of assumptions between researcher and co-observer. The participant was able to adapt to new situations even though the assumptions based on previous mechanics no longer applied, for example when the box was no longer available and the participant had to figure out a new solution to unlock the chamber. This week saw some disparity between researcher and co-observer when it came to making deductions, but still a positive performance, whereas doing interpretations increased overall. The participant deduced that the laser had to be redirected to unlock the chamber, thus in support of the higher level of performance observed by the researcher. Doing interpretations increased overall in terms of performance for redirecting the energy pellet to knock down turrets. Week 7 saw a continual performance at high levels for evaluation of arguments, and an increase for systematic working ways, as participant 4 consulted GROW more frequently. Good arguments were for example provided for mistakes during the redirection of lasers, where he stated *"This laser should go into that hole. How can I get it there? Maybe this portal"*. The participant seldom required support from the researcher/mediator to complete tasks, and could choose relevant strategies to complete tasks, based on insight, for example working through the GROW model when getting stuck with the turrets firing at him. Week 7 saw once again a steady performance regarding persistence and accuracy. The participant made minor errors in terms of laser redirection, in which the participant had to reattempt directing the laser through two portals. This week saw an increase in clarity and the same level as previously for relevancy. High levels of feedback were linked to thoughts, such as: *"Let's see what happens when I put this portal here"*. The participant was thinking logically as he was solving the puzzle problems doing things step by step. Feedback

was still clear, involving statements like: <i>"This platform is moving. I need to wait before I jump on it"</i> .	
Date: 17 May 2018 Time: 11:00 am Participant: 4 Week: 8 Activity: Portal 2 chapter 5	Observer: Byron Bunt
Week 8 saw another consecutive above average performance for participant 4 when it came to drawing inferences, but saw a leap in performance when it came to recognition of assumptions. Statements like "I know this button requires a box", or "I can only shoot portals on this surface" prove this. The participant deduced that the laser had to be redirected to unlock the chamber, thus in support of the higher level of performance observed by the researcher. Doing interpretations increased overall in terms of performing mid-air portal jumps. This week saw positive performances in both making deductions as well as doing interpretations. Week 8 saw an increase in evaluation of arguments and a consistent performance of using the GROW model. The participant constantly evaluated his mistakes and would ask questions based on the errors made while performing the mid-air portal placement upside down, which according to the researcher could be classified as sophisticated performance. Week 8 saw an increase in persistence levels, as the researcher did not need to assist the participant at all. The researcher did not need to assist the participant at all as he was coping using the GROW strategy. The researcher argued that coping mechanisms, such as the GROW strategy, which assisted the participant in terms of not giving up, was always used, making the observation at sophisticated level justifiable. The same applied for accuracy. The participant making slight errors in the more advanced test chambers, such as repeatedly missing timed momentum jumps or failing to redirect lasers on the first attempt, which could not be classified as sophisticated performance. Week 8 saw high levels of feedback, scoring high for both clarity and relevancy. High levels of feedback that was linked to thoughts, such as: "This laser must be pointed over there, to open the door". The participant was thinking logically as he was solving the puzzle problems doing things step by step. Very relevant comments that linked with the steps in the GROW model were witnessed. The participant started asking questions like <i>"What is my goal here?"</i>	
Date: 24 May 2018 Time: 11:00 am Participant: 4 Week: 9 Activity: Portal 2 chapter 6	Observer: Byron Bunt

Week 9 saw an incremental leap for participant 4 in terms of drawing inferences, where the participant was able to draw proper conclusions from the puzzles. The participant drew proper conclusions from the puzzles, for example in relation to how to reposition the lasers into receptacles. The participant could master the momentum jumps required moving from a vertical fling to a horizontal fling, and requiring a double jump. Doing interpretations increased overall in terms of performance for disabling turrets with boxes. Another superb performance in terms of recognition of assumptions for another week in a row. This week saw continuity of performance from previous weeks for both making deductions as well as doing interpretations. Week 9 continued the exceptional evaluation of arguments with high systematic working ways. Plausible reasons were provided by the participant for each step taken during the solving of a problem, such as when performing a mid-air portal placement. The participant seldom required support from the researcher/mediator to complete tasks, and could choose relevant strategies to complete tasks, based on insight, for example working through the GROW model when getting stuck with the turrets firing at him. This week once more saw top level performance for persistence and accuracy as well. The participant making slight errors in the more advanced test chambers, such as repeatedly missing timed momentum jumps or failing to redirect lasers on the first attempt, which could not be classified as sophisticated performance. Feedback this week was very clear and relevancy increased to maximal score. High levels of feedback were linked to thoughts, such as: "If I drop this box maybe it won't shoot at me". The participant was able to complete advanced momentum jumps successfully, as the logic behind the momentum jumps involves understanding that momentum is carried through portals, so if something goes through one portal with speed, it comes out the other with that same momentum. Very relevant comments that linked with the steps in the GROW model were witnessed. The participant started making statements such as: *"Maybe I should try putting a portal there and see what happens with the laser"*.

Date: 31 May 2018

Time: 11:00 am

Participant: 4

Week: 10

Activity: Portal 2 chapter 7

Observer: Byron Bunt

Week 10 saw a continuation in the trend of participant 4 performing highly for drawing inferences as well as recognition of assumptions. The participant drew proper conclusions from the puzzles, for example in relation to how to reposition the lasers into receptacles. The participant could master the momentum jumps required moving from a vertical fling to a horizontal fling, and requiring a double jump. This week once again showcased participant 4's high levels of making deductions as well as doing interpretations, continuing this performance over a 4-week trend. Deductions relating to turret avoidance, mid-air portal placement and energy pellet manipulation were all correct. Doing interpretations increased overall in terms of performance for doing

double flinging momentum jumps. Another week of exceptional evaluation of arguments, with high levels of working systematically. Plausible reasons were provided by the participant for each step taken during the solving of a problem, such as when performing a mid-air portal placement. The participant seldom required support from the researcher/mediator to complete tasks, and could choose relevant strategies to complete tasks, based on insight, for example working through the GROW model when getting stuck with the turrets firing at him. Week 10 saw more exceptional levels of persistence and accuracy. The participant effortlessly navigated the more complex puzzles such as the mid-air portal placement by jumping correctly through the first portal and flinging out the other. Feedback for this week was exemplary, scoring maximum points for clarity and relevancy. The participant was able to complete advanced momentum jumps successfully, as the logic behind the momentum jumps involves understanding that momentum is carried through portals, so if something goes through one portal with speed, it comes out the other with that same momentum. The participant's feedback was extremely relevant, as the participant made statements like *"This ball of energy keeps bouncing. Maybe I can bounce it on that turret"*.

Date: 7 June 2018

Time: 11:00 am

Participant: 4

Week: 11

Activity: Portal 2 chapter 8

Observer: Byron Bunt

Week 11 continued participant 4's run of excellent performance for both drawing inferences and recognition of assumptions criteria. The conclusions drawn by the participant in terms of advanced portal mid-air placement and momentum jumps, could be classified as sophisticated. Week 11 saw the same levels of performance for making deductions, but disagreement surrounding the performance of doing interpretations, but still a positive outcome. Deductions relating to turret avoidance, mid-air portal placement and energy pellet manipulation were all correct. This week continues the trend of participant 4 expertly evaluating his arguments, and working very systematically. The participant continuously evaluated mistakes, and questioning the errors he made while performing the mid-air portal placement upside down. The participant started tasks by working according to the GROW strategy for solving a problem, and could apply previously used and internalised strategies such as observing the environment first and reflected an awareness of game rules and operations, such as how momentum is carried through portals. Week 11 once more continued the trend of participant 4 not requiring any assistance and working extremely accurately. The participant effortlessly navigated the more complex puzzles such as the mid-air portal placement by jumping correctly through the first portal and flinging out the other. The participant applied the correct steps to solve the puzzle problems in the various test chambers, and making no mistakes. Week 11 saw a continuation of optimal performance for clarity and relevancy in the feedback provided. Week 11

witnessed optimal performance for clarity in the feedback provided, with statements like *"If I fall through this portal, I will come flying out of that one"*. The participant was able to complete advanced momentum jumps successfully, as the logic behind the momentum jumps involves understanding that momentum is carried through portals, so if something goes through one portal with speed, it comes out the other with that same momentum. More statements were made by the participant while he was playing, that linked to the GROW strategy: *"My main obstacle is this closed door. What can I use to solve this?"*

Date: 14 June 2018

Time: 11:00 am

Participant: 4

Week: 12

Activity: Portal 2 chapter 9

Observer: Byron Bunt

Week 12 saw some of the highest quality performance from participant 4 so far, outstanding scores once again for drawing inferences and recognition of assumptions. The conclusions drawn when shooting portals while jumping would add to the momentum when falling through the other portal. He was able to correctly recognise the assumption that the energy pellet is needed to progress past the gun turrets blocking his way. Week 12 saw an exponential leap for participant 4 in terms of both making deductions and doing interpretations. The participant was able to scrutinise puzzle situations and could create hypotheses on a continuous basis in order to solve puzzle problems, such as creating the hypothesis that using the energy pellet as a weapon against the turrets by knocking them off of their platforms. The participant could start interpreting multi-faceted puzzles, in which energy pellets needed to be redirected to knock over turrets preventing progress. Another excellent week for evaluation of arguments and an increase to the highest level for working systematically. The participant evaluated how his mistakes could be rectified, such as his arguments pertaining to how the energy pellet needed to knock over the turrets. The participant could formulate own rules and strategies to guide task completion using the GROW model, by applying it to redirecting the energy pellet. Another week of top class performance for persistence and accuracy. The participant made effective use of the GROW strategy to complete tasks and not give up. Continual optimal performance for relevancy and clarity criteria. The participant was transparent at all times, clearly articulating reflections and communicating thoughts and actions with precision, examples include: *"My goal is to reach that platform. I need to place a portal over here"*. The researcher believed that the participant's game play involved advanced logical thought, in which multiple laser redirections were performed. This puzzle requires advanced logic in knowing that lasers need to be redirected through the two portals and knowing at which angle to redirect the laser through the portals. More statements were made by the participant while he was playing, that linked to the

GROW strategy: *"This little ball of energy keeps bouncing. Maybe I can bounce it on one of those things that shoot at me".*

Date: 21 June 2018

Time: 11:00 am

Participant: 4

Week: 13

Activity: Portal 2 Co-op

Observer: Byron Bunt

Outstanding levels of drawing inferences and recognition of assumptions. He was able to correctly recognise the assumption that the energy pellet is needed to progress past the gun turrets blocking his way. Making deductions and doing interpretations scoring at the highest level. The participant was able to scrutinise puzzle situations and could create hypotheses on a continuous basis in order to solve puzzle problems, such as creating the hypothesis that using the energy pellet as a weapon against the turrets by knocking them off of their platforms. The participant could start interpreting multi-faceted puzzles, in which energy pellets needed to be redirected to knock over turrets preventing progress. The participant was effective at interpreting the various mechanisms presented within the puzzle test chambers, such as the momentum jumping. Peak performance for evaluation of arguments as well as systematic working ways. The participant evaluated how his mistakes could be rectified, such as his arguments pertaining to how the energy pellet needed to knock over the turrets. The participant could formulate own rules and strategies to guide task completion using the GROW model, by applying it to redirecting the energy pellet. Persistence and accuracy levels, both scored on maximum points. The participant performed at optimal levels, persisting in terms of trying new ideas relating to redirecting the energy pellet into turrets to knock them down. Feedback was of an outstanding quality. The participant applied the correct steps to solve the puzzle problems in the various test chambers, and making no mistakes. Maximal points for clarity and relevancy. The participant was transparent at all times, clearly articulating reflections and communicating thoughts and actions with precision, examples include: *"This portal only opens on this kind of wall"*. Week 13 saw peak performance for logic, with both observers agreeing to award a maximal score of 4. More statements made by the participant while he was playing, that linked to the GROW strategy: *"I can see that this platform only moves after a few seconds. If I jump through the portal, I need to time it to reach it"*.

APPENDIX H

OBSERVATION CRITERIA

Observation Checklist:	
Week: _____	
Drawing inferences (skill)	
Novice	
Participant is completely unable to draw conclusions regarding certain puzzle mechanics based upon evidence and reasoning ability, such as trial and error.	1
Able	
Participant is mostly unable to draw conclusions regarding certain puzzle mechanics based upon evidence and reasoning ability, such as trial and error.	2
Skilled	
Participant is moderately able to draw conclusions regarding certain puzzle mechanics based upon evidence and reasoning ability, such as trial and error.	3
Sophisticated	
Participant is fully able to draw conclusions regarding certain puzzle mechanics based upon evidence and reasoning ability, such as trial and error.	4
Recognizing assumptions (skill)	
Novice	
The participant is unable to distinguish between past assumptions that existed in the context of the portal activity, such as knowing how the button and box work together.	1
The participant is also unable to adapt when past assumptions no longer apply in new contexts within the portal test chambers.	
Able	
The participant is slightly able to distinguish between past assumptions that existed in the context of the portal activity, such as knowing how the button and box work together.	2
The participant is also only slightly able to adapt when past assumptions no longer apply in new contexts within the portal test chambers.	
Skilled	
The participant is mostly able to distinguish between past assumptions that existed in the context of the portal activity, such as knowing how the button and box work together.	3

The participant is also mostly able to adapt when past assumptions no longer apply in new contexts within the portal test chambers.	
Sophisticated	
The participant is fully able to distinguish between past assumptions that existed in the context of the portal activity, such as knowing how the button and box work together.	4
The participant is also fully able to adapt when past assumptions no longer apply in new contexts within the portal test chambers.	
Making deductions (skill)	
Novice	
The participant is fully unable to apply deductive reasoning during the gameplay of Portal, and cannot scrutinize specific puzzle situations or to create hypotheses.	1
Able	
The participant is mostly unable to apply deductive reasoning during the gameplay of Portal, and seldom scrutinizes specific puzzle situations or creating hypotheses.	2
Skilled	
The participant is mostly able to apply deductive reasoning during the gameplay of Portal, often scrutinizing specific puzzle situations and being able to hypothesise solutions.	3
Sophisticated	
The participant is able to fully apply deductive reasoning during the gameplay of Portal, by scrutinizing specific puzzle situations and being able to hypothesise solutions.	4
Doing interpretations (skill)	
Novice	
Participant is completely unable to interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how the portals only open on specific surfaces.	1
Able	
Participant is partially unable to interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how the portals only open on specific surfaces.	2

Skilled	
Participant is mostly able to interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how the portals only open on specific surfaces.	3
Sophisticated	
Participant is fully able to interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how the portals only open on specific surfaces	4
Evaluating arguments (skill)	
Novice	
Cannot provide reasons for each of the steps followed during the solving of a problem.	1
Participant does not reflect on the steps that were chosen to solve the problem.	
Able	
Provides very few reasons for each of the steps followed during the solving of a problem.	2
Participant reflects very seldomly on the steps that were chosen to solve the problem.	
Skilled	
Provides moderate amount of reasons for each of the steps followed during the solving of a problem.	3
Participant reflects often on the steps that were chosen to solve the problem.	
Sophisticated	
Can provide reasons for each of the steps followed during the solving of a problem.	4
Reflects continuously whether the steps that were chosen to solve the problem were the correct ones.	
Systematic working ways (disposition)	
Novice	
The participant just starts with the task without any plan of action. Needs assistance from the mediator to initiate actions successfully.	1

Able	
The participant starts with a task by working according to a basic strategy for solving problems. Starts to work spontaneously and starts to apply and transfer what is taught/modelled by the mediator.	2
Still requires the assistance of a mediator.	
Skilled	
The participant starts with a task by working according to a basic strategy for solving a problem. The participant can provide reasons for each of the steps followed during the solving of a problem.	3
Participant can choose strategies based on obtained insight. Seldom requires the support of a mediator.	
Sophisticated	
The participant starts with a task by working according to the GROW strategy for solving a problem.	4
Can apply previously used and internalised strategies and reflect an awareness of rules and operations.	
Can formulate own rules and strategies to guide task completion.	
Persistence (disposition)	
Novice	
The participant could not carry on with the task. Participant opted out very early on.	1
Dependent on the mediator for success.	
Able	
The participant tried to complete the task, but eventually gave up and opted out.	2
Skilled	
The participant almost completed the task, but at the end could not complete the task and gave up.	3
Sophisticated	
The participant utilized coping mechanisms throughout the task and completed it without giving up.	4
Completely autonomous.	

Accuracy (disposition)	
Novice	
The participant never strives for accuracy, constantly makes errors when trying to solve the puzzles in the various test chambers.	1
Able	
The participant seldom strives for accuracy, mostly makes errors when trying to solve the puzzles in the various test chambers.	2
Skilled	
The participant often strives for accuracy, frequently ensuring that they are doing the correct thing when trying to solve the puzzles in the various test chambers.	3
Sophisticated	
The participant continuously strives for accuracy, constantly ensuring that they are doing the correct thing when trying to solve the puzzles in the various test chambers.	4
Logic	
Novice	
The participant cannot perform simple logical steps when trying to solve a problem, such as redirecting laser beams into receptacles.	1
Able	
The participant can perform simple logical steps when trying to solve a puzzle, but still struggles with more advanced procedures.	2
Skilled	
The participant can perform advanced logical steps when trying to solve a puzzle, however still struggles with some more complex procedures.	3
Sophisticated	
The participant can perform advanced logical steps when trying to solve a problem within the portal test chambers, where combinations of mechanisms need to be overcome.	4
Clarity	
Novice	
The participant is not transparent, cannot articulate reflections and does not communicate with precision regarding their actions and thoughts.	1

Able	
The participant is seldom transparent, sometimes articulating reflections and communicating with precision regarding their actions and thoughts.	2
Skilled	
The participant is mostly transparent, clearly articulates reflections most of the time and communicates with precision regarding their actions and thoughts often.	3
Sophisticated	
The participant is transparent at all times, clearly articulating reflections and communicates with precision regarding their actions and thoughts.	4
Relevancy	
Novice	
The participant's thoughts and ideas that are verbalized do not make any sense when compared to the actual task at hand.	1
Able	
The participant's thoughts and ideas that are verbalized make only some sense when compared to the actual task at hand.	2
Skilled	
The participant's thoughts and ideas that are verbalized mostly relate to what is performed when compared to the actual task at hand.	3
Sophisticated	
The participant's thoughts and ideas that are verbalized relate to what is performed when compared to the actual task at hand.	4

APPENDIX I

INTERVIEW PROTOCOL

Interview Protocol

Do you play video games frequently at home? / Have you ever played a puzzle video game before? What makes them enjoyable for you?

Please describe in your own words what the puzzle video game Portal (which was played during the intervention program) is all about.

How would you describe your experience playing the puzzle video game Portal? What were you expected to do in the game?

What did you like/not like about the Portal puzzle video game?

Did playing this game benefit you in any way? How?

How did solving the puzzles in the game make you feel?

Do you think that your critical thinking or problem solving skills were enhanced while playing the game? Explain.

Lastly, do you believe that playing video games can help you acquire certain knowledge or skills more effectively than in a formal classroom setting? Motivate.

APPENDIX J

EXAMPLE - INTERVIEW: VERBATIM TRANSCRIPTS AND CODING

TRANSCRIPT: PARTICIPANT 1		OPEN CODES	AXIAL CODES
1.	Researcher: Good afternoon sir. I just have a few	Ja, I do a lot.	Frequent play of video games
2.	questions for you regarding your participation in		
3.	my study. The first question I have; do you play		
4.	video games frequently at home?		
5.	Participant 1: Ja, I do a lot		
6.	Researcher: Okay, and have you ever played a	No, I've never heard of such games before	Inexperience with puzzle video games
7.	puzzle video game before? Like Portal?		
8.	Participant 1: Like Portal? No I've never heard of		
9.	such games before.		
10.	Researcher: So it was the first time (playing it)?		
11.	Participant 1: Yes.	Fun, relax, solving mysteries, looking forward to doing more, more effort, solve, ignite, looking forward, must crack it	Enjoyment, relaxation, excitement, sense of achievement
12.	Researcher: What makes games enjoyable for		
13.	you? Why do you play them?		
14.	Participant 1: I play games for fun and they relax		
15.	you. Actually solving mysteries and something		
16.	else, because you are always looking forward to		
17.	doing more, putting more effort in it to solve		
18.	something. So they actually ignite that thing of		
19.	saying "you know what? I'm looking forward to		
20.	this, I must crack it".		
21.	Researcher: Ja, so like to achieve something		

22. Okay my next question then is, now looking at the 23. Game Portal, describe in your own words what 24. the game is all about. Just from what you've 25. seen. 26. Participant 1: The game is all about developing 27. How you think, your problem solving skills, as to 28. how you will solve a certain situation and a 29. problem if you are in it. And it requires you to 30. very quickly and never forget. So the game it's 31. very quickly and never forget. So the game it's 32. Like, it lets you think, it allows you to think really 33. fun actually. It makes thinking really fun. 34. Researcher: Can you describe the objects in the 35. Game? What were you doing? 36. Participant 1: The objects, the different portals, 37. You know the orange one and the blue one, like 38. the gun, the machine that you had, boxes, 39. picking up the boxes, they were quite exciting, 40. you know this portal is for this for exit and that 41. one is for that one. So it was very very exciting. 42. Researcher: Alright. My next question. How would 43. You describe your experience playing the game?	Developing thinking, problem solving, moving out of comfort zone, think fast, never forget, makes thinking fun Different portals, orange and blue, the gun, boxes, one is for exit	Development of critical thinking and problem solving Discomfort as a role in playing Portal Thinking is fun Obstacles and mechanics of the game

44.	Participant 1: My whole experience with the game	Enjoyed doing it, every Monday I have to go do this, put pressure on me, it developed me	Enjoyed experience Routine pressure Developmental
45.	It was like I enjoyed doing it. It got to a certain		
46.	Point whereby I always, whenever it's Monday,		
47.	that thing would come into my mind, " you know		
48.	what I have to go do this". It would always put		
49.	that pressure on me that I must play this game.	Liked everything, too short, time was limited, I could crack it, not enough, everything was perfect	Enjoyed all aspects of the game Time as a negative factor Difficulty not an issue
50.	So my experience was really fun, it was exciting,		
51.	it developed me. It developed me really really		
52.	Good		
53.	Researcher: Alright, excellent. Let me ask this		
54.	Question. What did you like and what didn't you		
55.	Like about the game?		
56.	Participant 1: Well, I liked everything about the		
57.	Game. It was too short. If it were up to me I would		
58.	Sit the whole day on it. The thing was that the time		
59.	was limited. There was not enough for us to play		
60.	And I felt like you know, I could crack it. So the		
61.	time was not enough. Everything about the game		
62.	The obstacles, everything they were perfect.		
63.	Researcher: So nothing along the lines of it being		
64.	Too difficult or anything like that?		
65.	Participant 1: No nothing was too difficult, it's just		

66.	A matter of how you were thinking. If you are not	Nothing too difficult, how you were thinking, not focusing on the game would make it difficult, put your mind to it then it becomes easier	Focus and attention simplified experience
67.	focusing on the game, thinking of something else		
68.	it would become difficult. That's what I realised		
69.	About it. But the minute you put your mind to it		
70.	then it becomes easier and you crack them all.		
71.	But when you step out of that zone then it is	Achieved something big, looking forward to next one, so exciting, can't wait to see next one	Sense of accomplishment Excitement
72.	difficult.		
73.	Researcher: So its drawing your attention and		
74.	focusing a bit, and you'll do better. Then my next		
75.	question. When you solved those puzzles, how		
76.	did it make you feel?		
77.	Participant 1: It made me feel like I've achieved		
78.	something big, like I was looking forward to the		
79.	next one, no matter if it was going to be difficult		
80.	but I was looking forward to it. It was so exciting.		
81.	It was like after cracking this one then I can't wait		
82.	to see the next one.		
83.	Researcher: My next question. Do you think that		
84.	your critical thinking and problem solving skills		
85.	were enhanced when you were playing this		
86.	game?		
87.	Participant 1: Very much, very much. They were		

88. very enhanced because even in my own studying 89. even in my own academics, every time I have 90. something, my focus and attention, it has 91. expanded or something. I am now able to focus 92. more. I'm looking forward to spending more time 93. on something. So that developed from the game. 94. Researcher: So basically what you are telling me 95. is that the game helped you in your academic 96. work as well. So it wasn't just something you 97. learnt from the game, it actually benefitted you in 98. the rest of your life as well. 99. Participant 1: Ja, definitely. 100. Researcher: My last question. Do you believe 101. that playing video games can help you acquire 102. certain knowledge or skills more effectively than 103. sitting in a classroom? 104. Participant 1: I think the gaming one is more 105. effective, because it covers all senses. You can 106. see visuals, you can hear something. So its 107. more effective than just sitting in class, you will 108. just be there. So this one of a game, it's good, 109. It's very good.	Very much, very enhanced, my focus and attention has expanded, able to focus more, looking forward to spending time on something Yes, definitely Gaming is more effective, covers all senses, see visuals, hear something, sitting in class you will just be there	Attention and focus were enhanced Taking time to complete tasks Beneficial for academic work Multi-faceted, engaging nature of games better than formal classroom

110.	Researcher: So it's like you can interact more.		
111.	Because in a classroom you can only interact so		
112.	much. But a game you are constantly interacting		
113.	in the environment. So you definitely then agree		
114.	that a video game can teach a person better?		
115.	Participant 1: Definitely. Without a doubt. It's the	Definitely, without a doubt, best teacher to recommend	Video games teach content effectively
116.	best teacher I would recommend.		
117.	Researcher: Alright. Thank you so much for your		
118.	time sir. I appreciate it.		

TRANSCRIPT: PARTICIPANT 2		OPEN CODES	AXIAL CODES
1.	Researcher: Good afternoon mam.		
2.	Participant 2: Good afternoon sir.		
3.	Researcher: I'd just like to ask you a few questions		
4.	regarding your participation in my research study.		
5.	My first question to you is do you play video games		
6.	at home?		
7.	Participant 2: Honestly, no.	No	No experience playing games
8.	Researcher: So you've never played a game like		
9.	portal before in your life? That game you were		
10.	playing in the research?		
11.	Participant 2: It was my first time actually playing	First time	First time playing a game
12.	a game.		
13.	Researcher: Did you enjoy it when you were		
14.	playing it?		
15.	Participant 2: Too much. Because it helped me in	Too much	Enjoyment playing game
16.	my critical thinking.		
17.	Researcher: Okay, now in your own words, what		
18.	was the video game Portal all about?		
19.	Participant 2: According to my own opinion, I think		
20.	the game helped with critical thinking especially.		
21.	It helped you to think more. Immediately when		Cognitive demand

22.	you start to play the game, you will think that it's	It helped you to think more, you will think it's difficult, but as time goes by, the game just needs you to think	Ease over time
23.	difficult, but once time goes by, you can see that		
24.	the game just needs you to think.		
25.	Researcher: Alright. And the setting of the game?		
26.	Like what were you expected to do in terms of	Looking for the exit, some kind of challenge in life, you have to find the exit, way out of situation	Challenging nature
27.	actually playing it. What were you doing in the		
28.	game?		
29.	Participant 2: I was actually looking for the exit.		
30.	I'll take it as if it was some kind of challenge in life,	Goal driven nature	
31.	If ever you want something, you want to go out in		
32.	something, you have to find the exit way, the way		
33.	to get out of that situation.		
34.	Researcher: There was obviously always some	Find the boxes, have to always look around, find a way to get the boxes	Exploratory nature
35.	kind of obstacle. I mean life would be so easy if		
36.	we could just walk directly to the exit. There were		
37.	certain things blocking your path. So what were		
38.	you expected to do to get to the exit?		
39.	Participant 2: You had to find the boxes, that was		
40.	the first challenge, and you have to always look		
41.	around, you have to always find the way to get		
42.	the boxes.		
43.	Researcher: And obviously the portals would add		

44.	another level of difficulty as well.		
45.	Participant 2: Yes.	Yes	
46.	Researcher: Okay my next question would be:		
47.	How would you describe your experience playing		
48.	it? Was it a positive experience?		
49.	Participant 2: Yes it was really a positive	Yes, really positive experience	Positive experience playing game
50.	experience.		
51.	Researcher: Okay. Did it benefit you in any way?		
52.	Participant 2: A lot, because firstly I wasn't the		
53.	person who liked TV games, or I've never played		
54.	them. But then this one helped me too much.	This helped me too much, start by thinking its difficult until you are in that situation, game is just interesting, wants you to just think	Cognitive benefits of game
55.	Because you start by thinking it is too difficult until		
56.	you are in that situation, you get to see that, no,		
57.	this game is just interesting. It wants you to just		
58.	think. That's what it's all about.		
59.	Researcher: It's definitely designed to get you to		
60.	think. My next question. What did you like and		
61.	what didn't you like about it?		
62.	Participant 2: I liked everything about the game.	I liked everything about the game	All aspects enjoyable
63.	Most honestly, yes.		
64.	Researcher: Okay, so there's nothing about the		
65.	difficulty, being too hard, that you wanted to stop		

66. playing, or anything like that?		
67. Participant 2: No.	No	No negative aspects
68. Researcher: Next question. When you were		
69. solving the puzzles, when you got to the exit, how		
70. did it make you feel?		
71. Participant 2: It made me feel happy. It seems like	Made me feel happy, okay I made	Feelings of happiness
72. Okay I made it. Because that's what I wanted.	it, that's what I wanted	
73. Researcher: And even though the puzzles were		
74. sometimes very complicated, and then once you		
75. got to the end, surely it may have felt that you've		
76. done something difficult, achieved a goal.		
77. Participant 2: Yes.	Yes	Achievement
78. Researcher: Alright, then my second last question		
79. Is in your opinion, do you think games can		
80. develop critical thinking and problem solving		
81. skills?		
82. Participant 2: Yes.	Yes	
83. Researcher: Okay, how do you think they can do		
84. that?		
85. Participant 2: It's because games just need you	Need you to concentrate all the	Attention grabbing nature of games
86. to concentrate all the time, compared to in	time, lecturer will be teaching and	versus tedious and repetitive nature of
87. classrooms, if ever in class the lecturer will be		formal education

88.	teaching and teaching and teaching, sometimes	teaching and teaching, lose focus	
89.	you just lose focus all of a sudden. So it is way	all of a sudden	
90.	too different than a game.		
91.	Researcher: And I suppose taking into account		
92.	the fact that you're in control, you have that		
93.	deeper interaction with a game than you would		
94.	say for example in a classroom. That links with		
95.	my last question. So do you believe that playing		
96.	a video game can help you acquire knowledge		
97.	and skills better than in a formal classroom?		
98.	Participant 2: Yes I think so.	Yes I think so	Games more effective at teaching
99.	Researcher: Alright. Thank you very much mam,		
100.	I appreciate your time.		

TRANSCRIPT: PARTICIPANT 3		OPEN CODES	AXIAL CODES
1.	Researcher: Good day. I just want to ask you a few	Yes, sometimes	Experience playing video games
2.	Questions based on the research that you helped		
3.	Me with. My first question to you would be, do you		
4.	Play video games at home?		
5.	Participant 3: Yes, sometimes.		
6.	Researcher: Okay and have you played games	No	Inexperience playing puzzle video games
7.	similar to that Portal game, like a puzzle game		
8.	Before?		
9.	Participant 3: No.		
10.	Researcher: Okay. So what do you like about		
11.	Games then?	Understand what the game is about, prove something, achieve something	Understanding Sense of achievement
12.	Participant 3: You have to understand what the		
13.	Game is about and you have to prove something.		
14.	I think if you play a game you have to achieve		
15.	Something.		
16.	Researcher: Okay now the game that you played,	Must know what you want to achieve, know your goal	Goal driven nature
17.	The Portal game, describe in your own words		
18.	What it's all about. What did you see? What did		
19.	You experience?		
20.	Participant 3: You must know what you want to		
21.	Achieve. You must know your goal.		

22. Researcher: Like when you were playing it, what			
23. Was the aim of the game?			
24. Participant 3: Aim of the game was to find the exit	Find the exit door, walk around, see what can be used	Navigation and exploration of environment	
25. Door, and to find that exit door you must first walk			
26. Around and see what you can use to get to that			
27. Exit door.			
28. Researcher: Okay. Next question. How would you	Using my mind, thinking what should be done	Thoughtful experience	
29. Explain the experience you had while playing?			
30. What were you expected to do from the research			
31. Point of view? How did you manage to navigate			
32. Through the game?	Discover something, look everywhere, what I can find to use	Exploratory experience	
33. Participant 3: I was using my mind, thinking what			
34. I should do.			
35. Researcher: Like for example, you had to solve			
36. Puzzles. How did you solve those puzzles?	Positive	Positive experience	
37. Participant 3: You have to discover something,			
38. you have to find the boxes and look everywhere			
39. What can I find to use so that I can go through the			
40. Exit door.			
41. Researcher: And do you think that your			
42. Experience was positive? Was it negative?			
43. Participant 3: It was positive.			

44. Researcher: Explain to me, what did you feel		
45. When you solved those puzzles? Did you feel		
46. Excited or happy?		
47. I felt excited, because when I found the box I felt	Felt excited, happy going to another step, achieved my goal	Excitement
48. Happy because I'm going to another step, I have		
49. Achieved my goal, so I have to find another step.		Sense of achievement
50. Researcher: Okay, and what did you not like		
51. About the game? Were there things that were too		
52. Difficult?		
53. Participant 3: No I don't think so.		No issues with the game
54. Researcher: So you were just happy and positive		
55. About the experience?		
56. Participant 3: Yes.	Yes	Positive experience
57. Researcher: My next question. After playing,		
58. Remember we did it now for quit a long time. Did		
59. It benefit you in any way, going through the game		
60. And solving those puzzles?		
61. Participant 3: Yes.	Yes	Beneficial nature of the game
62. Researcher: How so? Did it get you thinking a bit		
63. More, maybe?		
64. Participant 3: Yes. I need to think more when I'm		Cognitive benefits
65. Doing something. Even when I play other games		

66.	You have to know what do I want to achieve in	Yes, think more, have to know	Goal planning benefits
67.	This game, and how I will do that.	what do I want to achieve in this	
68.	Researcher: My second last question, do you	game, and how I will do that	
69.	Think that your critical thinking, your ability to		
70.	Analyse a situation, your problem solving skills,		
71.	Were they enhanced, did they improve while you		
72.	Were playing the game?		
73.	Participant 3: Yeah, they improved, because first	Yeah they improved, I was not	Critical thinking enhanced
74.	Time I was playing I was not understanding what	understanding what I was doing,	
75.	I was doing, but as time goes on I developed	as time goes on I developed	
76.	Critical thinking and knowing what I must do.	critical thinking and knowing what	
77.	Researcher: Lastly, do you believe that playing	I must do	
78.	Video games can help you acquire knowledge		
79.	Better than in a classroom setting?		
80.	Participant 3: I think yes, you learn better because	Yes, doing it yourself, games	Independent learning benefits of
81.	You are doing it for yourself, because in the	involve your experience	games
82.	Classroom the teacher will be explaining, but here		Experiential learning benefits of
83.	It involves your experience.		games
84.	Researcher: Alright, and does the fun have		
85.	Something to do with it as well? The enjoyment?		
86.	Participant 3: Yes.		
87.	Researcher: So if you are motivated to learn		
88.	Something because it's fun, you want to learn it		

89.	More?	Yes	Enjoyment as motivation to learn
90.	Participant 3: Yes.		
91.	Researcher: Thank you for your time, I appreciate		
92.	it.		

TRANSCRIPT: PARTICIPANT 4		OPEN CODES	AXIAL CODES
1. Researcher: Alright, good morning sir. I just want			
2. To ask you a couple questions regarding your			
3. Participation in my study. My first question would			
4. Be, do you play video games at home?			
5. Participant 4: Sometimes I do.	Sometimes I do		
6. Researcher: So would you say it is frequent? Do			
7. You play every day? Every second day?			
8. Participant 4: Maybe in the week, 3 times.	3 times in a week		Frequent playing of video games
9. Researcher: 3 times. My next question. Have you			
10. Ever played a puzzle video game before?			
11. Something like Portal?			
12. Participant 4: No. It was my first time.	No, first time		Inexperience playing puzzle video games
13. Researcher: Alright. Then, what do you think			
14. Makes games so enjoyable? Why do you like			
15. Them?			
16. Participant 4: Ah, it is so challenging, it makes you	Challenging, think harder		Challenging nature of games, cognitive demands
17. Think harder.			
18. Researcher: Okay, when you were playing now			
19. For the duration of the study, you were playing the			
20. Game Portal. Describe in your own words what			
21. That game is all about.			

22.	Participant 4: I can say that it's all about maybe		
23.	Testing your intelligence, the level of your thinking	Testing intelligence, level of thinking	Cognitive stimulation
24.	Researcher: How would you describe your		
25.	Experience playing that game? What were you		
26.	Expected to do?		
27.	Participant 4: I was facing some challenges so	Facing challenges, think on my own, overcome challenges	Solving challenges
28.	That I had to think on my own, to overcome the		Independent thinking
29.	Challenges that I face.		
30.	Researcher: What kind of challenges were there?		
31.	If you had to describe the game basically.		Progression
32.	Participant 4: The goal was to proceed to the next	Proceed to next stage, overcome obstacles	
33.	Stage, by overcoming the obstacles that you were		Solving problems
34.	Facing.		
35.	Researcher: My next question then would be what		
36.	Did you like and what didn't you like about the		
37.	Game?		
38.	Participant 4: What I like about the game is that it		
39.	Taught me to think harder, and boost my	Taught me to think harder, boost intelligence, challenging and frustrated me	Cognitive improvement as a positive
40.	Intelligence. And then I can say the opposite side,		
41.	It was so challenging that it frustrated me.		Difficulty as a negative
42.	Researcher: Alright. Then moving on to my next		
43.	Question. How did the game benefit you? Did it		

44. benefit you?		
45. Participant 4: Yes it did.	Yes it did	Beneficial experience
46. Researcher: Okay, how did it benefit you?		
47. Participant 4: That you have to teach yourself how	Teach yourself to think on your own	Independent thinking as a benefit
48. to think on your own, in some situations.		
49. Researcher: Alright. And did it develop your		
50. Critical thinking or problem solving skills, or		
51. anything like that?		
52. Participant 4: Yes.		
53. Researcher: It did do that. Okay so that leads to		
54. My next question. So you said it did. Now in your		
55. opinion, do you believe that critical thinking and		
56. problem solving can be enhanced while playing		
57. any game? Do you think the games you've played		
58. helped you with your problem solving skills?		
59. Participant 4: No.	No	Playing games do not improve skills
60. Researcher: So you think only a game like Portal		
61. could do that?		
62. Participant 4: Yes.	Yes	Only puzzle video games can develop skills
63. Researcher: So the other games, what do you		
64. think they are doing then?		
65. Participant 4: The other games are just for		Other games merely entertain

66.	entertainment, because we play mostly soccer.	Just for entertainment, play mostly soccer	Only minor thought provoked in most games
67.	Researcher: So you think there isn't that deeper		
68.	level of thinking in other games. It has to be like		
69.	Portal?		
70.	Participant 4: Yes.	Yes	
71.	Researcher: Okay my last question. Do you		
72.	believe that video games can help you acquire		
73.	certain knowledge or skills more effectively when		
74.	you compare it to a classroom?		
75.	Participant 4: I think I can learn better from playing	Learn better from playing games,	Focus and attention better in games
76.	games. Because in games you will be focusing	focusing and listening, you can	than in class
77.	And listening so that you can think for yourself.	think for yourself, get bored, lose	
78.	Sometimes in a classroom you get bored and	concentration	
79.	then you lose concentration.		Classroom gets boring, lose
80.	Researcher: So games make learning fun		concentration
81.	basically?		
82.	Participant 4: Yes.	Yes	
83.	Researcher: Alright sir, thank you very much for		
84.	your time. I appreciate it.		

Interview content analysis: Grouping of codes into themes

1. Do you play video games frequently at home? / Have you ever played a puzzle video game before? What makes them enjoyable for you?

Participant 1	Participant 2	Participant 3	Participant 4	Theme
Frequent play of video games Inexperience with puzzle video games Enjoyment, relaxation, excitement, sense of achievement	No experience playing games First time playing a game Enjoyment playing game	Experience playing video games Inexperience playing puzzle video games Sense of achievement	Frequent playing of video games Inexperience playing puzzle video games Challenging nature of games, cognitive demands	Experience vs inexperience playing games Total inexperience playing puzzle games Games are enjoyable, exciting, challenging and test your mind

2. Please describe in your own words what the puzzle video game Portal (which was played during the intervention program) is all about.

Participant 1	Participant 2	Participant 3	Participant 4	Theme
Development of problem solving skills Thinking is fun	Cognitive demand Ease over time Goal driven nature Exploratory nature	Goal driven nature Navigation exploration environment	Cognitive stimulation Independent thinking	Cognitive stimulation Exploration and navigation Goal driven

3. How would you describe your experience playing the puzzle video game Portal? What were you expected to do in the game?

Participant 1	Participant 2	Participant 3	Participant 4	Theme
Enjoyable experience Routine pressure Developmental nature	Positive experience playing game	Thoughtful experience Exploratory experience Positive experience	Progression Overcome challenges	Positive, enjoyable experience Developmental, exploratory, thoughtful experience

4. What did you like/not like about the Portal puzzle video game?

Participant 1	Participant 2	Participant 3	Participant 4	Theme
Enjoyed all aspects of the game Time as a negative factor Difficulty not an issue Focus and attention simplified experience	All aspects enjoyable No negative aspects	No issues with the game Positive experience	Cognitive improvement as a positive Difficulty as a negative Challenging, frustration	Enjoyment of Portal in general/positive experience Focus and attention enhanced Cognitive improvement Negatives: Difficulty as a negative, Time as a negative, challenging Positives: Cognitive improvement, focus and attention, no negatives, no issues, no difficulty

5. Did playing this game benefit you in any way? How?

Participant 1	Participant 2	Participant 3	Participant 4	Theme
Beneficial for academic work	Cognitive benefits of game	Cognitive benefits Goal planning benefits	Beneficial experience Independent thinking as a benefit	Cognitive benefits of Portal Goal planning benefits Independent thinking benefits

6. How did solving the puzzles in the game make you feel?

Participant 1	Participant 2	Participant 3	Participant 4	Theme
Sense of accomplishment and encouragement Excitement	Feelings of happiness Achievement of goals	Sense of goal achievement Excitement	Beneficial experience	Solving puzzles lead to excitement, happiness and accomplishment, and achievement

7. Do you think that your critical thinking or problem solving skills were enhanced while playing the game? Explain.

Participant 1	Participant 2	Participant 3	Participant 4	Theme
Attention and focus were enhanced- academic work Taking more time to complete tasks	Attention grabbing nature of games enhance skills	Better understanding of what game required	Playing games do not improve skills Only puzzle video games can develop skills Other games merely entertain Only minor thought provoked in most games	Attention and focus enhanced Only puzzle games can enhance skills Task involvement Improved understanding of game expectations

8. Do you believe that playing video games can help you acquire certain knowledge or skills more effectively than in a formal classroom setting? Motivate.

Participant 1	Participant 2	Participant 3	Participant 4	Theme
Multi-faceted, engaging nature of games better than formal classroom – learning with all senses Video games teach content better	Tedious and repetitive nature of formal education Games more effective at teaching	Independent learning benefits of games Experiential learning benefits of games Enjoyment as motivation to learn	Focus and attention better in games than in class Classroom gets boring, lose concentration Games make learning fun	Games motivate learning through fun Engaging and experiential nature of games leads to better learning Formal classes as tedious and repetitive, loss of concentration

APPENDIX K
THIRTEEN WEEK PVG-CEP INTERVENTION

Week 1: Introduction to Portal	
Portal activity	Outcomes
Introductory session explaining the controls and mechanics of the game. The GROW problem solving strategy was also explained in this session. Information was reinforced by having a hard copy printout placed in front of the participants.	Participants should be able to begin playing the game and become accustomed to it, making basic assumptions about game mechanics
Week 2: Portal 1 chambers 0 – 9	
Portal activity	Outcomes
Portal 1 chamber 0	This Test Chamber presents the player to GLaDOS, Portals, the Weighted Storage Cube the Heavy Duty Super-Colliding Super Button, the Chamberlock and the Emancipation Grill.
Portal 1 chamber 1	This Test Chamber presents the player to the idea of static and mobile linked portals.
Portal 1 chamber 2	This Test Chamber awards the player the skill to utilise the single-portal version of the Handheld Portal Device, permitting them to generate blue portals of their own.
Portal 1 chamber 3	This Test Chamber presents the player to the rudimentary principles of portal-placement.
Portal 1 chamber 4	This Test Chamber combines the fundamentals of portal placement and the usage of the Weighted Storage Cube.

Portal 1 chamber 5	This Test Chamber necessitates the player to utilise numerous Weighted Storage Cubes in order to proceed.
Portal 1 chamber 6	This Test Chamber introduces the player to High Energy Pellets, as well as areas that are not portal-conductive.
Portal 1 chamber 7	This Test Chamber presents the player to the Unstationary Scaffold.
Portal 1 chamber 8	This Test Chamber is the ninth level of the game and familiarises the player to Goo.
Portal 1 chamber 9	This Test Chamber presents Material Emancipation Grills as a test component to the player, necessitates the player to make use of a Weighted Storage Cube while evading a Material Emancipation Grill.
Week 3: Portal 1 chambers 10 – 19	
Portal activity	Outcomes
Portal 1 chamber 10	This Test Chamber familiarises the player to Flinging.
Portal 1 chamber 11	This Test Chamber presents the player to the advanced Handheld Portal Device which permits the formation of both blue and orange portals.
Portal 1 chamber 12	This Test Chamber chains the method of Flinging with the activation of Buttons utilising Weighted Storage Cubes.
Portal 1 chamber 13	This Test Chamber contains numerous Weighted Storage Cubes as well as Buttons.
Portal 1 chamber 14	This Test Chamber contains Weighted Storage Cubes and Buttons, as well as the High Energy Pellet.

Portal 1 chamber 15	This Test Chamber familiarises the player with more complicated Flinging methods.
Portal 1 chamber 16	This Test Chamber presents players with Turrets, and the means in which they can be evaded or deactivated.
Portal 1 chamber 17	This Test Chamber presents the player with the Weighted Companion Cube. The Chamber also features numerous High Energy Pellets.
Portal 1 chamber 18	This Test Chamber needs the player to apply their knowledge of complex Flinging techniques, momentum, High Energy Pellets and Weighted Storage Cubes in order to complete the chamber.
Portal 1 chamber 19	This is the final Test Chamber and features the Unstationary Scaffold and High Energy Pellets, and Goo is present as the main threat.
Week 4: Portal 2 Chapter 1	
Portal activity	Outcomes
Portal 2 chapter 1.1	This test chamber familiarises the concept of guiding Portals with Switches.
Portal 2 chapter 1.2	This test chamber familiarises the player with the single-Portal version of the Aperture Science Handheld Portal Device.
Portal 2 chapter 1.3, 1.4	These chambers present the notion of utilising numerous Weighted Storage Cubes in combination with intermediate Portals, as well as using the Aperture Science Handheld Portal Device to retrieve items that would otherwise be inaccessible.
Portal 2 chapter 1.5	This chamber presents the player to some of the simple principles behind Portal physics, specifically the manner in which speed and momentum can be utilised in combination with Portals.

Portal 2 chapter 1.6	This chamber's main focus of the level is to build upon the ideas of speed and momentum that were presented in the preceding Test Chamber.
Portal 2 chapter 1.7,1.8	These chambers form the final part of the initial phase of testing. Like the other levels in Chapter 1, the level is set within two dilapidated Test Chambers. The first of the two Chambers corresponds with Test Chamber 07 from the original Portal.
Week 5: Portal 2 Chapter 2	
Portal activity	Outcomes
Portal 2 chapter 2.1	This level introduces the Thermal Discouragement Beam, and the way in which it can be used to activate Panels and thereby grant access to inaccessible areas.
Portal 2 chapter 2.2	This chamber introduces the Discouragement Redirection Cube, and the way in which it can be used in combination with the Thermal Discouragement Beam in order to activate Panels. This level also introduces the ability of the Redirect Cube to act as a Weighted Storage Cube and activate Heavy Duty Super-Colliding Super Buttons.
Portal 2 chapter 2.3	This level introduces the player to multiple Thermal Discouragement Beams within a single chamber.
Portal 2 chapter 2.4	This level continues to use the Thermal Discouragement Beam as its primary mechanic, and demonstrates the way in which interrupting the Discouragement Beam can be used to the player's advantage.
Portal 2 chapter 2.5	This level introduces the player to the Aerial Faith Plate, and the way in which it can be used to circumvent hazards.

Portal 2 chapter 2.6	This level introduces the player to advanced manoeuvres using Aerial Faith Plate, particularly the way in which the momentum provided by the Faith Plate can be used in conjunction with Portals in order to allow the player to gain access to areas that would otherwise be beyond reach.
Portal 2 chapter 2.7	This level requires the player to utilise their knowledge of the Thermal Discouragement Beam, Buttons and momentum in order to successfully solve the Test Chamber.
Portal 2 chapter 2.8	The level takes place within a dilapidated Test Chamber, and requires the player to circumvent a large Emancipation Grid and successfully activate a Thermal Discouragement Beam's receptacle using a Discouragement Redirection Cube.
Week 6: Portal 2 Chapter 3	
Portal activity	Outcomes
Portal 2 chapter 3.9	The level is set inside a decrepit Test Chamber, and needs the player to combine the momentum delivered by an Aerial Faith Plate with a Thermal Discouragement Beam and Discouragement Redirection Cube in order to proceed to the next level.
Portal 2 chapter 3.10	This level needs the player to employ their knowledge of Thermal Discouragement Beams, Aerial Faith Plates, Discouragement Redirection Cubes and momentum in order to finish the test.
Portal 2 chapter 3.11	This level introduces the player to the Hard Light Bridge, and the manner in which it can be utilised to reach otherwise unreachable regions, with the usage of Portals.
Portal 2 chapter 3.12	This level features the Hard Light Bridge, and includes Goo as its primary environmental hazard.
Portal 2 chapter 3.13	This level reintroduces the player to Turrets, and the way in which they can be disabled through direct interaction, or by using a Weighted Storage Cube.

Portal 2 chapter 3.14	This level features the Thermal Discouragement Beam and introduces Relays, which act similarly to Receptacles and must be activated by the Beam in order to gain access to the Chamberlock.
Portal 2 chapter 3.15	This level features the Hard Light Bridge as well as Turrets, and demonstrates the way in which the Bridge can be used to prevent Turrets from harming the player.
Portal 2 chapter 3.16	This level requires the player to use the Thermal Discouragement Beam in order to deal with multiple Turrets, by destroying them with the Discouragement Beam.
Portal 2 chapter 3.17	This level requires the player to perfect advanced techniques using the Hard Light Bridge in order to access the Chamberlock.
Week 7: Portal 2 Chapter 4	
Portal activity	Outcomes
Portal 2 chapter 4.18	This level needs the player to employ advanced knowledge of the Hard Light Bridge and Thermal Discouragement Beam in order to exit the chamber.
Portal 2 chapter 4.19	This level involves the player using advanced knowledge of the Thermal Discouragement Beam, Aerial Faith Plate and momentum in order to proceed. This level presents Turrets as its main hazard.
Portal 2 chapter 4.20	This level needs the player to merge exact Portal-placement and numerous Thermal Discouragement Beams in order to proceed.
Portal 2 chapter 4.21	This level is set within a Test Chamber and the maintenance areas of the Aperture Science facility. This level progresses the main plot, and does not contain any noteworthy Portal-related puzzles.

Week 8: Portal 2 Chapter 5	
Portal activity	Outcomes
Portal 2 chapter 5 Turret Manufacturing	This level is depicted inside one of the maintenance and construction regions of the Aperture Science facility. This level progresses the central story, and does not comprise any noteworthy Portal-related challenges.
Portal 2 chapter 5 Turret Control Center	This level advances the central plot, and Turrets are present as the primary hazard.
Portal 2 chapter 5 Neurotoxin generator	This level requires the player to utilise the Thermal Discouragement Beam in order to proceed, but does not feature any direct hazards due to the placement of the Beam.
Portal 2 chapter 5 Tube ride	This level does not feature any hazards, and the player is not required to interact with any objects.
Portal 2 chapter 5 GLaDOS's Lair	It is set within the maintenance areas of the Aperture Science facility, as well as GLaDOS' Lair. This level does not feature any hazards, and advances the central plot.
Week 9: Portal 2 Chapter 6	
Portal activity	Outcomes
Portal 2 chapter 6 The pit	It is set within the ruins of the old Aperture Science Enrichment Centre. This level does not feature any significant Portal-based challenges.
Portal 2 chapter 6 Beyond the seal	This level features Goo as its main hazard, and also reveals some of the history behind Aperture Science.
Portal 2 chapter 6 Enrichment Sphere 1	This level introduces Repulsion Gel, and way in which it can be used to the player's advantage when combined with momentum. This level features Goo as its main hazard.

Portal 2 chapter 6 Enrichment Sphere 2	This level features Repulsion Gel, and introduces players to the concept of coating surfaces with Gel through the use of well-placed Portals. This level features Goo as its main hazard.
Portal 2 chapter 6 Enrichment Sphere 3	This level features Repulsion Gel, and introduces players to the ability of Gels to coat objects. This level also introduces Water and its ability to remove the effects of Gels from objects and surfaces. Goo is present in this level as its main hazard.
Portal 2 chapter 6 reconciliation	Goo is present in this level as its main hazard. This level also reunites the player with GLaDOS, who accompanies the player throughout the rest of the game.
Week 10: Portal 2 Chapter 7	
Portal activity	Outcomes
Portal 2 chapter 7 Enrichment Sphere 4	The level takes place within Aperture Science Enrichment Sphere #4, and introduces Propulsion Gel as well as the way in which it can be used in conjunction with Repulsion Gel. Goo is present as the primary hazard.
Portal 2 chapter 7 Enrichment Sphere 5	This level needs the player to merge the effects of both Propulsion Gel and Repulsion Gel in order to exit the level. Goo is presented as the main threat.
Portal 2 chapter 7 Enrichment Sphere 6	This level introduces Conversion Gel, its ability to make virtually any surface Portal-conductive and the way in which it can be used to enable the player to take advantage of standard Portal mechanics such as the use of momentum. Pistons are present as the primary hazard.
Portal 2 chapter 7 Ascension	This level requires the player to utilise momentum, and combine the effects of Repulsion Gel, Propulsion Gel and Conversion Gel in order to proceed.

Week 11: Portal 2 Chapter 8	
Portal activity	Outcomes
Portal 2 chapter 8 Test chamber 1	This level introduces the Excursion Funnel, and the way in which it can be used to move the player and objects as well as circumvent the laws of gravity.
Portal 2 chapter 8 Test chamber 2	This level features the Excursion Funnel as its primary mechanic.
Portal 2 chapter 8 Test chamber 3	This level features the Aerial Faith Plate and the Excursion Funnel as its primary mechanics.
Portal 2 chapter 8 Test chamber 4	This level features the Excursion Funnel, and introduces the way in which Buttons can be used to change the direction of Funnels. Turrets are present as an additional hazard in this level.
Portal 2 chapter 8 Test chamber 5	This level features the Aerial Faith Plate and the Excursion Funnel as its primary mechanics.
Portal 2 chapter 8 Test chamber 6	This level features the Aerial Faith Plate and the Hard Light Bridge as its primary mechanics. Turrets are present as the main hazard in this level.
Portal 2 chapter 8 Test chamber 11	This level requires the player to utilise their knowledge of the Aerial Faith Plate, Excursion Funnel and Thermal Discouragement Beam in order to proceed.
Portal 2 chapter 8 Test chamber 12	This level introduces the Laser Field, and features the Thermal Discouragement Beam as its primary mechanic.
Portal 2 chapter 8 Test chamber 15	This level features both Excursion Funnel and Repulsion Gel, and demonstrates the way in which the Funnel can be used to transport Gels to wherever they are needed.

Portal 2 chapter 8 Test chamber 16	This level features both the Excursion Funnel and Repulsion Gel, and demonstrates the way in which the Gel can be used to dispose of some threats. Turrets are present as an additional hazard in this level.
Week 12: Portal 2 Chapter 9	
Portal activity	Outcomes
Portal 2 chapter 9 Mash Up	The level takes place within an Aperture Science Test Chamber and the maintenance areas of the facility, and presents the Aerial Faith Plate, Excursion Funnel and Conversion Gel. Crushers are presented as the main danger in this level.
Portal 2 chapter 9 Holmes vs Moriarty	This level presents the Aerial Faith Plate, Excursion Funnel and Repulsion Gel, and Turrets and Crushers are regarded as the main threats.
Portal 2 chapter 9 Morton's Fork	This level comprises of Conversion Gel and Propulsion Gel, and both Bombs and Crushers are present as the main threats.
Portal 2 chapter 9 Finale	The level takes place within the maintenance areas of the Aperture Science facility, as well as Wheatley's Lair, and presents Conversion Gel, Repulsion Gel and Propulsion Gel. Bombs and Neurotoxin are present as the main dangers.
Week 13: Portal 2 Co-op	
Portal activity	Outcomes
Portal 2 co-op course 1 chamber 1	This very first co-op chamber in the game is precisely what you expect it to be, very easy with only buttons and portals being the features you have to work with.
Portal 2 co-op course 1 chamber 2	This is the second co-op chamber in the game, and it presents players to the usage of the Edgeless Safety Cube. Goo is present as the main danger.

Portal 2 co-op course 1 chamber 3	It presents players to the usage of the Thermal Discouragement Beams and Discouragement Redirection Cubes. Turrets are present as the main danger.
Portal 2 co-op course 1 chamber 4	There are no obvious dangers in this chamber, but the player in charge of the buttons can accidentally crush the player in the maze with the blocks.
Portal 2 co-op course 1 chamber 5	This is the sixth level in Co-op mode of Portal 2 and the fifth chamber in the course. Goo is presented as the main threat.
Portal 2 co-op course 1 chamber 6	This level takes place "behind the scenes" and doesn't hold a disassembly machine. It also familiarises the players with Circuit Breakers.

APPENDIX L

INTEGRATED OBSERVATIONS AND ANECDOTAL RECORDS

Integrated observations and anecdotal records

Interpretation guide: The research indicated in brackets where the supportive information cited as part of the observations, could be found in the Anecdotal records, for example (*cf.* Appendix G 1.2, where G indicates the Appendix, 1 indicates the participant, and 2 the week during which the anecdotal record was compiled).

Participant 1

Inference

Graph 6.2 reveals that during week 1, participant 1 was unable to draw correct conclusions regarding the puzzle mechanics of the box and button, scoring on level 1 for drawing inferences from both the researcher and co-observer, meaning that he started on a low level of performance. Week 2 continued similar low levels of performance, once more showing agreement between the two observers. The anecdotal records testify that participant 1 started chamber 1 confidently but made many mistakes throughout the first 3 chambers. Possible mistakes could have included not solving the box and button mechanic properly, and did not consult the GROW model (*cf.* Appendix G 1.1, 2). Week 3 saw some disparity between the researcher and co-observer, as the researcher scored drawing inferences on level one, where the co-observer scored at level 2. The researcher felt that participant 1 was not yet ready to be classified as able due to weak conclusions being drawn. Participant 1 started positively, remembering some of the skills from the previous weeks. This did however not manifest completely, as he struggled drawing the correct inferences about the puzzles, such as concluding incorrectly that portals will always open on any surface, and still making limited use of the GROW model (*cf.* Appendix G 1.3). Week 4 saw unity once more, with the level of performance scored at 2. Collected anecdotal records outline that participant 1 started off week 4 with much more enthusiasm, with a marked improvement in drawing inferences correctly (*cf.* Appendix G 1.4). This was evident in statements like “*I know that this button needs a box*”. Weeks 5 – 7 saw a 4-week trend emerge, with drawing inferences being scored at level 2, showcasing growth. Weeks 5 - 7 saw fairly similar inferences being drawn for Participant 1 in comparison to previous weeks. Correct conclusions were drawn from the momentum jump mechanic as well as the laser redirection mechanic, as the correct

redirected beam allowed the participant to unlock doors (*cf.* Appendix G 1.5 – 1.7). Week 8 saw once more disparity between observers, with the researcher scoring higher on level 3, while the co-observer scored a 2, as the researcher believed that the conclusions drawn in relation to portal placement and momentum jumping were more advanced in the sense that the participant was able to understand that portals are only placed on specific surfaces. As from week 8 growth was noted for drawing inferences, as Participant 1 was able to move through the puzzle chambers more effortlessly, drawing correct conclusions regarding turrets and how they can be moved through portals (*cf.* Appendix G 1.8). The researcher felt that the conclusions drawn on certain puzzle mechanics was sufficiently skilled in order to move up to the “skilled” category, such as being able to conclude that portals only open on specific surfaces. Week 9 saw parity once more, with an overall score of 3 being reached. The same applied for week 10. Weeks 9 – 10 saw a perfect display of drawing inferences, leading to a maximum score, as the participant was able to draw correct conclusions based on very complex portal manoeuvres, such as mid-air portal placement (*cf.* Appendix G 1.9 – 1.10). Week 11 saw a uniform spike in performance to maximal levels, with both observers scoring a 4. The same applied to week 12. During week 12 high levels of drawing inferences were observed from Participant 1, as he correctly concluded the solutions to very advanced mechanics, such as timed platform manoeuvres (*cf.* Appendix G 1.12). The final week saw disparity, as the researcher scored 4 and the co-observer 3. The researcher was sufficiently impressed with the conclusions drawn during timed platform manoeuvres. Week 13 saw optimally high levels of drawing inferences (*cf.* Appendix G 1.13). Once again, the researcher felt that the conclusions drawn regarding the mechanics of the puzzles in the game were of a higher standard and should be classified as sophisticated, as the participant for example, was able to conclude that turrets can be dropped through portals. The video recordings supported the researcher’s observation.

Recognising assumptions

Graph 6.3 displays that disparity was noted in the observations during weeks 1-3, as the co-observer and researcher disagreed on whether the participant showcased novice or able levels for recognising assumptions. An example to explain the disparity relates to whether the participant correctly recognised assumptions based on the button and cube

mechanic or not. This trend persisted throughout weeks 2 to 6, and the researcher felt that recognition of assumptions was of a higher order in terms of assuming conclusions based on the cube and button mechanic, and whether portals can only open on specific surfaces. The anecdotal records highlight that after week three, participant 1 started positively, remembering some of the skills from the previous weeks, such as how the portals are linked and that one can walk through these portals without requiring one to be opened in a certain order. This did however not manifest completely, as he struggled and still made incorrect assumptions about the puzzles (*cf.* Appendix G 1.1 - 1.3). Week 4 saw an increase in performance observed by both observers, despite the slight disparity between the observations. The researcher scored level 3 for recognising assumptions, while the co-observer scored at level 2, as the co-observer felt that the assumptions made by the participant regarding turrets and how they can be used through portals was less advanced, as the participant was frequently shot by the turrets. Disparity was noted again during weeks 4-7, as the researcher and co-observer disagreed on whether the participant showcased abled or skilled levels of recognising assumptions. The researcher felt that the quality of adapting when past assumptions no longer applied in new contexts within the portal test chambers was sufficiently skilled in order to move up to the “skilled” category. The participant was able to recognise that later test chambers no longer made use of cubes and he had to adapt to this new mechanism. This trend persisted for weeks 5 and 6 as well, showcasing growth, in comparison to weeks 1-3. In support of the growth noted, the collected anecdotal records outline that participant 1 started off weeks 4 – 6 with much more enthusiasm, with a marked improvement in recognising assumptions, as the participant correctly assumed that turrets were hostile and needed to be avoided (*cf.* Appendix G 1.4 – 1.6). Week 7 saw a change in score, as the researcher scored lower at level 2, whereas the co-observer scored higher at level 3, as assumptions about the laser redirection were not recognised, with frequent mistakes in terms of placing lasers through portals still requiring practice (*cf.* Appendix G 1.7). Week 8 saw both observers in agreement, with the level of performance scored at a 3. The same result was obtained in week 9. Anecdotal records highlight that week’s 8 - 9 saw an increase for recognising assumptions, as Participant 1 was able to move through the puzzle chambers more effortlessly (*cf.* Appendix G 1.8 – 1.9). Week 10 saw the co-observer scoring higher at maximum level 4, and the researcher at level 3. The anecdotal records highlight that week 10 saw high levels of recognising assumptions being performed by Participant 1, as he

was able to successfully state his assumptions up front regarding portal placements by stating that portals can only be opened on white surfaces, for momentum usage through portals by stating that he had to fall through the one to come out of the other with speed, as well as turret and laser redirection by stating that turrets could be thrown through portals (*cf.* Appendix G 1.10). The researcher was also convinced that the participant's ability to adapt to new situations in later puzzles in which past assumptions were altered, such as when using portals to redirect lasers into multiple portals, saw improvement. Week 11 saw parity restored, with both observers scoring at maximum level of 4, and an improvement in recognising of assumptions (*cf.* Appendix G 1.11). Weeks 12 and 13 showcased a continuous trend of maximal performance, showing growth. Overall, the performance of participant 1 regarding recognising assumptions highlighted growth when comparing week 1 to week 13, from level 1/2 to level 4. As the observers agreed on the final assessment of the participant during week 13, the noted disparities were not regarded as influential for the final score allocated to the participant.

Making deductions

As displayed on Graph 6.4, week 1 saw parity between the observers, scoring participant 1 at the lowest level of performance for making deductions, at level 1 (novice). Week 2 saw some disparity, as the researcher scored a level 2, whereas the co-observer remained at a level 1. Anecdotal records reveal responses of the participant, such as: *"I can't find the box"* or *"I can't shoot a portal here"*, showing some issues with deductive reasoning in terms of being unable to logically deduce solutions (*cf.* Appendix G 1.2). Disparity was noted for week 2, for which the co-observer and researcher disagreed on whether the participant showcased novice levels or abled levels of making deductions. The researcher felt that participant 1 was ready to be classified as able, as the participant could deduce some solutions to the locked doors in the chambers after a lot of trial and error. Week 3 saw parity restored, with both scoring participant 1 at level 2. Weeks 4 – 5 continued this trend, showcasing growth, in comparison to week 1 and 2, and supported by the anecdotal records that revealed that deductive reasoning saw marginal improvement in terms of deducing the correct manner in which to use the box and button mechanic. This was evident in statements like *"I know that this button needs a box"*, or *"There's a button here. I must find a box"* (*cf.* Appendix G 1.4 – 1.5). During week 6

differences were reported again, with the researcher scoring at level 2, and the co-observer scoring at level 3. Anecdotal records reveal that a slight improvement was noticed regarding participant 1's deductive reasoning, with improvements in correct portal placement on white surfaces (*cf.* Appendix G 1.6). Disparity was noted again in week 6, in which the researcher and co-observer disagreed on whether the participant showcased abled or skilled levels of making deductions. The co-observer felt that the application of deductive reasoning during the game play of Portal, and the scrutinisation of specific puzzle situations or creating hypotheses were sufficient to move up to the "skilled" category. The participant seemed to be abler to deduce solutions for the box and button mechanic even when boxes were not immediately apparent. Week 7 saw the researcher score participant 1 at level 1, whereas the co-observer scored at level 2. Anecdotal records highlight that week 7 saw a dip in performance for making deductions (*cf.* Appendix G 1.7). Further disparity is noted for week 7, again relating to the showcased performance being categorised as either novice or abled. In this instance, the co-observer felt that the application of deductive reasoning during the game play of Portal, and the scrutinisation of specific puzzle situations were of a higher standard as he could deduce potential solutions to the laser redirection more effortlessly, and should be classified as able. Week 8 saw agreement with the observers scoring participant 1 at level 2. This score was repeated again in week 9. Anecdotal records also testify that weeks 8 - 9 also saw great improvement for making deductions. Participant 1 was more skilfully finding the solutions to the puzzles (*cf.* Appendix G 1.8 – 1.9). Week 10 showed disagreement, as the researcher scored on level 2 while the co-observer scored at level 3. In support of the aforementioned, the anecdotal records also indicate that that making deductions was performed at an average level, with issues relating to manipulation of the energy pellet into receptacles showing deductive errors, such as knowing when to open another portal for the energy pellet to bounce through (*cf.* Appendix G 1.10). Disparity was again noted for week 10, relating to the showcased performance being categorised as either skilled or abled. The co-observer felt that the application of deductive reasoning during the game play of Portal, and the scrutinisation of specific puzzle situations were of a higher standard and should be classified as skilled. The participant could deduce how to work with momentum jumps by falling through portals the first time he tried it. Week 11 saw agreement with both observers scoring participant 1's ability to make deductions at level 3. The anecdotal records report that participant 1 performed the making of deductions at

high levels, just missing optimal performance by correctly deducing how advanced momentum jumps and mid-air portal placements work (*cf.* Appendix G 1.11). During week 12 the researcher scored the participant's performance at level 3, while the co-observer scored at level 4. According to the anecdotal records, deductions were made on optimal levels showing growth in comparison to previous weeks, as deductions were correctly made regarding turrets and how they could be bypassed using portals (*cf.* Appendix G 1.12). The final week saw both observers score participant 1 at a maximum score of 4. This observation is supported by the anecdotal records stipulating that deductions were, similar to the previous week, done at optimal levels regarding the advanced mid-air portal placements (*cf.* Appendix G 1.13).

Doing interpretations

According to Graph 6.5, weeks 1 and 2 saw agreement about the ability of the participant to do interpretations, as both observers scored at level 1 (*cf.* Appendix G 1.1 – 1.2). The participant seemed to be a novice; unable to interpret the various mechanisms presented within the puzzle test chambers, such as being unable to interpret how the portals only open on specific surfaces. Week 3 saw disparity between observers, as the researcher scored at level 1, and the co-observer scored at level 2. According to the researcher, the participant was seen repeatedly trying to open portals on wrong surfaces within the early test chambers, supporting the observation at novice level. Week 4 saw agreement, with participant 1 being scored at level 2 by both observers (*cf.* Appendix G 1.4). Weeks 5 – 7 saw exactly the same level of performance, showcasing a point of stagnation for participant 1's performance when coming to doing interpretations. In support of this stagnation, the anecdotal records highlight that week's 5 - 7 saw a steady performance for doing interpretations, as the participant could interpret the testing environments that if you fell into the water that you would die (*cf.* Appendix G 1.5 – 1.7). Week 8 showed disagreement between the observers, as the researcher scored at level 3, while the co-observer maintained the score of 2. Anecdotal records reveal that week 8 also saw great improvement for doing interpretations from the researcher's perspective, as Participant 1 was more skilfully finding the solutions to the puzzles (*cf.* Appendix G 1.8). The researcher felt that the application of interpretations during the game play of Portal, and the interpretations relating to how the portals only open on specific surfaces was sufficient

enough in order to move up to the “skilled” category, with the participant being able to interpret using portals in relation to momentum jumping. Week 9 saw agreement reached, as participant 1 was scored on level 3 by both observers, supported by the anecdotal records that stipulate that doing interpretations saw an increase during Week 9, as the participant correctly interpreted the need to redirect lasers into receptacles (*cf.* Appendix G 1.9). Week 10 showed disparity, as the researcher scored on level 3 while the co-observer scored at the maximum level of 4. Information in the anecdotal records support the observation that doing interpretations was carried out at a high level, however just not enough to meet optimal levels, as the participant could interpret how momentum was conserved when falling through portals, but could not perform the more complex double jump (*cf.* Appendix G 1.10). Further disparity is noted for week 10, again relating to the showcased performance being categorised as either skilled or sophisticated. In this instance, the co-observer felt that the application of interpretations during the game play of Portal, and the interpretations of the various mechanisms presented within the puzzle test chambers, were of a higher standard and should be classified as sophisticated. According to the co-observer, the participant was able to successfully navigate through the chambers with ease and not getting stuck with specific puzzle mechanisms, being able to piece together the solutions by observing the environment of the game. Week 11 showed agreement as both observers scored participant 1’s ability to do interpretations at level 3. Anecdotal records state that interpretations were performed at high levels, with the participant successfully interpreting the need to use boxes to avoid being shot at by turrets (*cf.* Appendix G 1.11). Week 12 saw an improvement in performance, as both observers gave a maximal score of 4. This same result was observed in week 13. The anecdotal records note that interpretations were done at optimal levels as well, with the participant interpreting correctly the very advanced procedure of redirecting the energy pellet through portals to knock down turrets, implying a significant increase from previous weeks (*cf.* Appendix G 1.12 – 1.13).

Evaluating arguments

Based on Graph 6.6, week 1 started with disagreement, with the researcher scoring at level 1, and the co-observer at level 2 for the participant’s ability to evaluate arguments. Anecdotal records state that the portal dynamics seemed to confuse the participant at

first, with statements like the following: *“What is this orange hole? Must I go through it?”* and *“Where must I go now?”* (cf. Appendix G 1.1). Disparity was noted for week 1, for which the co-observer and researcher disagreed on whether the participant showcased novice levels or abled levels of evaluation of arguments. The researcher felt that participant 1 was a novice, due to the fact that the participant only seldom evaluated his performance, by only mentioning that he was struggling with the puzzles, and not looking at how to solve them. Week 2 saw agreement, with both observers scoring a level 1. Anecdotal records reveal that participant 1 was still not able to properly evaluate his arguments, by only highlighting when he made mistakes, and not reflecting on them (cf. Appendix G 1.2). Week 3 saw disparity again, with the researcher scoring at level 1, and the co-observer scoring at level 2. Anecdotal records go on to state that participant 1 was still not able to effectively evaluate his arguments, performing at a mediocre level, by only sometimes reflecting on mistakes, such as when placing portals on wrong surfaces (cf. Appendix G 1.3). Weeks 4 and 5 saw agreement, with both observers scoring at level 2. The anecdotal records reveal that participant 1 could marginally evaluate his own arguments during weeks 4 – 5, by stating that he was making a mistake, but now adding some reflections, like *“Maybe I should try to move this box here”*, or *“Maybe I should redirect this laser”* (cf. Appendix G 1.4 – 1.5). Weeks 6 – 7 saw levels of disparity, with the researcher scoring at level 2 and the co-observer at level 3. Anecdotal records highlight that participant 1 was able to correctly judge his arguments as valid or not, as noted by the co-observer (cf. Appendix G 1.6 – 1.7). The co-observer felt that the application of evaluation of arguments during the game play of Portal, and the reasons provided for each of the steps followed during the solving of a problem was sufficient enough in order to move up to the “skilled” category, with the participant for example working out step by step how to do a momentum portal jump. Week 8 saw agreement, and both observers scored the ability to evaluate arguments at level 3. Participant 1 also improved on evaluation of arguments as noted in the anecdotal records, with the participant being able to state upfront that he made a mistake when doing a momentum jump (cf. Appendix G 1.8). Week 9 saw the same level of performance, and the evaluation of arguments successfully carried out, as the participant stated that he made a mistake with the laser redirection mechanic (cf. Appendix G 1.9). Week 10 saw disparity, as the researcher scored on level 3 while the co-observer scored higher, at level 4. Participant 1 scored very high for evaluating arguments as indicated in the anecdotal records (cf.

Appendix G 1.10). In this instance, the co-observer felt that the application of skill for the evaluation of arguments during the game play of Portal, and the reasons provided for each of the steps followed during the solving of a problem, were of a higher standard and should be classified as sophisticated, as the participant would frequently evaluate minor mistakes and try to adapt them, such as with the momentum jumps. Week 11 saw agreement again, with both observers scoring at the maximum level of 4, indicating exceptional performance. Anecdotal records state that participant 1 evaluated his arguments at optimal levels, as he could state upfront when making a mistake when getting shot at by turrets (*cf.* Appendix G 1.11). Week 12 saw the same level of exceptional evaluation of arguments, while week 13 saw disparity with the researcher scoring at level 4 while the co-observer scored at level 3. Participant 1 was optimally evaluating his arguments as revealed in the anecdotal records, by constantly reflecting on actions, such as *“Okay, I know I have to get passed this turret, but if I walk in front it will shoot me. Maybe I can drop it in a portal”* (*cf.* Appendix G 1.12 – 1.13). The video recordings verified the optimal performance observed by the researcher.

Systematic working ways

According to Graph 6.7, week 1 saw agreement from both observers, scoring participant 1's ability to work systematically at level 1. The observation confirmed that the participant just started with tasks, without any plan of action. He also needed assistance from the researcher to initiate actions successfully. The anecdotal records also testify that participant 1 was provided with the GROW model to consult during the playing of the game, but only made limited use of it and did not work with a system in mind (*cf.* Appendix G 1.1). Weeks 2 and 3 saw the same levels of disparity between the observers, with the researcher scoring at level 2, and the co-observer at level 1. The co-observer felt that participant 1 was a novice as the participant apparently did not consult the GROW model. In support of the co-observer, the anecdotal records reveal that the GROW model was still only implemented in a limited fashion (*cf.* Appendix G 1.2 – 1.3). Weeks 4 and 5 saw agreement, with both observers scoring the performance at level 2. The anecdotal records highlight that participant 1 started making greater use of the GROW model, leading to a higher score for systemic working ways (*cf.* Appendix G 1.4 – 1.5). Week 6 saw disagreement, with the researcher scoring at level 2 while the co-observer scored at

level 1. According to the anecdotal records, systemic working ways saw a dip, as Participant 1 consulted the GROW model far less than on previous occasions (*cf.* Appendix G 1.6). Week 7 saw agreement again, with both observers scoring at level 2, possibly because the GROW model was again consulted more regularly, as indicated in the anecdotal records (*cf.* Appendix G 1.7). During weeks 4, 5 and 7, growth was noticed, as the participant appeared to become abler to start a task by working according to a basic strategy for solving problems, working spontaneously and starting to apply and transfer what was taught/modelled by the researcher. Weeks 8 - 10 witnessed more growth towards becoming more skilled in working systematically during the game play of Portal, and the participant started with a task by working according to a basic strategy for solving a problem. For example, when faced with a locked doorway, the participant would consult the GROW model and try to find a new solution, and also providing reasons for each of the steps followed during the solving of a problem. Week 8 – 10 saw the same levels of performance scored by both observers, noting growth at level 3. In support of the aforementioned, the anecdotal records reveal that participant 1 started making more use of the GROW model, leading to improved systematic working ways (*cf.* Appendix G 1.8 – 1.10). Week 11 saw disagreement between the observers, with the researcher scoring at level 3 while the co-observer scoring at level 4. As noted in the anecdotal records participant 1 utilised the GROW model frequently, possibly informing the co-observer's observation (*cf.* Appendix G 1.11). Week 12 saw agreement restored, with both observers scoring at level 4, the maximum score. The anecdotal records mention that participant 1 was working systematically, fully consulting the GROW model (*cf.* Appendix G 1.12). The last week saw another exceptional performance when it came to working systematically. The anecdotal records testify that participant 1 was fully consulting the GROW model and working step by step (*cf.* Appendix G 1.13). Overall, the progress of participant 1 over the 13-week period highlight growth, and his ability to work systematically seemingly developed during the course of the intervention programme. During weeks 11 – 13 the growth noted towards becoming sophisticated in terms of working systematically, was motivated by the participant's efforts to start a task by working according to the GROW strategy for solving a problem. Furthermore, he could apply previously used and internalised strategies, and reflected an awareness of rules and operations. The participant could formulate own rules and strategies to guide task completion, such as by first looking completely around the room and listing objects.

Persistence

Following from Graph 6.8, weeks 1 – 3 saw the same levels of performance for participant 1 when it came to persistence, as both observers scored at a level 2. To justify the aforementioned observation, the anecdotal records state that participant 1 asked the researcher for assistance more than once, revealing low levels of persistence (*cf.* Appendix G 1.1 – 1.3). Statements like *“What is this orange hole? Must I go through it?”* and *“Where must I go now?”*, or *“Sir, I think I need your help here”* confirm the aforementioned observation. The participant tried to complete the tasks, but eventually gave up and opted out, and was dependent on the researcher for achieving success. Weeks 4 – 6 saw a rise in performance with both observers in agreement, scoring at a level of 3. This observation is supported by the anecdotal records where it is noted that participant 1 showed greater persistence, not requiring help from the researcher as often as before (*cf.* Appendix G 1.4 – 1.6). Week 7 saw disparity, as the researcher scored participant 1 at level 2 while the co-observer scored at level 3. The co-observer and researcher disagreed about whether the participant showcased abled levels or skilled levels of persistence. This was mainly due to difference in opinion regarding the quality of utilising coping mechanisms throughout the task and completing puzzles without giving up. The researcher was of the opinion that the participant was not coping well with the puzzles and required assistance occasionally, especially with portal placement. Week 8 saw agreement once more, with both observers scoring at level 3. The anecdotal records highlight that persistence remained the same compared to previous weeks, as Participant 1 did not require a lot of assistance from the researcher (*cf.* Appendix G 1.8). From weeks 4 - 8 growth was noticed, in comparisons to weeks 1 – 3, as the participant appeared to become more skilled in persisting, and almost completed tasks. Although he struggled to complete tasks, he was prepared to try again. During weeks 9 – 11 the researcher scored persistence at level 3 while the co-observer scored it at level 4. The anecdotal records reveal that persistence levels were quite high, noting similar levels of performance compared to previous weeks, which was comparable with the levels 3 and 4 observed by the researcher and co-observer, respectively (*cf.* Appendix G 1.9 – 1.11). Disagreement was noted again in weeks 9 - 11, about whether the participant showcased skilled levels or sophisticated levels of persistence. The co-observer felt that participant 1 was ready to be classified as sophisticated, while the researcher felt that participant 1 was only

skilled. The researcher noted less assistance being asked for, as well as using the GROW model as a coping mechanism. Week 12 saw agreement restored with both observers scoring persistence at the maximum level of 4. The same performance was highlighted in the final week as well. Anecdotal records state that persistence was also optimally performed in weeks 12 - 13, as the participant did not need any help from the researcher (*cf.* Appendix G 1.12 – 1.13). From weeks 9 - 13 sustained growth was observed towards becoming more sophisticated in persistence during the game play of Portal, and the participant utilised coping mechanisms, such as the GROW model for solving problems throughout the task and completed it without giving up.

Accuracy

According to Graph 6.9, week 1 saw agreement between the observers regarding participant 1's accuracy levels, both scoring at level 1, indicating poor performance. Week 2 saw disagreement, with the researcher scoring at level 1 whereas the co-observer scored at level 2. Anecdotal records highlight statements like *"I can't find the box"* or *"I can't shoot a portal here"* that were made, showing some issues with accuracy, as the participant was inaccurately solving the puzzles by making minor errors (*cf.* Appendix G 1.2). The co-observer based his observation that the participant could be regarded as able on the fact that participant 1 was continuously striving for accuracy, and constantly ensured that he was doing the correct thing when trying to solve the puzzles in the various test chambers. On the other hand, the researcher argued that participant 1 was a novice, as he tended to make frequent mistakes, such as opening portals on incorrect surfaces repeatedly. Week 3 saw agreement again, with both observers scoring at level 1, confirming the researcher's observation the previous week. The anecdotal records also confirm that participant 1's accuracy dropped slightly during this week, as he was making more mistakes (*cf.* Appendix 1.3). Weeks 4 – 5 saw the same levels of performance observed by both observers, as they both scored at level 2. In addition, the anecdotal records confirm that participant 1 showed mediocre levels of accuracy whilst performing the puzzle solutions (*cf.* Appendix G 1.4 – 1.5). Week 6 saw disparity again, with the researcher scoring at level 2 while the co-observer scored at level 3. Anecdotal records reveal that accuracy took a slight increase according to the co-observer (*cf.* Appendix G 1.6). The researcher felt that participant 1 was still only abled, as the participant made

fewer mistakes as previously, however repeating some mistakes, like not redirecting the laser in the correct direction. Week 7 saw agreement, with both observers scoring at level 2, supporting the previous observation of the researcher, and justified by the anecdotal records that stipulated that accuracy remained the same compared to previous weeks, as Participant 1 did not require a lot of assistance from the researcher (*cf.* Appendix G 1.7). Weeks 8 – 10 saw agreement again, with both observers scoring slightly higher, at level 3, which was confirmed by the anecdotal records where it is noted that accuracy levels were quite high in terms of mid-air portal placements (*cf.* Appendix G 1.8 – 1.10). During week 11 disagreement occurred between the researcher and co-observer, with the researcher scoring a 3 while the co-observer scored a 4. The anecdotal records support the researcher's score as the records reveal that participant 1 did not require aid from the researcher, and solved the puzzles very accurately (*cf.* Appendix G 1.11). Disparity was noted again in week 11, in which the co-observer and researcher disagreed on whether the participant showcased skilled levels or sophisticated levels of accuracy. The co-observer felt that participant 1 was ready to be classified as sophisticated, while the researcher felt that participant 1 was now only displaying skilled levels of accuracy, as some errors occurred during the solving of the puzzles. Week 12 saw agreement, with both observers scoring 3 for accuracy. The last week ended on a high note with both observers scoring maximum points for accuracy. In turn, the anecdotal records highlight that accuracy was also optimally performed during weeks 12 - 13, as the participant did not require any assistance, and solved the puzzle problems accurately (*cf.* Appendix G 1.12 – 1.13).

Logic

Graph 6.10 indicates that week's 1 – 3 started with agreement between the researcher and co-observer regarding the application of logic for participant 1, scoring at the lowest level of 1. The participant could not perform simple logical steps when trying to solve a problem, such as redirecting laser beams into receptacles. The application of logic was problematic for the participant in terms of not being able to logically conclude that the two portals are connected. Week 4 saw disparity between the observers, with the researcher scoring at level 2, and the co-observer at 3. The researcher noted that logic was not properly applied when the laser beams were being redirected through the portals, as the

participant sometimes kept on trying to reposition the portals incorrectly, resulting in being regarded as only able. From weeks 4 - 6 growth was noticed, as the participant appeared to become more abled, and could perform simple logical steps when trying to solve a puzzle such as directing lasers into portals, but still struggled with more advanced procedures, like momentum jumps. Disparity was noted again in week 7, in which the co-observer and researcher disagreed on whether the participant showcased skilled levels or abled levels of accuracy. The participant still made mistakes in terms of how the portals could change the laser's direction, confirming development at level 2. During weeks 7 - 9 growth was observed towards becoming more skilled in logic during the game play of Portal, and the participant could perform advanced logical steps such as redirecting the energy pellet through portals to knock down turrets when trying to solve a puzzle, however still struggled with some more complex procedures, such as mid-air portal placements. Weeks 10 – 11 saw disagreement once again, as the researcher scored participant 1 at level 3, while the co-observer scored higher at level 4. This was mainly due to difference in opinion regarding the quality of performing advanced logical steps when trying to solve a problem within the portal test chambers, where combinations of mechanisms needed to be overcome. In comparison to the co-observer, the researcher noted that some steps in solving problems were illogical, in relation to advanced mid-air portal placement. Weeks 12 – 13 saw agreement restored, as both observers felt that participant 1's application of logic was at the highest level, as he could logically apply the solution of knocking turrets over with the energy pellet and performing complex timed procedures.

Clarity

Graph 6.11, displays the performance of participant 1 regarding the development of clarity in reasoning over the 13-week intervention programme.

Weeks 1 – 4 started off with similar levels of performance, with both the researcher and co-observer scoring at level 2, pointing to the participant being able at reasoning with clarity. As noted in the anecdotal records the participant was asked to convey his thoughts in words when playing, but started out by mumbling a few words here and there, which negatively impacted on the observation for clarity (*cf.* Appendix G 1.1 – 1.4). Evidence for clarity seldom emerged and the participant only sometimes articulated reflections and communicated with precision regarding his actions and thoughts, such as when faced

with the laser redirection mechanic, the participant would only state that he was struggling. Weeks 5 – 7 saw disparity, as the co-observer scored higher at level 3 while the researcher remained at level 2. The anecdotal records reveal that clarity remained at the same level when it comes to the quality of the feedback, thus supporting the observation of the researcher (*cf.* Appendix G 1.5 – 1.7). The researcher argued that participant 1 was only at able level, given statements made such as: *“I am lost, what now?”*, implying that he was not clear in terms of what he saw or his thinking (*cf.* Appendix G 1.5). Week 8 – 11 saw parity restored, with both observers agreeing on a score of 3, showing growth. Anecdotal records stipulate that participant 1’s feedback was clear over the course of weeks 8 -11, as he stated *“I need to open this door”, or “Maybe this red beam can open it”, or “This thing shoots at me, I need to avoid it”* (*cf.* Appendix G 1.8 - 1.11). From weeks 5 - 11 growth was noticed, as the participant appeared to become more skilled in clarity, as he was mostly transparent, clearly articulating reflections most of the time and communicating with precision his actions and thoughts, with statements like *“Maybe if I jump down into this portal, it might make me fly out this one”*. Week 12 saw an even greater improvement in terms of clarity, as participant 1 was scored at level 4 by both observers. The anecdotal records noted that the feedback was also optimal, being extremely clear with statements like *“I can maybe get passed this turret if I drop a box on it”* (*cf.* Appendix G 1.12). Week 13 ended off with some disagreement, as the researcher scored at level 4 whereas the co-observer scored at level 3. The anecdotal records testify that the feedback was also ideal, being exceptionally clear, with statements like *“This ball of light keeps bouncing. Maybe I can bounce it on top of these turrets”* (*cf.* Appendix G 1.13). The researcher felt that participant 1 was still only skilled, as the participant made statements that showed some confusion, such as *“This laser, what must I do with this now?”* in the final week. During weeks 12 - 13 the participant tried to be transparent at all times, and to clearly articulate reflections, and communicate actions and thoughts with precision. The video recordings supported the observation of the researcher.

Relevancy

As observed from Graph 6.12, weeks 1 – 3 saw participant 1’s relevancy scored at level 1 from both observers, implying low levels of relevancy when analysing the feedback that

was given. According to the anecdotal records, participant 1 did not clearly express his thoughts, which negatively impacted on relevancy, with statements like *“I can see a camera in front of me”*, and *“I am in a room”*, as well as *“I can see the exit”*, which had no bearing on solving the puzzle (cf. Appendix G 1.1 – 1.3). Week 4 saw disagreement, as the researcher scored relevancy at level 1 while the co-observer scored at level 2. The anecdotal records note that the participant’s feedback was more relevant, scoring moderately in this category, with statements like *“I can see this door is locked”*, thus supporting the observation of the co-observer who felt that the response of the participant made some sense in relation to the need for finding a way to unlock the door (cf. Appendix G 1.4). Weeks 5 - 6 witnessed some growth as the participant’s thoughts and ideas that were verbalised started making some sense when compared to the actual task at hand, including statements like *“I’m not sure how to open this door”* cf. Appendix G 1.5). Anecdotal records reveal that participant 1’s feedback was still moderately relevant in relation to the box and button puzzle, with statements like *“I can see this button, but I can’t find the box”* (cf. Appendix G 1.6). Week 7 saw disagreement, as the researcher scored at level 1 again, while the co-observer scored at level 2. This observation is supported by the anecdotal records that reveal that the relevancy of feedback saw a dip, as some irrelevant statements were being made, such as *“This game is getting difficult”*, when the participant faced the first momentum jump mechanic (cf. Appendix G 1.7). This was mainly due to difference in opinion regarding the quality of the participant’s feedback in terms of game play that did not make any sense when compared to the actual task at hand, which was to jump through a portal in order to maintain momentum and fling across a great gap. The researcher felt that participant 1 was a novice, with statements like *“This laser can go through the portals”*. Weeks 8 – 9 saw further disparity, with the researcher scoring relevancy at level 2 while the co-observer scored at level 3. The anecdotal records reveal statements like *“If I jump through here, I should come out at this other side”* (cf. Appendix G 1.8 - 1.9). The disparity was mainly due to difference in opinion regarding the quality of the participant’s thoughts and ideas that were verbalised mostly relating to what was performed when compared to the actual task at hand, in which the co-observer felt that participant 1 was ready to be classified as skilled, while the researcher felt that participant 1 was still only abled, as statements like *“This platform is moving so slowly. Maybe if I jump at the right time I can fall on top of it”*. Week 10 saw agreement between observers, scoring participant 1’s relevancy at level 3. According to the anecdotal records,

participant 1's feedback improved in terms of relevancy, with statements clearly linked to critical reflection, such as *"I know that the portals can only open on this wall. That means I must put it there"* (cf. Appendix G 1.10). During weeks 8 - 10 it seemed that the participant was becoming more skilled in relevancy during the game play of Portal, as the participant's thoughts and ideas that were verbalised mostly related to what was performed when compared to the actual task at hand, including statements like *"Where must this box go?"* The task expected him to use the box as a weapon against turrets, by dropping it through a portal onto a turret. For weeks 11 – 12 differences in observation were noted, at the same levels for both weeks, with the researcher scoring at level 3 (skilled) while the co-observer scored at level 4 (sophisticated). The anecdotal records stipulate that feedback was also optimal, being extremely relevant in terms of statements like *"This energy ball, maybe it can bounce on those turrets over there"* (cf. Appendix G 1.11 - 1.12). Week 13 showed optimal relevancy levels, with statements like *"This lift is taking me to the fire. I need to figure out how to get over to that side before I burn"*.

Participant 2

Drawing inferences

Week 1 started off with disparity between the two observers regarding the participant's skills to draw inferences, with the researcher scoring at level 2 and the co-observer scored at level 1, as the participant failed to draw correct conclusions regarding the two-way nature of the portals, coming in and out of each other. Week 2 saw agreement between the observers, with both scoring participant 2 at level 1, thus supporting the initial observation of the co-observer. The anecdotal records confirm that participant 2 really struggled in week 2, as conclusions drawn about the box and button mechanic were incorrect (cf. Appendix G 2.2). Week 3 showed disagreement again, with the researcher scoring at level 2 and the co-observer at level 1. The anecdotal records highlight that week 3 saw a slight rise in drawing inferences with average levels of performance, as conclusions drawn on correct portal placement saw improvement, thus confirming the observation of the researcher (cf. Appendix G 2.3). Weeks 4 - 5 showed agreement again, with participant 1's performance scored low at level 1 by both observers. The anecdotal records mention that participant 2 once more did not exceed expectations regarding drawing inferences, as the same low performance was observed for another consecutive

week, in which she could not correctly conclude the solution for the laser redirection mechanic (*cf.* Appendix G 2.4 - 2.5). Week 6 showed slight improvement in inferential ability, with both observers scoring participant 2 at level 2, which is supported by the anecdotal records that reveal that week 6 saw a slight improvement when it came to drawing inferences surrounding the moving platforms and timing to jump through a portal to land on them (*cf.* Appendix G 2.6). Week 7 witnessed a dip in performance to the lowest level, level 1. The anecdotal records motivated the dip, as the conclusions drawn by the participant for the momentum jumps, were incorrect (*cf.* Appendix G 2.7). Week 8 followed with more disparity between the observers, as the researcher rated the participant as remaining at level 1 while the co-observer scored at level 2. The anecdotal records also highlight that the performance of participant 2 during week 8, was poor in relation to drawing inferences, as conclusions drawn surrounding the laser redirection mechanic lead to frequent mistakes, as the participant incorrectly concluded that the beam was not harmful (*cf.* Appendix G 2.8). During weeks 9 – 11, both observers awarded a score of 2, and the anecdotal records confirm that participant 2 continued to underperform in weeks 9 - 11, only managing to draw inferences on a mediocre level, as seen in the multiple re-attempts on the mid-air portal placement, momentum jumps and laser redirections (*cf.* Appendix G 2.9 - 2.11). Week 12 saw another dip in performance to the lowest level, possibly due to the increase in difficulty level of the puzzle, which included advanced use of the energy pellet to knock turrets off of their pedestals. The anecdotal records also describe the participant's performance during week 12 as very poor (*cf.* Appendix G 2.12). The final week saw disagreement, as the researcher scored at level 1 while the co-observer scored at level 2. In this regard, the anecdotal records highlight that the final week witnessed one of the worst performances yet for participant 2 as the final puzzle incorporated all previous puzzle mechanics, in which she incorrectly concluded the procedures to tackle each segment (*cf.* Appendix G 2.13). The observation of the researcher was supported by the video recordings.

Recognising assumptions

According to Graph 6.15, week 1 started with a disagreement between the two observers regarding the participant's ability to recognise assumptions, with the researcher scoring at level 2, while the co-observer scored at level 1. The anecdotal records reveal that

participant 2 began anxiously, struggling with the controls, mostly trying to move the mouse to the centre of the screen. This assumption that the view must always be centred would mean that the player could not look around to see if there were objects or surfaces on the ceiling or floor (*cf.* Appendix G 2.1). Week 2 saw agreement, as both observers scored at level 1, as the participant, according to the anecdotal records struggled, as she assumed that the box and button mechanic would remain the same, whereas it became more complex. She therefore struggled to adapt when the box was removed entirely, in which a new solution was needed (*cf.* Appendix G 2.2). Week 3 saw disparity, with the researcher scoring at level 2 while the co-observer scored again at level 1. According to the anecdotal records a slight improvement in recognition of assumptions was observed, that supported the researcher's observation, where the participant could recognise assumptions relating to how momentum can be carried through portals (*cf.* Appendix G 2.3). Week 4 saw another dip in performance, with both observers scoring her performance at level 1. Collected anecdotal records outlined that during week 4 assumptions were not recognised, given the more complex laser redirection that involved more than one laser (*cf.* Appendix G 2.4). Week 5 saw more disagreement between the researcher and co-observer, with the researcher scoring at level 2 and the co-observer at level 1. The researcher noted some growth, probably because assumptions regarding the use of momentum jumps were tested more often, with which the participant became familiar (*cf.* Appendix G 2.5). Week 6 noted improved performance, with both observers scoring at level 2. The anecdotal records support this observation, as participant 2 began to test assumptions regarding momentum jumping with greater success (*cf.* Appendix G 2.6). During weeks 7 – 9 both observers scored the participant at level 2, as her performance showed some decline. The noted decline in performance is supported by the anecdotal records that testify to a dip in performance, as the participant was unable to recognise the assumptions based on portals only open on specific surfaces, or that lasers needed to be redirected, or even that turrets should be avoided (*cf.* Appendix G 2.7 – 2.9). Week 10 saw some disparity, as the researcher scored at level 2 and the co-observer at level 1. In support of this observation, the anecdotal records mention that participant 2 struggled once more in Week 10, scoring very low for recognition of assumptions, as she assumed that the mid-air portal jump manoeuvre would remain static, whereas it became more complex while trying to fire upside down (*cf.* Appendix G 2.10). The researcher noted that when presented with a similar mechanic, like the box

and button, and the box was removed the participant was able to recognise her assumptions and try a new solution. Without the box, another mechanism is needed to unlock the chamber door, which may involve the player standing on the button and shooting a portal through the now opened door. As soon as the player steps off the button the door will close, but now the portal has already been placed behind the door, allowing entry.

Week 11 witnessed a slight increase in performance, with both observers scoring at level 2. The anecdotal records reveal that participant 2 continued to underperform in week 11, only managing to recognise assumptions on a mediocre level, as the participant could not adapt when the box was removed from the box and button mechanic, thus she needed to recognise that a new solution is needed to unlock the door (*cf.* Appendix G 2.11). During weeks 12 – 13 low levels of performance from participant 2 was observed, with both observers scoring at level 1. In support of the aforementioned, the anecdotal records highlight that the final week saw one of the worst performances for participant 2, as the participant seemingly forgot all of the past assumptions from previous mechanics and fumbled and made multiple errors. All around scores were very low for recognition of assumptions (*cf.* Appendix G 2.13).

Making deductions

Graph 6.16, highlights the participant's performance for the critical thinking skill of making deductions over the 13-week intervention programme. Both observers agreed that this particular skill was applied extremely poorly, as can be seen during the first five weeks of the intervention. Both observers scored making deductions at level 1, showing a trend of stagnation. Collected anecdotal records outline that week's 1 - 5 saw participant 2 failing to make any meaningful deductions. The participant was unable to deduce how to accurately make momentum jumps, and failed to understand that she needs to fall through the portal to be flung out the other portal, as well as errors when redirecting lasers and hurting herself. Turrets were also incorrectly deduced to be a threat, seemingly walking right in front of them (*cf.* Appendix G 2.1 – 2.5). Weeks 6 – 9 saw some disparity among the two observers, as the researcher scored participant 2 at level 2 while the co-observer's score remained at level 1. The anecdotal records for weeks 6 - 9 outline that participant 2 once more did not exceed expectations, as no deductions were made at all

regarding how momentum can be carried through portals, or how turrets could be disabled using falling boxes, or how aerial faith plates require timing to jump (*cf.* Appendix G 2.6 – 2.9). Weeks 10 – 13 witnessed extremely low levels of performance once again relating to making deductions, as both observers making observations at level 1, which were confirmed by the anecdotal records, which stated that the participant struggled to deduce how to solve the laser redirection mechanic, as well as the complex mid-air portal placement and energy pellet manipulation (*cf.* Appendix G 2.10 – 2.13). Overall, no improvement was shown, perhaps only slightly from week 6 – 9. Various reasons could exist as to why this low performance was witnessed. Either participant 2 struggled to understand the basic premise of the video game Portal, such as how the portal mechanics function, or how the puzzles worked and the portal gun operated.

Doing interpretations

Graph 6.17, highlights that the performance of participant 2 was very poor throughout the implementation of the intervention.

During weeks 1 – 5 participant 2 demonstrated fluctuating levels of development for doing interpretations that varied between the novice and able level. The anecdotal records testified that the participant seemed to be unable to interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how the portals only open on specific surfaces, or boxes being placed on buttons, redirecting laser beams into receptacles or how momentum jumps work (*cf.* Appendix G 2.2 – 2.5). Weeks 6 - 11 saw a continuing trend of poor performance in terms of doing interpretations, implying that a trend of stagnation was evident. This could be due to the increasing difficulty of the game itself, and possible not having mastered the basics for playing Portal. The mastery of the basics, such as basic movement and portal placement, is a prerequisite to continue being successful at solving future puzzles. The anecdotal records confirm that the participant could not make basic interpretations about the puzzle dynamics, constantly getting stuck in places, such as when falling from high placed with misplaced portals, getting killed by the lasers, failing to gain momentum for the longer jumps, avoiding turrets, using the energy pellet as well as mistiming the aerial faith plate jumps (*cf.* Appendix G 2.6 – 2.11). Week 12 saw disparity, as the researcher scored at level 1 while the co-observer scored at level 2, with the researcher noting that the participant was

incorrectly interpreting what to do with the energy pellet and not using it to knock off turrets. Week 13 ended with poor performance once again, with both observers scoring at level 1, as the last chamber involved all of the previous mechanics, and the participant was unable to interpret the correct sequence to start the solution.

Evaluating arguments

Graph 6.18, highlights the participant's ability to apply skills to evaluate arguments over the 13-week intervention programme. Participants were required to constantly give feedback to the observers by stating what they see and what they were thinking. In the case of participant 2, almost no feedback was given during the duration of the entire intervention, despite the two observers constantly asking her to provide feedback. The observations of the participant's performance during weeks 1 -10 revealed low levels in relation to evaluation of arguments, with the researcher scoring the participant at level 1 for the duration of the 10 weeks. Similar observations were reported by the co-observer, however some growth towards level 2 was noted by the co-observer during weeks 4 and 5, as she was able to argue successfully relating to the momentum jumps by evaluating that she needed to jump higher. Overall, the anecdotal records revealed that arguments were never evaluated properly by the participant (*cf.* Appendix G 2.1 – 2.10). The participant was not able to provide reasons for each of the steps followed during the solving of a problem, and she made repetitive mistakes when trying to redirect lasers. Weeks 11 - 12 saw a slight improvement, as both observers scored participant 2 at level 2, as she began to give feedback only slightly towards the end of the puzzle, with statements like *"I've got to get up there. But there is no place to make a portal. Maybe if I jump up here there might be a spot"*(*cf.* Appendix G 2.11). Week 13 saw disparity again, as the researcher scored at level 1 while the co-observer scored at level 2. According to the anecdotal records, the final week witnessed one of the worst performances for participant 2, as she did not evaluate her arguments for failing to start the complex procedure of timing the energy pellet to bounce on the turrets and knock them off. The video recordings verified the observation of the researcher as correct.

Systematic working ways

According to Graph 6.19, the observers witnessed low levels of performance in relation to working systematically during weeks 1 – 5. The observations of the researcher tended to regard the application of this disposition at level 1, with some improvement noticed during weeks 2, 4 and 5. The co-observer however, assessed the performance of the participant during weeks 1 – 5 at novice level, level 1. In support of the observations, the anecdotal records state that working with the GROW model was ignored, thus leaving no room for working systematically (*cf.* Appendix G 2.2). The small improvements noted during weeks 2, 4 and 5 were linked to the observation that during these weeks the participant made an attempt to work with the GROW model, which contributed to her being more systematic during her game play scoring marginally higher for systematic working ways, as she could systematically approach the momentum jumps by breaking down the steps, like first jumping and falling through one portal, and flinging out the other (*cf.* Appendix G 2.5). Most of the time, the participant just started with the tasks without any plan of action and needed assistance from the researcher (mediator) to initiate actions successfully. Therefore, weeks 6 – 9 saw the same level of performance, as the GROW model was only seldom consulted, and both observers scored at level 2. The anecdotal records report that participant 2 did try to consult the GROW model on occasion, but did not try to implement it fully as she stopped when identifying the objects but not following through with a way forward, in terms of errors made when doing momentum jumps, turret avoidance or laser redirection, scoring low for systematic working ways (*cf.* Appendix G 2.6 – 2.9). Weeks 10 – 13 showed disparity between the two observers, as the researcher felt that participant 2 was not making sufficient use of the GROW model, scoring her performance at level 1, while the co-observer kept his observation at level 2, and argued that although the participant was not successful in applying the GROW strategy, she at least made some attempt to use it, in order to help her progress (*cf.* Appendix G 2.10 - 2.13). The video recordings supported the researcher's observation.

Persistence

According to Graph 6.20, week 1 saw disparity, as the researcher scored at level 2 while the co-observer scored at level 1. Weeks 2 – 5 saw the same levels of persistence, as

both observers scored at level 1. The anecdotal records reveal that participant 2 continued to ask for assistance from the researcher, almost on a continual basis, leaving little room for persistence, and not consulting coping mechanisms like the GROW strategy (*cf.* Appendix G 2.2 – 2.5). Week 6 saw disagreement, as the researcher scored at level 2 and the co-observer scored at level 1. In support of the slight improvement noted by the researcher, the anecdotal records state that the researcher did not have to assist as much, and merely facilitated by asking questions. The participant was able to apply the GROW model and follow it (*cf.* Appendix G 2.6). During week 7 both observers scored the participant at level 2, as the participant began to cope better with the puzzles and asked for less assistance to complete the puzzles by using the GROW model. Week 8 saw disparity again, with the researcher scoring at level 1 and the co-observer scored at level 2. In support of the decline in performance noted by the researcher, the anecdotal records reveal that participant 2 again asked the researcher for assistance, while not using the GROW strategy that was provided to the participants as a coping mechanism (*cf.* Appendix G 2.8). Disparity in observation continued during week 8. The researcher noted that the GROW strategy was not used at all, which continued during weeks 9 – 10, and novice levels of persistence being observed that continued to the end of the intervention, with minimal growth to able level noted during week 11 when the participant made an attempt to consult the GROW strategy. Participant 2 regularly asked for assistance, leading to low persistence scores at the conclusion of the study (*cf.* Appendix G 2.9 – 2.13). The participant continuously asked the researcher for help, to the point that the researcher felt that he was solving all the puzzles for the participant (*cf.* Appendix G 2.12 – 2.13).

Accuracy

Graph 6.21 highlights the observation's for the participant's ability to work accurately over the course of the 13-week intervention programme. Weeks 1 – 2 saw low levels of performance, as both observers scored at level 1, which according to the anecdotal records could be linked to extremely inaccurate work that lead to multiple mistakes being made with the simple box and button mechanic, such as dropping the box or not placing it correctly on the button (*cf.* Appendix G 2.1 – 2.2). Week 3 saw disparity, as the researcher scored at level 1 and the co-observer at level 2. In support of the researcher's

observation, the anecdotal records note that the participant once again asked for assistance from the researcher, almost on a continual basis, leaving little room for working accurately on her own, with statements like *“Sir I need your help with this one”* (cf. Appendix G 2.3). Weeks 4 – 10 evidenced fluctuating levels of performance alternating between novice and able level, followed by novice levels during week 11 to 13. The participant constantly needed assistance from the researcher, making frequent portal placement mistakes (cf. Appendix G 2.4 – 2.13). Evidence in the anecdotal records state that during week 6 accuracy of the puzzle solutions left much to be desired, as repeated failures, and not learning from mistakes when for example, doing momentum jumps, were observed (cf. Appendix G 2.6). The researcher noted highly inaccurate statements being made such as: *“I need to move this box, but it won’t fit in the portal”* or *“Sir, this jumping thing I can’t do it properly”*. These statements are inaccurate as it does not necessarily link with the problems and how to solve them, merely stating the problem but not processing it.

Logic

Graph 6.22, provides an overview of the participant 2’s ability to reason logically while playing the video game Portal during the 13-week intervention programme. Weeks 1 – 5 saw similar low novice levels of logic, as both observers scored the participant’s performance at level 1. The participant was unable to apply simple logic steps towards using the box and button mechanic, as the participant could not logically deduce that the box must be placed on top of the button. Week 6 saw a slight improvement, with both observers scoring at level 2, as the participant was able to apply logic in order to solve the laser redirection mechanic, as the logical solution would entail directing the laser through one portal and out of the other one. Weeks 7, 10, 11 and 13 saw disparity between the observations of the researcher and co-observer, fluctuating between novice and able levels of performance. According to the researcher, the participant was unable to apply logic to perform the mid-air portal placement, momentum jumps, turret avoidance and energy pellet manipulation, influencing the observation score negatively at novice level, which was confirmed by the video recordings.

Clarity

Graph 6.23, reveals the performance of participant 2 regarding clarity over the 13-week intervention programme. Week 1 started with poor performance, with both observers scoring level 1 for clarity, as the participant failed to articulate her actions and thoughts during game play. According to the anecdotal records participant 2 seldom spoke, only stating what she saw, and not evaluating or reflecting on her actions or thoughts, leading to the low scores for clarity. Statements such as *“Wow, this game is difficult”*, or *“I’m stuck, please help me sir”* indicate that she struggled with the game (cf. Appendix G 2.1). Week 2 saw disparity, as the researcher scored at level 1 while the co-observer scored at level 2. The anecdotal records however support the observation of the researcher, as it is noted that participant 2 once more barely spoke a word the entire time, aside for asking for assistance, and giving no clear feedback regarding her thoughts and actions (cf. Appendix G 2.2). Performance at novice level prevailed during weeks 3 – 4, as both observers scored at level 1. Minimal feedback was witnessed, and when it did occur it was not clear and not specific to the situation in the puzzle video game, such as *“I do not know where to go now”*, or *“I am lost now, this game is hard!”* (cf. Appendix G 2.3 – 2.4). Weeks 5 – 6 saw a slight improvement, with the two observers agreeing that the performance was at level 2. In this regard, the anecdotal records revealed a slight improvement in the feedback given, with it being clearer than in the past, comprising statements like: *“Sir, this box, I can’t move it. What must I do?”* or *“This red light, I think it must move over here”* (cf. Appendix G 2.5 – 2.6). A decline in performance that stagnated at novice level was again noted during weeks 7 – 11. The anecdotal records highlight once more, that no feedback was given, even though the participant was asked to provide feedback (cf. Appendix G 2.7 - 2.11). Although some disparity was noted for the observations during weeks 12 – 13, the anecdotal records confirm that the participant operated at novice level, because no feedback was given (cf. Appendix G 2.12 – 2.13). The observation of the researcher was also supported by the video recordings.

Relevancy

Graph 6.24, displays the performance of participant 2 regarding relevant reasoning. Participant 2 started the first week at novice level, displaying some growth to able level according to the co-observer during weeks 2 – 5. The anecdotal records however report

that minimal feedback was witnessed, and when it did occur it was not clear or relevant to the situation happening in the puzzle video game, such as *“What is going on here?”* or *“I need some help”* (cf. Appendix G 2.2 – 2.5). The aforementioned evidence confirms the researcher’s observation at novice level for weeks 2 – 5. Weeks 6 – 9 saw agreement regarding participant 2’s reasoning with relevancy, as both observers scored the participant’s performance at level 1. To confirm these observations, the anecdotal records mentioned that feedback remained poor, and the participant played the game in silence most of the time, not putting into words what she was seeing and thinking. She only made statements in relation to how hard the game is (cf. Appendix G 2.6 – 2.9). Week 10 saw an improvement as participant 2 managed to give some relevant feedback regarding what she saw and thought, scoring a level 2 from both observers. Although the feedback given was still limited, the anecdotal records report that the feedback to some extent related to the game, such as: *“Sir, I need some help with this one, this box won’t move”* (cf. Appendix G 2.10). Weeks 11 – 13 witnessed fluctuating levels of performance at novice and able level, with the anecdotal records highlighting no relevant feedback in relation to thoughts and feelings about the task at hand, but only in relation to difficulty, for example: *“This is impossible”, or “These things keep shooting me!” or “This bouncing thing, I can’t get it into the portal!”* (cf. Appendix G 2.11- 2.13). The video recordings supported the observation of the researcher.

Participant 3

Drawing inferences

Graph 6.26, highlights the performance of participant 3 over the 13-week intervention programme, specifically observing the critical thinking skill of drawing inferences. Week 1 saw participant 3 perform very poorly, as both observers scored her performance at level 1. Initially the participant was unable to draw conclusions regarding certain puzzle mechanics, such as button and box mechanic. Weeks 2 – 3 saw disparity, as the researcher scored at level 2 while the co-observer scored at level 1. The anecdotal records report a slight improvement for drawing inferences, as the participant made better conclusions regarding portal placement, which supports the researcher’s observation at level 2 (cf. Appendix G 3.2). However, it is also noted that conclusions drawn regarding portal placement were still problematic, as the participant frequently made errors while

trying to place portals, which rather pointed to novice levels in relation to making deductions. Week 4 saw agreement, as both observers scored participant 3 higher, namely at level 2. The participant became abler to draw conclusions about puzzle mechanics, such as correct portal placement on surfaces. For the co-observer, the participant's performance remained at level 2 until week 9. During weeks 5 – 8 the researcher regarded the participant's performance at level 3, as the researcher argued that she appeared to be able to draw correct conclusions based on laser redirection, turret avoidance and momentum jumps most of the time (*cf.* Appendix G 3.5 – 3.7). In addition, the researcher felt that the conclusions made about certain puzzle mechanics was sufficiently skilled in order to move up to the skilled category, such as in the case of momentum jumping while falling through one portal and coming out the other, she could correctly conclude that falling with speed meant that she would fly out with speed of the other portal. Week 8 saw agreement between the observers again, with the inferential ability of participant 3 scored at level 2 by both observers. In support of this observation, the anecdotal records highlight that week 8 saw a dip in performance for drawing inferences, as the more complicated momentum jumps distracted her as she could not conclude correctly that multiple portal placements were needed to traverse a larger chamber (*cf.* Appendix G 3.8). Week 9 saw slight disparity between the observations of the observers, which was restored during weeks 10 – 11, and both observers agreeing on a level 3 score. The anecdotal records mention that the observed performance at level 3 could be linked to the participant being able to manipulate portals to overcome turrets, or to manipulate the energy pellet to knock down turrets (*cf.* Appendix G 3.10 – 3.11). Weeks 12 – 13 saw a declining performance in terms of drawing inferences, as both observers scored at level 2. The anecdotal records support this observed decline in performance by referring to incorrect conclusions made by the participant in relation to the mid-air portal jumps, as she could not correctly time the portal placements as she struggled to conclude that she could shoot multiple times. This also happened with the aerial faith plates puzzles, where she mistimed the jumps constantly (*cf.* Appendix G 3.12 - 3.13).

Recognising assumptions

Graph 6.27, displays the performance of participant 3 over the 13-week intervention programme regarding the recognition of assumptions. Weeks 1 – 4 saw fluctuating levels of novice and able levels of performance. The participant struggled to adapt her play, when past assumptions no longer applied in new contexts within the portal test chambers. The anecdotal records outline that in week 4, the participant's recognition of her assumptions improved slightly, with statements like: *"I remember this box, I must put it somewhere"*, or *"I can go through this hole, just like last time"*, supporting the researcher's observation at level 2 (cf. Appendix G 3.4). During weeks 5 – 8 both observers reported able levels of performance. Anecdotal records highlight that week 8 saw continued performance at an average level when it came to recognition of assumptions (cf. Appendix G 3.5 - 3.8). Week 9 saw disagreement again, with the researcher scoring higher at level 3, and the co-observer scoring at level 2, as the researcher noted that the participant was able to recognise the assumptions of the momentum jumps, by correctly concluding that speed was needed when coming out of the other portal. Weeks 10 – 11 saw an improvement with both observers scoring at level 3. The anecdotal records obtained, mention that week's 10 – 11 saw the same above average performance for participant 3 in recognition of assumptions, as she could recognise successfully the assumptions pertaining to the energy pellet and how it could be used as a weapon to knock of the turrets (cf. Appendix G 3.10 – 3.11). Week 12 saw a slight decline in performance, with both observers scoring at level 2. The anecdotal records state that this week saw a dip in performance for recognition of assumptions, presumably due to the final puzzles' difficulty level, as it involved a culmination of all skills learnt up until this point, including every mechanic in the game and requiring skill in terms of timing (cf. Appendix G 3.12). Week 13 ended with a higher score, as both observers scored her performance at level 3. Anecdotal records highlight that the final week saw recognition of assumptions scored slightly higher, as the participant could recall all of the old assumptions about mechanics used in past chambers to correctly navigate the final chamber (cf. Appendix G 3.13).

Making deductions

Graph 6.28, displays the participant's ability to apply skills to make deductions during the 13-week intervention programme while playing the video game Portal. Weeks 1 – 3 saw low levels of performance, as both observers scored the participant at novice level. The observation is supported by the anecdotal records, where it is noted that the participant made incorrect deductions regarding surfaces upon which the portals could open (*cf.* Appendix G 3.1 – 3.3). Week 4 saw an improvement in performance, with both observers scoring at level 2. In support of the observed growth, the anecdotal records revealed that week 4 saw an improvement when it came to making deductions, as the participant could deduce solutions in relation to the basic box and button mechanic, by placing the box on top of the button and unlocking the chamber door (*cf.* Appendix G 3.4). Weeks 5 – 6 saw disparity, as the researcher scored at level 2 while the co-observer scored at level 1. Given the information in the anecdotal records that testified to the fact that the participant could deduce solutions to the laser redirection mechanic more effortlessly than previously, the researcher felt that her performance could be classified as able (*cf.* Appendix G 3.5 – 3.6). Weeks 7 – 11 saw a five-week trend develop, with similar levels of performance, and both observers scoring at level 2 for the entire time, because the participant seldom deduced solutions on the first attempt she made to solve problems, for instance in relation to the momentum jumps, turret avoidance, energy pellet manipulation, aerial faith plate timed jumps or laser redirection (*cf.* Appendix G 3.7 – 3.11). Weeks 12 – 13 saw growth, as the performance moved up to level 3 for both observers. The anecdotal records reveal that the last few weeks ended on a high note for the participant regarding making deductions, which she performed at above average level, with complicated mid-air portal jumps being performed well (*cf.* Appendix G 3.12 – 3.13).

Doing interpretations

Graph 6.29 reveals the performance of participant 3 over the 13-week intervention programme with specific reference to the critical thinking skill of doing interpretations.

Week 1 started with a poor performance, with both observers scoring her performance at novice level 1, implying that she was not able to interpret the various mechanisms present within the puzzle test chambers, with the most basic one being the box and button

mechanic. Week 2 saw improvement, with both observers scoring higher at level 2. In support of the observations, the anecdotal records state that this week saw a slight improvement for doing interpretations, as the participant was able to interpret the environment and successfully navigated the first few test chambers (*cf.* Appendix G 3.2). Weeks 3 – 4 saw disparity, with the researcher scoring at level 2, and the co-observer scoring at level 1. According to the anecdotal records the interpretation of the box and button mechanic was interpreted successfully after a few tries, which supports the researcher's observation of viewing the participant as abler. She appeared to be abler to interpret how the portals only open on specific surfaces (*cf.* Appendix G 3.3 – 3.4). The able level of performance was noted by both observers during weeks 5 – 6 as well (*cf.* Appendix G 3.5 – 3.6). Weeks 7 saw disparity again, with the researcher scoring at level 3 and the co-observer scoring at level 2. The anecdotal records confirm the observation score of the researcher, as the participant became more successful at interpreting the laser redirection mechanic, as she could successfully connect the laser through both portals, effectively unlocking the chamber door (*cf.* Appendix G 3.7). Performing interpretations at skilled level was observed by both observers during week 8. The anecdotal records testify that during week 8 the participant only made a few errors in interpreting more advanced momentum jumps (*cf.* Appendix G 3.8). Week 9 saw differing scores again, as the researcher scored at level 3 and the co-observer at level 2, supported by the anecdotal records that showcased participant 3's ability to do interpretations at above average, because she could interpret how to manipulate turrets through portals after a few tries (*cf.* Appendix G 3.9). Week 10 once more saw congruence, with both observers scoring at level 3, acknowledging the observation of the researcher noted during week 9. Week 11 diverged in terms of score, with the researcher awarding a score of 3 while the co-observer saw fit to score at level 2. The researcher felt that the participant's application of interpretations during the game play of Portal, in particular the interpretations relating to how to do momentum jumps and mid-air portal placement, were sufficient enough in order to move up to the skilled category. Week 12 saw a decline in performance by both observers, presumably due to increasing difficulty of the game. The participant could not complete the very complex mid-air portal jumping successfully at first (*cf.* Appendix G 3.12). The final week saw a slight improvement, as the observers mutually awarded a score of 3. Anecdotal records state that this last week ended on a high note with doing interpretations performed on an above average level,

with the participant successfully interpreting the advanced chambers in which the energy pellet had to be used to knock down turrets (*cf.* Appendix G 3.13).

Evaluating arguments

Graph 6.30 displays the performance of participant 3 regarding the critical thinking skill of evaluating arguments over the 13-week long intervention programme.

Weeks 1 – 3 saw very low levels of performance, as both observers scored at level 1, classifying the participant as a novice in relation to evaluating arguments. According to the anecdotal records the participant performed poorly for evaluation of arguments, as she did not try to explain her mistakes when confronted with the box and button mechanic (*cf.* Appendix G 3.1 – 3.3). Week 4 saw slight improvement, with both observers scoring at level 2, and the anecdotal records testifying that she started to explain her errors when confronted with the laser redirection mechanic (*cf.* Appendix G 3.4). Week 5 saw some disparity, as the researcher scored at level 2 while the co-observer scored at level 1. The researcher felt that participant 3 was ready to be classified as able, as she evaluated her actions when making mistakes, such as when she misfired in mid-air trying to do an advanced momentum jump. Weeks 6 – 9 saw similar levels of performance, with both observers scoring participant 3 at level 2. The anecdotal records revealed that the participant was able to evaluate her mistakes, for example when she made incorrect portal placements, incorrectly timing momentum jumps or when incorrectly redirecting lasers (*cf.* Appendix G 3.6 – 3.9). Weeks 10 – 13 saw improvement as well as a new trend of growth, as both observers felt that participant 3's ability to evaluate her own arguments was at level 3. The anecdotal records support the growth noted, indicating that the participant could now begin to evaluate her performance properly by looking at where she went wrong with the momentum jumps, turret avoidance and energy pellet manipulation (*cf.* Appendix G 3.10 – 3.13).

Systematic working ways

Graph 6.31 captures the performance of participant 3 regarding systematic working ways over the course of the 13-week intervention programme. Weeks 1 – 2 saw low levels of performance, as both observers scored at level 1, due to the fact that she did not work systematically, for not consulting the GROW strategy once (*cf.* Appendix G 3.1 – 3.2).

Week 3 saw disparity, as the researcher scored at level 1 while the co-observer scored at level 2. The co-observer's observation is supported by the anecdotal records highlighting that participant 3, although sporadically, did start consulting the GROW strategy, which earned her a slightly higher score for systematic working ways (*cf.* Appendix G 3.3). Week 4 saw both observers score at level 1, mainly because the participant did not consult the grow strategy at all to work systematically. Weeks 5 – 6 saw improvement, and both observers scored the participant's performance at level 2, for putting in a greater effort to consult the GROW strategy to work more systematically (*cf.* Appendix G 3.5 – 3.6). Week 7 saw disparity again, with the researcher scoring at level 2 while the co-observer scored at level 1. Anecdotal records reveal that week 7 saw slight disparity between researcher and co-observer for systematic working ways (*cf.* Appendix G 3.7). The researcher motivated his observation by referring to the fact that the participant incorporated the GROW strategy more often during the completion of the puzzle problems, and followed the steps in the strategy more closely. The anecdotal records reveal that week 8 showcased an increase for systematic working ways, as the participant continued to consult the GROW strategy more frequently, with both observers scoring the participant's performance at level 3 (*cf.* Appendix G 3.8). She could also provide reasons for each of the steps followed during the solving of a problem. Week 9 saw disparity again, however, the researcher was of the opinion that the participant continued to consult the GROW strategy, similar to the way she did during week 8, and therefore kept his score at level 3. The participant also started to spontaneously apply and transfer what was taught/modelled by the researcher in terms of using the GROW model within the game context. Weeks 10 – 11 saw agreement, with a slight dip in performance, as both observers scored at level 2. The anecdotal records confirm this dip, as the participant suddenly did not consult the GROW strategy when solving the puzzle problems (*cf.* Appendix G 3.10 – 3.11). However, weeks 12 – 13 saw improvement again, with greater effort by the participant to work closely with the GROW strategy to solve the puzzle problems (*cf.* Appendix G 3.12 – 3.13).

Persistence

Graph 6.32, displays the performance of participant 3 regarding persistence over the course of the 13-week intervention programme, in which participants played the video game Portal.

Week 1 started at low levels of performance, as both observers scored at level 1. The participant could not complete the tasks, and eventually gave up and opted out due to the difficulty experienced with the button and box mechanic. Due to this difficulty, she was dependent on the mediator for success. Week 2 saw improvement, as both observers viewed her performance as able. To support the aforementioned, the anecdotal records revealed that week 2 saw slight improvement in terms of persistence, as the participant required less assistance by trying to complete the puzzles herself (*cf.* Appendix G 3.2). The researcher/mediator however, still had to provide support to the participant towards achieving success. Week 3 saw disparity, as the researcher scored at level 2, and the co-observer at level 1. Anecdotal records state that week 3 saw disparity between researcher and co-observer in terms of persistence (*cf.* Appendix G 3.3). According to the anecdotal records, the participant utilised coping mechanisms throughout the task such as trying to observe the environment more closely and listing objects and complete puzzles without giving up. Therefore, the researcher felt that participant 3 was ready to be classified as able. Week 4 saw agreement, as both observers scored at level 2, because the participant struggled with the laser redirection puzzle, more than once asking for assistance (*cf.* Appendix G 3.4). Weeks 5 to 8 witnessed fluctuating levels of performance between able (co-observer) and skilled (researcher). The co-observer continued with similar observations for weeks 9-12, whereas the researcher's observations linked to the skilled level of performance. The researcher argued that persistence levels had increased, as the participant was now trying harder to do things herself, especially when it came to the momentum jumps (*cf.* Appendix G 3.5). During weeks 6 - 12 the co-observer argued that the participant sometimes had to ask for some help, probably influencing the observation of the co-observer at able level (*cf.* Appendix G 3.6). The last week saw an improvement in performance, as both observers scored at level 3, implying that she completed tasks autonomously, without giving up.

Accuracy

Graph 6.33, highlights the participant's application of the disposition to work accurately.

Weeks 1 – 4 saw similar low levels of accuracy, as both observers scored participant 3 at novice level. 1. According to the anecdotal records the participant made the same basic errors repeatedly, for example: Constantly opening portals on the wrong surfaces, not placing boxes correctly on buttons, not gaining sufficient momentum to make jumps or avoiding turrets (*cf.* Appendix G 3.1 – 3.4). Week 5 saw disparity, as the researcher scored at level 2 and the co-observer at level 1. The researcher believed that accuracy levels had increased to average, as the participant could accurately redirect lasers without making mistakes frequently (*cf.* Appendix G 3.5). Weeks 6 – 7 saw an improvement in performance, as both observers scored at level 2. Although she tried to strive for accuracy, the participant still made mistakes when working with the box and button mechanic. The participant did not set the box down accurately, so the chamber door would remain locked, causing frustration (*cf.* Appendix G 3.6 – 3.7). Weeks 8 – 9 saw similar levels of disparity, as the researcher scored at level 2, while the co-observer scored at level 1. Anecdotal records highlight that accuracy levels were once again scored as average for weeks 8 – 9, implying that the participant became abler in working accurately (*cf.* Appendix G 3.8 – 3.9). In this regard, the researcher noted more accurate attempts at solving puzzles, such as when trying to place the portals more accurately when redirecting the lasers into receptacles. Weeks 10 – 13 saw great improvement, as both observers scored at level 3. The anecdotal records note that that the participant frequently ensured that she was doing the correct thing when trying to solve the puzzles in the various test chambers (*cf.* Appendix G 3.10 – 3.13).

Logic

Graph 6.34 highlights the application of the universal standard of reasoning to reason with logic. Week 1 saw low levels of performance, as both observers scored at level 1. The participant could not perform logical steps when trying to solve a problem in relation to redirecting laser beams into receptacles. During week 2, both observers saw improvement, with both awarding a score of 2, regarding the participant abler to perform simple logical steps during the solving of the puzzles, such as when confronted with the

momentum jumps, the participant could logically deduce that if she jumped into the one portal she would fly out of the other. Weeks 3 – 4 saw disparity, as the researcher scored at level 2 while the co-observer scored at level 1. The researcher argued that the participant applied sufficient logic to redirect laser beams into receptacles, and therefore regarded her as skilled. Week 5 – 13 witnessed varied levels of performance, at able and skilled levels. Able levels of performance were linked to the participant being able to perform simple logical steps when trying to solve a puzzle, but struggled with advanced procedures for example, when performing the multi-faceted momentum jumps. The participant was required to fall through one portal and fling out the other, but was unable to get the timing of the action right. The skilled levels of performance aligned with the participant's performance of applying advanced logical steps when trying to solve a puzzle, but struggled with some more complex procedures, especially with the laser redirection. Logic is required to manipulate the laser through a portal at an angle placed on a wall. Both observers concluded their observations of the participant's performance in relation to logic at skilled level. Logic is required when directing the boxes to fall on top of the turrets to disable them. This was also applied throughout. More advanced logic was also required to perform the timed aerial faith plate jumps in order to catch a box in mid jump. This was witnessed as well. Finally, the most advanced logic was required in order to manipulate the energy pellet through portals in order to knock over turrets, which this participant could manage to do.

Clarity

Graph 6.35, displays the performance of participant 3 regarding reasoning with clarity over the 13-week intervention programme. During weeks 1 – 3, participant 3 worked as a novice in relation to clarity, was not transparent about any actions performed during the solving of the puzzles, and very seldom articulated reflections and communicated actions and thoughts with precision. The anecdotal records confirm that this participant played the game in absolute silence, except when asking the researcher for help (*cf.* Appendix G 3.1). Week 2 saw disparity, with the researcher scoring at level 2 while the co-observer scored at level 1. The researcher noted improved levels of clarity, as the participant made some effort to reflect on her thoughts when dealing with the momentum jumps. She stated *"I know I have to fall through this portal, then I will come out of that one and jump over*

there”. Week 3 saw agreement, with both observers scoring at level 1 again, due to a lack of communication from the participant’s side about thoughts and action (cf. Appendix G 3.3). From weeks 4 - 13 growth was noticed, as the participant appeared to become abler in communicating with clarity, as reflections about actions and thoughts were sometimes articulated. Weeks 4 – 8 in particular, saw similar levels of performance in terms of clarity, setting a trend of performance stagnation at level 2, because participant 3 only gave limited feedback at times, which was not too clear. During week 9 more decline in performance to a novice level was again observed, as no communication about actions were given. Weeks 10 – 13 observed similar performances in terms of participant 3’s clarity of feedback, with both observers scoring at level 2. The anecdotal records state that the final weeks once more showcased average performance for complying with clarity criteria (cf. Appendix G 3.10 - 3.13), implying that the participant was seldom transparent about her actions and thoughts.

Relevancy

Graph 6.36, displays the performance of participant 3 in relation to relevant reasoning.

Weeks 1 – 3 started at low levels of performance, with both observers scoring at level 1. The anecdotal records for weeks 1 - 3 revealed limited feedback provided by the participant, supported by statements like *“I don’t know where I am going”* (cf. Appendix G 3.1 - 3.3). Week 4 saw disparity, as the researcher scored at level 1 while the co-observer scored at level 2. The researcher’s observation is supported by the anecdotal records that continued to note that reasoning with relevancy remained low (cf. Appendix G 3.4). The researcher felt that participant 3 was a novice, as irrelevant statements such as: *“This is difficult”. What must I do?”* were noted. During weeks 5 – 8 improved performance was observed, with both observers scoring at level 2 for the duration of the time. In addition, the anecdotal records revealed that week’s 5 - 8 continued the trend of average performance in terms of relevancy, as the quality of the feedback provided did not improve, and was done sporadically (cf. Appendix G 3.5 - 3.8). During weeks 4 to 8, the participant could however verbalise some sensible ideas and thoughts in relation to the task at hand, such as *“This red beam, I think it should go into this hole. Maybe this door will open then”*. Fluctuating levels of performance between novice and able level, were observed during weeks 9 – 11 (cf. Appendix G 3.9). The agreement between the

observers that week 10 could be scored at able level, was based on the evidence observed that the participant provided some relevant feedback about her game play, with statements like *“Maybe if I jump into this portal. Maybe I can get to that side”* (cf. Appendix G 3.10). Proper feedback was however not part of her game play during week 11, that influenced the co-observer’s observation at novice level. The co-observer argued that the feedback provided in terms of game play did not make any sense. The researcher on the other hand, noted some relevance in statements like: *“This laser needs to go through this portal”*. The performance of the participant during weeks 12 – 13 convinced the observers that the participant’s performance testified to more relevant feedback in relation to her game play, that could be awarded a score of 3, with statements like “I wonder if I can’t shoot a portal behind that fence.”, or “I can drop a box from this high up and it will fly through the portal”. or *“This bouncing ball, maybe I can use it to hit that turret on top there”* (cf. Appendix G 3.12 - 3.13).

Participant 4

Drawing inferences

Graph 6.38 highlights the performance of participant 4 over the 13-week intervention programme, specifically observing the critical thinking skill of drawing inferences.

During weeks 1 – 4 fluctuating levels of performance were observed for participant 4 that varied between novice, able and skilled. The anecdotal records revealed that participant 4 was initially very quick to master the basic controls of Portal. His inferences were close to correct, and he managed to make connections regarding the mechanisms of the game quite quickly after repeating the mechanics after a few tries (cf. Appendix G 4.1 – G 4.4). The participant appeared to be effective at drawing conclusions regarding the box and button mechanics, and successfully managed to solve the laser redirection puzzles. Disparity was noted during weeks 2 and 4, in which the researcher and co-observer disagreed on whether the participant showcased able or skilled levels of drawing inferences, as the conclusions drawn in these weeks resulted in minor mistakes early on, such as failing to understand that lasers hurt the character, as the participant would constantly walk in front of them. Weeks 5- 8 saw the same performance level over a four-week period, with both observers scoring the participant’s performance at skilled level,

level 3. The anecdotal records mentioned that week's 5 -8 saw a continuation in the trend of participant 4 performing successfully when drawing inferences (*cf.* Appendix G 4.5 - 4.8). In particular, with the momentum jumps, the participant could provide reasons for why he needed to jump into the one portal in order to fling out of the other. Weeks 9 and 10 in particular, saw an improvement in performance when compared to previous weeks, with the two observers scoring the participant's performance at skilled level, level 4. The anecdotal records outline that week 9 - 10 evidenced that the participant drew proper conclusions from the puzzles, for example in relation to how to reposition the lasers into receptacles (*cf.* Appendix G 4.9 – 4.10). However, during week 11 the participant experienced problems in making proper inferences, thus performing only at the skilled level according to the co-observer (*cf.* Appendix G 4.11). The researcher however, felt that to some extent, the conclusions drawn by the participant in terms of advanced portal mid-air placement and momentum jumps, could be classified as sophisticated. Weeks 12 – 13 saw agreement restored, with both of the observers scoring at level 4. The anecdotal records evidenced outstanding performance in relation to drawing inferences regarding mid-air portal placements, as the conclusions drawn when shooting portals while jumping would add to the momentum when falling through the other portal (*cf.* Appendix G 4.12 – 4.13).

Recognising assumptions

Graph 6.39 reveals the performance of participant 4 regarding recognition of assumptions. Week 1 started with disparity, as the researcher scored the participant at skilled level, and the co-observer at able level. From the start, participant 4 set out as quite able in relation to recognising assumptions, implying that he managed to distinguish between past assumptions that existed in the context of the portal activity, such as knowing how the button and box work together, as well as adapting when past assumptions no longer apply in new contexts within the portal test chambers. Weeks 2 – 4 saw agreement, as both observers scored at level 3, confirming the researcher's observation during week 1. The anecdotal records note that week's 2 - 4 observed above average performance when it came to recognition of assumptions, as the participant adapted assumptions when faced with the button and box mechanic, once the box was removed, implying that the puzzle needed something else to be placed on the button (*cf.*

Appendix G 4.2). Weeks 5 – 7 saw disagreement, with the researcher scoring at skilled level, level 3 and the co-observer at able level, level 2. The anecdotal records obtained, mention that week's 5 - 7 saw the same high level of performance for participant 4 as during weeks 2 - 4, when it came to recognising assumptions (*cf.* Appendix G 4.5 – 4.7), confirming the observation of the researcher at skilled level. The researcher noted that the participant was able to adapt to new situations even though the assumptions based on previous mechanics no longer applied, for example when the box was no longer available and the participant had to figure out a new solution to unlock the chamber. Week 8 saw improvement in performance, with both observers observing performance at sophisticated level. In support of the observation, the anecdotal records highlight that week 8 saw a leap in performance when it came to recognition of assumptions, with the participant stating: *"I know this button requires a box"*, or *"I can only shoot portals on this surface"* (*cf.* Appendix G 4.8). Weeks 9 – 10 however revealed disparity, as the researcher scored at level 4, while the co-observer scored at level 3. The anecdotal records support the superb performance in terms of recognition of assumptions for weeks 9 – 10 (*cf.* Appendix G 4.9 – 4.10). In this regard, the participant could master the momentum jumps required moving from a vertical fling to a horizontal fling, and requiring a double jump. Weeks 11 – 13 saw maximal performance on the part of participant 4, as both observers awarded a maximum score of 4. The anecdotal records note that week's 11 - 13 saw some of the highest quality performances from participant 4, making him achieve outstanding scores once again for recognition of assumptions, as he was able to correctly recognise the assumption that the energy pellet is needed to progress past the gun turrets blocking his way (*cf.* Appendix G 4.11 – 4.13).

Making deductions

Graph 6.40 displays the participant's performance in making deductions across the 13-week intervention programme while playing the video game Portal. Weeks 1 – 4 saw similar levels of performance, with both observers scoring the participant's performance at able level, level 2. The anecdotal records support the observation, as the participant was distracted by the box and button mechanic as he struggled to deduce at first what the box was for, and failed to understand that it is needed to unlock the chamber (*cf.* Appendix G 4.1 – 4.4). Week 5 saw slight improvement, as the score moved up to skilled

level, level 3, for both observers. The anecdotal records obtained mention that week 5 saw a spike in making deductions, as the participant was able to apply his deductive reasoning while solving the puzzles, and for example deduced that the portals could be used to manipulate the turrets (cf. Appendix G 4.5). Week 6 saw a dip again in performance, with both observers scoring at level 2. This observation is supported by the anecdotal records that reveal that the increasing difficulty of the puzzles possibly influenced the participant's ability to make proper deductions, for example when he was faced with the difficult momentum jumps in which he made multiple mistakes in terms of not jumping high enough to provide enough momentum to fly out of the other portal (cf. Appendix G 4.6). Weeks 7 – 8 saw disparity, as the researcher scored at level 3 while the co-observer scored at level 2. The anecdotal records for weeks 7 – 8 report that the performance in relation to making deductions was positive with the participant deducing that the laser had to be redirected to unlock the chamber, thus in support of the higher level of performance observed by the researcher (cf. Appendix G 4.7 – 4.8). Weeks 9 – 11 saw agreement restored, with both observers scoring the participant's performance at skilled level, which was supported by the anecdotal records that supported the observations of the researcher during weeks 7 and 8. Deductions relating to turret avoidance, mid-air portal placement and energy pellet manipulation were all correct (cf. Appendix G 4.9 – 4.11). Weeks 12 – 13 testify to maximal performance, with both observers awarding a score for sophisticated performance, supported by the evidence in the anecdotal records (cf. Appendix G 4.12 – 4.13). The participant was able to scrutinise puzzle situations and could create hypotheses on a continuous basis in order to solve puzzle problems, such as creating the hypothesis that using the energy pellet as a weapon against the turrets by knocking them off of their platforms.

Doing interpretations

Graph 6.41 displays the performance of participant 4 with specific reference to the critical thinking skill of doing interpretations. Weeks 1 – 2 saw a strong start from participant 4, as both observers scored his performance at skilled level, level 3. The anecdotal records confirm that his interpretations were above average, with statements such as: *“There is something missing here, I need to find a box”* or *“This hole, if I go through this one I come out the other one”* (cf. Appendix G 4.1 - 4.2). Weeks 3 – 4 saw a slight dip in performance,

as both observers agreed to a score of 2, namely at able level. The anecdotal records confirm this slight dip in doing interpretations, as the puzzles got more difficult, for example when faced with the laser redirection mechanic, the participant kept on getting hit by the laser, or when facing turrets, the participant would be shot at very often (*cf.* Appendix G 4.3 – 4.4). Week 5 saw some disparity, with the researcher scoring performance at skilled level, and the co-observer scoring at able level. The anecdotal records confirm the researcher's observation, pointing to positive performance (*cf.* Appendix G 4.5), as the participant could interpret the various mechanisms presented within the puzzle test chambers, such as being able to interpret how the portals only open on specific surfaces. Week 6 saw agreement, with both observers agreeing to a level 2 score, as the participant appeared to become less able to interpret the various mechanisms presented within the puzzle test chambers, such as the laser redirection puzzle. Weeks 7 – 10 saw an improvement in performance again, with the two observers scoring performance at skilled level, which was supported by the anecdotal records that revealed that doing interpretations increased overall in terms of performance for redirecting the energy pellet to knock down turrets, performing mid-air portal jumps, disabling turrets with boxes as well as doing double flinging momentum jumps (*cf.* Appendix G 4.7 – 4.10).

Week 11 saw disparity, as the researcher scored at level 3 and the co-observer at level 4. The co-observer felt that the application of interpretations during the game play and the interpretations relating to how the portals only open on specific surfaces was sufficient enough in order to move up to the “sophisticated” category, as the participant could start interpreting multi-faceted puzzles, in which energy pellets needed to be redirected to knock over turrets preventing progress. Weeks 12 – 13 saw maximal performance, with both observers awarding a maximum score of 4. The anecdotal records for weeks 12 - 13 testify to a leap for participant 4 in terms of doing interpretations (*cf.* Appendix G 4.12 – 4.13). In particular, the participant was effective at interpreting the various mechanisms presented within the puzzle test chambers, such as the momentum jumping.

Evaluating arguments

Graph 6.42 displays the performance of participant 4 regarding the critical thinking skill of evaluating arguments. Participant 4 started as being able in relation to evaluating

arguments which fluctuated between skilled and able level across weeks 2 to 7. Although the participant applied skills to evaluate the puzzle game situations during the game play of Portal, reasons were seldom provided for each of the steps followed during the solving of a problem, such as performing the button and box mechanic. Week 2 saw disparity, with the researcher scoring at level 3 while the co-observer scored at level 2. The anecdotal records reveal that this week saw a rise for making evaluations of arguments, as the participant was able to provide reasons for doing momentum jumps, as he said “*I need to get over this gap. That portal over there is on the floor, the other one is up there. Maybe if I jump*” (cf. Appendix G 4.2). Week 3 saw agreement restored, with the two observers scoring at level 3. The anecdotal records note that week 3 saw a steady performance from participant 4 for evaluation of arguments (cf. Appendix G 4.3), as he could provide reasons for each of the steps followed during the solving of a problem, for example when doing the momentum jumps, with statements like “*If I fall through this one, I will fly out of that one*”. During week 4 the researcher scored performance at level 3, similar to week 3, and the co-observer scored at level 2. In support of the researcher’s observation, the anecdotal records testify, that week 4 once again had the same levels of performance for evaluating arguments as week 3, implying that the participant could provide reasons for the steps followed during problem solving for example, when doing momentum jumps (cf. Appendix G 4.4). Weeks 5 – 6 saw similar levels of performance, with both observers scoring at level 3. The anecdotal records report a continuing trend in the participant’s ability to evaluate his arguments, being at the same levels as noted for weeks 3 – 6 (cf. Appendix G 4.5 – 4.6), because the participant continued to provide plausible reasons for each of the steps followed during the solving of a problem. Similar levels of disparity were noted for week 2, 4 and 7, for which the co-observer and researcher disagreed on whether the participant showcased skilled levels or abled levels of evaluation of arguments, respectively. The researcher argued that the participant 4 was ready to be classified as skilled as good arguments were for example provided for mistakes during the redirection of lasers, where he stated “*This laser should go into that hole. How can I get it there? Maybe this portal*” (cf. Appendix G 4.7). Week 8 continued the disparity, but at higher levels of performance, as the researcher scored at level 4 and the co-observer at level 3. According to the anecdotal records (cf. Appendix G 4.8), the participant constantly evaluated his mistakes and would ask questions based on the errors made while performing the mid-air portal placement upside down, which according

to the researcher could be classified as sophisticated performance. Weeks 9 – 10 saw maximal performance, with both observers awarding a maximum score of 4. The anecdotal records also confirm exceptional performance in relation to the evaluation of arguments (*cf.* Appendix G 4.9 – 4.10), given the plausible reasons provided by the participant for each step taken during the solving of a problem, such as when performing a mid-air portal placement. Week 11 saw disparity, with the researcher scoring at level 4 and the co-observer scoring at level 3. The researcher felt that the performance of the participant could remain at sophisticated level, while the co-observer felt that his performance was only skilled. As observed during week 8, the participant continuously evaluated mistakes, and questioning the errors he made while performing the mid-air portal placement upside down. Weeks 12 – 13 saw peak performance, with both observers scoring at level 4, supported by the anecdotal records that outline peak performance for evaluation of arguments, as the participant evaluated how his mistakes could be rectified, such as his arguments pertaining to how the energy pellet needed to knock over the turrets (*cf.* Appendix G 4.12 – 4.13).

Systematic working ways

Graph 6.43 displays the performance of participant 4 regarding the systematic working ways over the course of the 13-week intervention programme.

Participant 4 started as being able in relation to systematic working ways during week 1 and seemed to maintain the able level of performance until week 6, with dips in performance noticed for week 3, as the co-observer regarded performance to only be at novice level. At novice level, the participant started working without any plan of action, did not consult the GROW strategy, and was in need of assistance from the researcher/mediator to complete actions successfully. Being able implied that although the participant still needed support from the researcher/mediator, he could apply a basic strategy for solving problems. During week 5, the researcher noted some growth to skilled level, which implied that the participant started to consult the GROW strategy on a more frequent basis during problem solving. Weeks 7, 9 and 10 witnessed growth to a skilled level by both observers, where the participant seldom required support from the researcher/mediator to complete tasks, and could choose relevant strategies to complete tasks, based on insight, for example working through the GROW model when getting

stuck with the turrets firing at him. During weeks 11 - 13 more growth was observed, and the participant became sophisticated in terms of working systematically. For the first time, the participant started tasks by working according to the GROW strategy for solving a problem, and could apply previously used and internalised strategies such as observing the environment first and reflected an awareness of game rules and operations, such as how momentum is carried through portals. The participant could formulate own rules and strategies to guide task completion using the GROW model, by applying it to redirecting the energy pellet. The disparities that were noted between the co-observer and researcher during weeks 5, 8 and 11, in mainly related to differing opinions about the effective use of the GROW strategy when faced with the planning for the difficult challenge of momentum jumps.

Persistence

Graph 6.44 displays the performance of participant 4 regarding persistence over the course of the 13-week intervention programme.

Week 1 started with both observers observing performance at able level. In this regard, the anecdotal records state that participant 4 did not require the researcher's assistance very frequently, and also completed the introduction by himself, showing modest levels of persistence (*cf.* Appendix G 4.1). Weeks 2 – 3 saw an improvement in persistence, with the two observers scoring at level 3. The anecdotal records support this observation as the participant consulted GROW model to ensure that he persists with solving of problems (*cf.* Appendix G 4.2 – 4.3). Weeks 4 – 6 saw disparity, as the researcher scored at level 3 while the co-observer scored at level 2. The anecdotal records report high levels of persistence levels, as the participant was able to navigate the test chambers without the researcher's assistance (*cf.* Appendix G 4.4 – 4.6). The participant also continued to complete puzzles without giving up, supporting the researcher's observation of performance at skilled level. The co-observer however noted that there were occasions where the participant wanted to give up, and needed some assistance from the researcher to solve problems. Week 7 saw agreement, with both observers scoring at level 3, thus confirming the observation of the researcher during week 6. Week 8 witnessed great improvement, as both observers awarded a score of 4. In turn, the anecdotal records agree that week 8 saw an increase in persistence levels, as the

researcher did not need to assist the participant at all as he was coping using the GROW strategy (*cf.* Appendix G 4.8). Week 9 saw some disagreement, with the researcher scoring at level 4 and the co-observer at level 3. The researcher argued that coping mechanisms, such as the GROW strategy, which assisted the participant in terms of not giving up, was always used, making the observation at sophisticated level justifiable. Weeks 10 – 11 saw agreement as the two observers gave a maximum score of 4. The anecdotal records confirm that week's 10 - 11 saw more exceptional levels of persistence, as the participant effortlessly navigated the more complex puzzles such as the mid-air portal placement by jumping correctly through the first portal and flinging out the other (*cf.* Appendix G 4.10 – 4.11). Week 12 saw some disparity, as the researcher scored at level 4 with the co-observer scoring at 3. Once again, the researcher was of the opinion that the participant made effective use of the GROW strategy to complete tasks and not give up. Week 13 saw a perfect performance, as both observers awarded a level 4 score. Based on the anecdotal records, the participant performed at optimal levels, persisting in terms of trying new ideas relating to redirecting the energy pellet into turrets to knock them down (*cf.* Appendix G 4.13).

Accuracy

Graph 6.45 highlights participant 4's ability to work accurately across the course of the 13-week intervention programme. Week 1 saw both observers award a score of 2, indicating able performance, as the participant made an attempt to work accurately and only made a few mistakes in terms of portal placement. Weeks 2 – 7 saw an improvement in performance regarding accuracy, leading to a trend of stagnation at skilled level, as observed by both observers. The anecdotal records for this period state that go on to the participant, compared to previous week 1, made minor errors in terms of laser redirection, in which the participant had to reattempt directing the laser through two portals (*cf.* Appendix G 4.2 – 4.7). Weeks 8 – 10 saw disparity, as the researcher scored the participant's performance at skilled level for the entire time, whilst the co-observer perceived the performance to be at sophisticated. The anecdotal records reveal exceptional levels of accuracy for weeks 8 – 10 (*cf.* Appendix G 4.8 – 4.10). The researcher motivates his observation by referring to the fact that the participant making slight errors in the more advanced test chambers, such as repeatedly missing timed

momentum jumps or failing to redirect lasers on the first attempt, which could not be classified as sophisticated performance. Weeks 11 – 13 saw great improvement, as both observers agreed to score the performance of the participant at sophisticated level. Anecdotal records state that the weeks 11 - 13 showcased top class performance for accuracy (*cf.* Appendix G 4.11 – 4.13), which was supported by the application of the correct steps to solve the puzzle problems in the various test chambers, and making no mistakes. Working with a step-by-step system allowed him to approach the puzzles systematically, and allowed him to accurately list the objects visible in the environment.

Logic

Graph 6.46 highlights participant 4's ability to apply logic while playing the video game Portal during the 13-week intervention programme. Week 1 saw mediocre performance, as both observers scored at able level, as the participant got stuck frequently in test chambers, without being able to identify ways to solve the problem. Weeks 2 – 6 saw improvement, with both observers agreeing to award a score of 3, at skilled level. Logical reasoning became more evident in the participant's ability to make fewer mistakes in terms of puzzle mechanics, as he was able to apply a step-by-step approach when solving the puzzles, such as first observing his surroundings and listing all of the objects. Weeks 7 and 8 saw disparity between the observations of the researcher and co-observer, with the researcher arguing that the performance could be regarded as skilled to sophisticated, whereas the co-observer was of the opinion that the performance was able to skilled. The researcher motivated his observation score by arguing, that the participant was thinking logically as he was solving the puzzle problems doing things step by step. Weeks 9 – 11 evidenced similar observations, as the two observers scored at level 4, arguing that the participant was able to complete advanced momentum jumps successfully, as the logic behind the momentum jumps involves understanding that momentum is carried through portals, so if something goes through one portal with speed, it comes out the other with that same momentum. Week 12 saw further disparity, as the researcher scored at level 4 while the co-observer scored at level 3. The researcher believed that the participant's game play involved advanced logical thought, in which multiple laser redirections were performed. This puzzle requires advanced logic in knowing that lasers need to be redirected through the two portals and knowing at which

angle to redirect the laser through the portals. Week 13 saw peak performance, with both observers agreeing to award a maximal score of 4. Overall, the performance over the entire period could be summed up as positive, when comparing week 1 to week 13, the scored move up from level 2 to level 4, implying growth in this area.

Clarity

Graph 6.47 displays the performance of participant 4 regarding clarity over the 13-week intervention programme. From week 1 to 6, the performance of the participant demonstrated characteristics of able (Weeks 1, 3, 4, 5, 6) and skilled (Weeks 2, 5) The observations at able level implied that the participant's feedback and communication about his thoughts and actions during the game play were not transparent and clear. The anecdotal records reveal that participant 4 tried to explain his actions and what he saw, but he did not reflect on those actions and his thinking involved in the actions. He merely stated what he saw, such as *"I am in the elevator"*, *"I can see a camera in front of me"*, or *"There is a box here"* (cf. Appendix G 4.1). The improved performance noted in week 2 is supported by the anecdotal records that note that the participant's feedback about his thoughts was more transparent and clear, mentioning the following: *"This door is locked. There must be something I can use"* (cf. Appendix G 4.2). The performance of the participant during weeks 3 – 4 reveal that in terms of participant 4's feedback, he scored lower as he only spoke about what he saw, and not about what he was thinking, for example: *"This room has a locked door"* or *"There is a red beam in front of me"* (cf. Appendix G 4.3 – 4.4). Week 5 saw disparity, as the researcher scored at level 3 and the co-observer at level 2, with the anecdotal records stating that the participant gave clearer feedback, with statements like *"This box can go on this button"* (cf. Appendix G 4.5), thus supporting the higher score of the researcher. Week 6 saw parity restored, with both observers scoring clarity at able level. The participant was seldom transparent, and did not communicate with precision regarding his actions and thoughts, examples include a statement like *"I'm not sure what to do with this box"* (cf. Appendix G 4.6). Weeks 7 – 9 saw the same performance scores at skilled level for both observers that signalled an improvement trend that signified growth. The anecdotal records confirm the noted improvement, as high levels of feedback that was linked to thoughts, such as: *"Let's see what happens when I put this portal here"* or *"This laser must be pointed over there, to*

open the door” or “If I drop this box maybe it won’t shoot at me” (cf. Appendix G 4.7 – 4.9). Week 10 saw a further development, as both observers scored clarity at sophisticated level, the highest score, following with a score at sophisticated level by the researcher, and a score at skilled level for the co-observer during week 11. According to the anecdotal records week 11 witnessed optimal performance for clarity in the feedback provided, with statements like “*If I fall through this portal, I will come flying out of that one*” (cf. Appendix G 4.11). Weeks 12 – 13 saw agreement, as clarity levels were scored at sophistication level. The participant was transparent at all times, clearly articulating reflections and communicating thoughts and actions with precision, examples include: “*My goal is to reach that platform. I need to place a portal over here*”, and “*This portal only opens on this kind of wall*”. Anecdotal records reveal that the participant’s feedback was of outstanding quality (cf. Appendix G 4.12 - 4.13).

Relevancy

Graph 6.48 displays the performance of participant 4 in relation to reasoning with relevancy. Week 1 saw disparity from the onset, with the researcher scoring performance at skilled level, while the co-observer felt the performance to be at able level. According to the anecdotal records participant 4 made attempts to try and explain his actions and what he saw, but he did not reflect on those actions and did not clearly relate his thinking to the task at hand. He merely stated what he saw, such as: “*I am in the elevator*”, “*I can see a camera in front of me*”, or “*There is a box here*” (cf. Appendix G 4.1), which rather supports the observation of the co-observer at able level, as the communication only made some sense in relation to the task at hand. Week 2 continued the disagreement, with the researcher scoring at sophisticated level, and the co-observer at skilled level. The anecdotal records stated that in week 2 participant 4 scored fairly high, as his feedback was consistent and clear, stating his intentions and what he was observing in the test chambers (cf. Appendix G 4.2), which supports the observation of the researcher, as the participant’s thoughts seemingly related better to the actual task at hand. Weeks 3 – 7 saw skilled levels of performance from both observers. Looking at the anecdotal records, the observation appears to be confirmed, as the anecdotal records reported that feedback was still clear, involving statements like: “*This portal can only open on this type of wall*” or “*This box must be placed on a button*” or “*This beam can go through portals*”

or *“If I fall through this one, I will fly out of that one over there”* or *“This platform is moving. I need to wait before I jump on it”* (cf. Appendix G 4.3 – 4.7). Weeks 8 – 9 saw great improvement, with both observers scoring performance at sophisticated level. Evidence noted in the anecdotal records point to very relevant comments that linked with the steps in the GROW model. The participant started asking questions like *“What is my goal here?”* and making statements such as: *“Maybe I should try putting a portal there and see what happens with the laser”* (cf. Appendix G 4.8 – 4.9). Week 10 saw some disparity, as the researcher scored at level 4 while the co-observer scored at level 3. The researcher was of the opinion, that the participant’s feedback was extremely relevant, as the participant made statements like *“This ball of energy keeps bouncing. Maybe I can bounce it on that turret”*. During weeks 11 – 13 both observers scored performance at sophisticated level. The anecdotal records confirm continual optimal performance in relation to relevancy with more statements made by the participant while he was playing, that linked to the GROW strategy: *“My main obstacle is this closed door. What can I use to solve this?”* or *“This little ball of energy keeps bouncing. Maybe I can bounce it on one of those things that shoot at me”* or *“I can see that this platform only moves after a few seconds. If I jump through the portal, I need to time it to reach it”* (cf. Appendix G 4.11 – 4.13).