

Enhancing the use of Problem-Based Learning by beginner Physical Sciences teachers while teaching Particulate Nature of Matter

Motlhale Judicial Sebatana

 orcid.org/0000-0001-6520-423X

Dissertation accepted in fulfilment of the requirements for the degree *Master of Education in Physical Sciences* at the North-West University

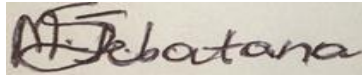
Supervisor:	Professor W.T. Dudu
Co-supervisor:	Dr A. Mutsvangwa
Assistant-supervisor:	Professor A. Golightly

Graduation ceremony: December 2020

Student number: 24240672

DECLARATION

I, the undersigned Motlhale Judicial, hereby declare that the work contained in this dissertation is my own original work and that I have not submitted it previously, in its entirety or part, at this or any other university for a degree.

A handwritten signature in black ink, appearing to read "M. Sebataana", is centered on a light-colored rectangular background.

Motlhale Judicial Sebataana

14 August 2020

Date

ACKNOWLEDGEMENTS

First and foremost, I express my deepest appreciation to my supervisor, Professor Washington Dudu. He believed in me more than I did; supported, guided and encouraged me every step of the way. I am truly grateful for his guidance and patience, allowing me to make mistakes with his Problem-Based Supervision (PBS).

Special thanks go to the following people:

- My co-supervisor, Dr Andrew Mutsvangwa.
- My assistant-supervisor, Professor Aubrey Golightly.
- My research-assistant, Mr Sfiso Mahlaba.
- My mentor, Professor John Dalton Bradley at the University of the Witwatersrand, Johannesburg.
- My mentor and director, Dr Pentecost Nkhoma.
- My language editor, Professor Muchativugwa Liberty Hove.
- My mother-figure at NWU, Mrs. Eva Mothibi.
- My mother, Kefilwe Sebatana, and my sisters (Kelebogile and late Rebaone).
- The NWU Faculty of Education staff, especially Mrs. Erna Greyling.
- My friends: Ms. Neo Tities, Mr. Michael Gent, and Mr. Martin Chanza.
- NWED, Superintendent General, Mrs. Semaswe, Principals, teacher-participants and their learners.

I reserve the greatest appreciation for my loving wife, Motseoa Sebatana, for the endless things you have done for me.

DEDICATION

I dedicate this dissertation to my late father, Jeremiah Koboyatshwene Sebatana, my inspiration.

ABSTRACT

This study focuses on facilitation for enrichment of beginner Physical Sciences teachers to utilise Problem-Based Learning (PBL) while teaching the topic - Particulate Nature of Matter (PNM) which might enhance skills such as collaboration, critical-thinking, creativity, and communication. The problem is that there is a gap between training of science teachers and the real practice. Beginner teachers are not fully equipped with the necessary pedagogic skills that compromises their teaching practices. The purpose of this study is to enhance the utilisation of PBL by beginner Physical Sciences teachers in the teaching of PNM through a Teacher Professional Development (TPD) training. This study contributes to research related to improving Physical Sciences beginner teachers' use of PBL. Social interdependence theory was adopted as the theoretical framework that underpins this research study, specifically focusing on shared influence between individuals in a small group. This study engaged with PBL-21st-century skills-development conceptual framework, adopting in the process a qualitative case study approach that is exploratory. This qualitative study was conducted within an interpretivist paradigm, allowing the researcher to view the world through the perceptions and experiences of the beginner teacher participants. Data was generated by means of an open-ended questionnaire, portfolio and interviews. This study employed purposive sampling, leading on to the snowballing technique and 5 participants were selected. Data was analysed using Saldaña's (2009) analytical framework, Golightly's (2013) and Family Secret's (2009) rubrics for learners' activities. The overall portfolio data was analysed using an adapted Smith *et al.*'s (2001) analytic tool. This study's findings show that TPD enhances beginner teachers' knowledge and implementation of PBL; before the TPD programme, beginner teachers had limited knowledge on PBL; post the TPD programme, the extent of utilisation of PBL in initiating and promoting the 21st-century skills was highly satisfactory; there are four PBL principles of practice which could be distilled. This study demonstrates that PBL can be effectively implemented in Chemistry education. With relevant 21st-century skills gained through PBL, the study established that this might in turn lead to Self-Directed Learning (SDL). This study recommends that beginner teachers who participated in this study continue to implement PBL every year in the teaching of Grade 10 PNM and related topics since they are fully conversant with the approach and have PBL skills and tasks they could gainfully deploy. This study should be adapted and extended to other science subject areas.

Keywords: *Problem-Based Learning (PBL); Beginner teachers; Particulate Nature of Matter (PNM); 21st-century skills; Self-Directed Learning (SDL)*

ABBREVIATIONS

PBL - Problem-Based Learning

PNM - Particulate Nature of Matter

SDL - Self-Directed Learning

TPD - Teacher Professional Development

PCK - Pedagogical Content Knowledge

NMM - Ngaka Modiri Molema

TABLE OF CONTENTS

DECLARATION	I
ACKNOWLEDGEMENTS	II
DEDICATION.....	III
ABSTRACT.....	IV
ABBREVIATIONS.....	V
CHAPTER 1: INTRODUCTION AND BACKGROUND OF THE STUDY	1
1.1 Introduction and background.....	1
1.2 Problem statement	3
1.3 Significance of the Study	4
1.4 Theoretical and Conceptual Framework	5
1.5 Purpose of the Study	5
1.6 Research Questions of the study.....	6
1.7 Delimitations of the Study.....	6
1.8 Explanation of keywords and phrases	6
1.9 Chapter Summary.....	7
CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK	9
2.1 Introduction.....	9
2.2 Theoretical Framework	9
2.3 Conceptual Framework.....	14
2.4 Problem-Based Learning.....	16

2.4.1	PBL formats (pure PBL, hybrid PBL, integrated PBL and embedded PBL)	18
2.4.2	PBL process.....	20
2.4.3	Role players in PBL (facilitator, group leader, scribe & group members)	22
2.4.4	Advantages of PBL	23
2.4.5	Disadvantages in PBL	24
2.4.6	Assessment in PBL.....	26
2.4.7	Related studies of Problem-Based Learning (PBL) in schools.....	28
2.4.8	Illustration of Problem-Based Learning Chemistry Examples	34
2.5	21st-Century Skills	36
2.5.1	Why are 21 st -century skills important?	39
2.5.2	How are 21 st -century skills enhanced?.....	40
2.6	Self-Directed Learning (SDL).....	43
2.6.1	Why is SDL important?	44
2.7	Traits of Beginner Physical Sciences Teachers.....	46
2.8	Particulate Nature of Matter (PNM)	49
2.9	Teacher Professional Development (TPD).....	50
2.10	Chapter Summary	53
CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY		55
3.1	Introduction.....	55
3.2	Research Design.....	55

3.3	Philosophical Orientation.....	58
3.4	Data Generation Instruments	61
3.4.1	Open-Ended Questionnaire.....	61
3.4.2	Teacher Professional Development (TPD) programme	62
3.4.3	Portfolio compilation	66
3.4.4	Interviews	69
3.5	Site Selection, Sampling Technique and Sample	70
3.5.1	Site Selection.....	70
3.5.2	Sampling technique and Participants	71
3.5.2.1	Teachers.....	72
3.5.2.2	Learners	73
3.6	Research Methods.....	74
3.7	Data Analysis	76
3.7.1	Open-Ended Questionnaire and Semi-Structured Interviews.....	76
3.7.2	The Portfolio.....	78
3.8	Researcher's Role	80
3.9	Trustworthiness	81
3.10	Ethical Considerations.....	82
3.10.1	Ethical considerations regarding research data.....	83
3.11	Chapter Summary.....	84

CHAPTER 4: PRE-TEACHER PROFESSIONAL DEVELOPMENT RESULTS	
PRESENTATION, INTERPRETATION AND DISCUSSION	86
4.1 Introduction.....	86
4.2 Open-Ended Question Concepts Overview.....	86
4.3 Beginner teachers’ teaching of the PNM.....	87
4.4 Beginner teachers’ knowledge of PBL (definition, process and implementation)	89
4.5 Beginner teachers’ promotion of the 21st-century skills (collaboration, critical-thinking, creativity & communication).....	93
4.6 Beginner teachers’ enhancing of SDL	95
4.7 Chapter Summary.....	98
 CHAPTER 5: RESULTS PRESENTATION, INTERPRETATION AND DISCUSSION	 99
5.1 Introduction.....	99
5.2 Research Question 1	99
5.2.1 Collaboration.....	100
5.2.1.1 Quality of the group process and outcome as a measure of success.....	100
5.2.1.2 Self-Directed Learning (SDL): Responsibility and evidence of interdependence	106
5.2.2 Critical thinking	107
5.2.2.1 Analyse and combine acquired information to develop own interpretations.....	107
5.2.2.2 Ability to connect relevant information and problem-solving.....	110
5.2.3 Communication	111

5.2.3.1	Able to perform interpersonal, written, and oral communication	111
5.2.3.2	Able to be part of the community	112
5.2.4	Creativity.....	113
5.2.4.1	Ability to offer new perspectives, generate novel and meaningful ideas, raise new questions, and come up with solutions.....	114
5.3	Discussion of Results for data presented for Research Question One	115
5.3.1	Collaboration.....	115
5.3.2	Critical-thinking	118
5.3.3	Communication	122
5.3.4	Creativity.....	123
5.3.5	Supposition remarks answering researcher question one	123
5.4	Research Question Two.....	124
5.4.1	Summary of Pre-Teacher Professional Development Results	124
5.4.2	Post-Teacher Professional Development Results	124
5.4.2.1	Content knowledge taught.....	125
5.4.2.2	PBL implementation	126
5.4.2.3	Instructions adapted to meet diverse learners	128
5.4.2.4	21 st -century skills observed.....	130
5.4.2.5	Assessment of learners' work to improve enhancement of 21 st -century skills	130
5.4.2.6	Reflections and professional development.....	131

5.4.2.7	Portfolio scores for each theme for the five teachers determining overall level of proficiency of PBL implementation	133
5.5	Discussion of results for data presented for research question 2 ..	136
5.5.1	Content knowledge taught.....	136
5.5.2	PBL implementation	137
5.5.3	Instructions adapted to meet diverse learners	137
5.5.4	21 st -centrury skills observed.....	138
5.5.5	Assessment of learners' work to improve enhancement of 21 st -century skills	138
5.5.6	Reflections and professional development.....	138
5.5.7	Overall judgment regarding PBL implementation	140
5.6	Research Question 3	141
5.6.1	Culture of learning and personal development	141
5.6.2	Expansion of teaching methodologies.....	142
5.6.3	Enhancement of individual-worth and realisation	142
5.6.4	Confidence and Knowledge integration.....	142
5.7	Discussion of Results for data presented for research question 3.....	142
5.8	Chapter Summary.....	144
CHAPTER 6: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS		146
6.1	Introduction.....	146
6.2	Significance of this research on teaching practice and self-directed learning (SDL)	146

6.3	Summary of Findings	147
6.3.1	Research Question One	147
6.3.2	Research Question Two	148
6.3.3	Research Question Three	149
6.4	Implications of findings to existing literature	149
6.5	Limitations of the study	150
6.6	Recommendations	151
6.6.1	Recommendations for application of this study	151
6.6.2	Recommendations for future study	151
6.7	Conclusions of the study	151
6.8	Reflections on my research journey	152
REFERENCES		154
APPENDICES		178
APPENDIX A: OPEN-ENDED QUESTIONNAIRE		178
APPENDIX B: 21ST CENTURY SKILLS OBSERVED DURING PBL		183
APPENDIX C: INTERVIEW QUESTIONS.....		184
APPENDIX D: INTER-RATER RELIABILITY COEFFICIENTS – FOR TEACHER- BASED ASSESSMENT RUBRIC FOR PBL.....		185
APPENDIX E: INTER-RATER RELIABILITY COEFFICIENTS – FOR OVERALL LEVEL OF PROFICIENCY OF PBL		186
APPENDIX F: EXAMPLE OF INTERVIEW TRANSCRIPT.....		187
APPENDIX G: ETHICS APPROVAL LETTER		189
APPENDIX H: PERMISSION TO CONDUCT RESEARCH		190
APPENDIX I: CONFIDENTIALITY UNDERTAKING		191

APPENDIX J: CONSENT FORM	194
APPENDIX K: ASSESSMENT RUBRIC FOR THE PBL ACTIVITY	197
APPENDIX L: PROBLEM-SOLVING RUBRIC.....	198
APPENDIX M: BEGINNER TEACHERS' PBL PORTFOLIO RUBRIC.....	201
APPENDIX N: TURNITIN REPORT.....	202
APPENDIX O: CERTIFICATE OF LANGUAGE EDITING.....	203

LIST OF TABLES

Table 3.1: Outline of one-day Problem-Based Learning Teacher Professional Development programme.....	67
Table 3.2: A summary of the participants' biographical data	73
Table 3.3: Each participant's number of learners in a grade 10 classroom	74
Table 3.4: Extract from the Physical Sciences ATP 2020 formulated from CAPS	75
Table 4.1: Teaching approaches used by teachers and their justifications.....	87
Table 4.2: Teacher participants understanding of Problem-Based Learning	90
Table 4.3: Beginner teachers' knowledge of PBL process and roles in PNM teaching (stated in verbatim).....	92
Table 4.4: Five 21 st -century skills identified by each beginner teacher.....	94
Table 5.1: Each 21 st -century skill with the theme(s) associated with it	100
Table 5.2: Results from evaluation of the teacher-based assessment rubric for the PBL activity.....	101
Table 5.3: Description of levels on aspects relating to Collaboration	105
Table 5.4: Each beginner teacher's learners' rating	109
Table 5.5: Indicators signifying learners' participation in the learning community	113
Table 5.6: Indicators eliciting how learner creativity was observed on the learner-based rubric	114

LIST OF FIGURES

Figure 2.1: PBL conceptual framework developed by Talat and Chaudhry (2014:96)	15
Figure 2.2: Problem-Based Learning (PBL) process. Adopted from Hmelo-Silver (2004:237)	21
Figure 3.1: Physical Sciences CAPS document extract of PNM	65
Figure 3.2: Demarcation of Ngaka Modiri Molema District	71
Figure 3.3: Saldaña's codes theory model for qualitative inquiry adopted (2009:12).....	77
Figure 4.1: Word-cloud of 21 st -century skills that might enhance SDL as suggested by beginner Physical Sciences teachers	97
Figure 5.1: Graph of scores awarded by each teacher on learners' achievement of PBL process	104
Figure 5.2: Graph showing score for each theme and overall level of proficiency for each of the five teachers	134

CHAPTER 1: INTRODUCTION AND BACKGROUND OF THE STUDY

1.1 Introduction and background

This study focuses on facilitation for enrichment of beginner Physical Sciences teachers to utilise Problem-Based Learning (PBL) while teaching the topic - Particulate Nature of Matter (PNM) which could enhance 21st-century skills such as collaboration, critical thinking, creativity and communication. Chaaban and Du (2017) cite a myriad of problems with beginner science teachers such as commencing their practice without formal induction programmes and taking a full load of work similar to that allocated to experienced teachers, among others. Chaaban and Du (2017) further indicate that there is a great concern over the training and content knowledge of beginner teachers. Davis, Petish and Smithey (2006) state that beginner science teachers have inadequate knowledge of the subjects they teach. This observation is contested by Kaptan and Timurlenk (2012) who state that most science teachers start their practice with some relatively good content knowledge. However, possessing adequate content knowledge does not immediately translate into effective pedagogical content knowledge (PCK) (Rollnick, Davidowitz & Potgieter, 2017). PCK is the teachers' understanding and transformation of the subject-matter knowledge into the teaching and learning situation (Van Driel, Verloop & de Vos, 1998). Coenders and Verhoef (2019) argue that beginner teachers' PCK needs to be developed and expanded. Mavhunga, Ibrahim, Qhobela and Rollnick (2016) contend that there is a significant challenge in improving the quality of PCK amongst the Physical Sciences teachers. This study defines beginner teachers as those with 5 or fewer years of teaching experience. In line with Chabaan and Du (2017), for fewer than 5 years of teaching experience, this study operates from the premise that there is little evidence of mastery of subject-matter by the beginner science teachers and their pedagogic practices lack robust strategies to sufficiently interrogate the Physical Sciences topic of Particulate Nature of Matter (PNM).

The direction of education in the 21st century is to prepare learners for the dynamic and unpredictable world, fostering creative behaviours, giving freedom for unique individual intelligence, and producing innovators by promoting 21st-century skills (Astuti, Aziz, Sumarti & Bharati, 2019). The 21st-century skills are core competencies for learning and creativity that could assist learners in today's ever-changing and globally interconnected world

(Howlett & Waemusa, 2019). The learners must be exposed to real-life problems, encouraged to communicate in and outside teaching-learning situations, collaborate with friends and think critically (Wyness & Dalton, 2018). These skills are required for both learners' academic achievement in Physical Sciences (Hlabane, 2016), and settling and participating in a rapidly changing world (Urbani, Roshandel, Michaels & Truesdell, 2017).

This study identifies the growing need for 21st century science teachers as a worldwide demand, not only in South Africa (Mentz & De Beer, 2019), but also seen in the United States of America (Bustamante, White & Greenfield, 2018). Academic achievements only, are not enough; learners also need to master 21st-century skills (Wan Husin, Mohamad, Othman, Halim, Rasul, Osman & Iksan, 2016). PBL is a viable approach in promoting both academic achievements and the appropriation of 21st-century skills (Kek & Huijser, 2016; Simamora, Sidabutar & Surya, 2017). However, teachers are currently not utilising PBL effectively due to various reasons which include lack of confidence, lack of PBL knowledge, full curriculum load and pressure to complete the prescribed curriculum (De Beer & Petersen, 2016; De Beer, 2017; Pretorius, 2015; Ramnarain & Schuster, 2014).

Loyens, Jones, Mikkers and van Gog (2015:35) define PBL as a teaching approach that is initially aimed at activating learners' prior knowledge, facilitating critical analysis of arguments, and promoting deep understanding of the content. PBL represents a major development in educational practice, exerting an impact on courses and disciplines across the curriculum (Phungsuk, Viriyavejakul & Ratanaolarn, 2017). PBL can be utilised in all disciplines to accomplish an effective and conducive teaching-learning situation (Jing & Luo, 2018). A variety of methods are recommended in promoting 21st-century skills including the deployment of various teaching pedagogies such as Problem-Based Learning (PBL), Project-Based and Inquiry Learning, Technology and Scenarios (Yasmin, Naseem & Masso, 2019; Havenga, 2015a; Barell, 2010). Problem-Based Learning can be used for a variety of topics in science (Loyens, *et al.*, 2015) and this study implemented it in the topic of the Particulate Nature of Matter (PNM) in order to initiate and extend 21st-century skills. The concept of PBL, its various models and processes, are further elaborated in Chapter 2.

It is evident that a Teacher Professional Development (TPD) programme is required to enable beginner teachers to translate the content knowledge they possess into a teachable form. TPD is designed to transform teachers professionally in terms of knowledge, skills, attitudes and

individual actions (Li, Yamaguchi, Sukhbaatar & Takada, 2019; Nguyen, 2019). It is intended to prepare them to meet the learners' development challenges, addressing such development as it pertains to suitability with regards the challenges encountered in the society (Ciampa, 2015). Moreover, providing extra support to the beginner science teachers on the use of PBL to enhance 21st-century skills for the benefit of their learners could help promote Self-Directed Learning (SDL) (El Mawas, & Muntean, 2018; Golightly, 2019). PBL is a teaching approach that promotes SDL (Morris, 2020; Ramli, Muljono & Afendi, 2018; Robinson & Persky, 2020). PBL allows learners to build their knowledge independently (Duda, Susilo & Newcombe, 2019; Naz & Hussain, 2020; Saeid & Eslaminejad, 2017). Ability to build own knowledge independently can be described as SDL, conceptualised as a process of analysing own learning needs, expressing the purpose and selecting accurate approaches for own learning needs by learners (Zainuddin & Perera, 2018). Knowles (1975), argues that SDL has three critical parts, specifically the learner, the teacher and the learning resources; the learning resources in this regard being PBL and the content of the PNM. According to Yasmin *et al.* (2019) SDL is associated with desirable educational outcomes and increased chances of finding a job.

According to the South African curriculum, Physical Sciences is a combination of two subjects which are Physics and Chemistry (Ogegbo, Gaigher & Salagaram, 2019; Samuel & Dudu, 2018). The particulate nature of matter (PNM) is one of the fundamental concepts in science so seminal in understanding subsequent topics in Chemistry. This topic is abstract and presents multiple teaching challenges in the Chemistry component of the curriculum (Harrison & Treagust, 2002; Kirbulut & Beeth, 2013; Pitjeng, 2015). Improvement of science education, including Chemistry, as a component of the broader Physical Sciences curriculum in high schools, requires robust development and appropriation of 21st-century skills (Toulia, Talbi, Moutaabbid & Radid, 2014). This study focuses on the topic Particulate Nature of Matter at the Further Education and Training (FET) phase, Grade 10.

1.2 Problem statement

Afandi, Sajidan, Akhyar and Suryani (2019), submit that teachers have a vital responsibility in developing their learners' 21st-century skills and they may not be ready. According to Cylen and Yiğitalp (2016), teachers fail in encouraging, guiding and promoting 21st-century skills in their learners. Chaaban and Du (2017) lament that the duration of the degree programme at

the university is not enough to equip beginner teachers with the necessary pedagogic skills, culminating in inadequacies in their teaching practices. Moreover, Björk, Stengård, Söderberg, Andersson and Wastensson (2019), Whalen, Majocha and van Nuland (2019) state that the early years of teaching are challenging for teachers as they transition from higher learning institutions into the classroom space. The major problem lies in the hiatus between the training of science teachers and the real classroom practice. The observation is that there is a dire need for the formal induction of beginner teachers into professional development to facilitate the effective teaching of science (Davis *et al.*, 2006; Kaptan & Timurlenk, 2012). Boholano (2017), states that successful teaching and learning emanates from specific strategies used by the teacher, justifying therefore why this study aims to encourage beginner teachers to employ PBL. The higher education institutional programmes are under increasing pressure to ensure that they produce graduates competent enough to develop tangible competencies amongst their learners in the 21st century (Kaufman & Ireland, 2016). There is a recognition that the current teaching approaches do not match the needs of a 21st-century world (Häkkinen, Järvelä, Mäkitalo-Siegl, Ahonen, Näykki & Valtonen, 2017). Christiansen and Bertram (2019) argue that teachers in South Africa do not exhibit sufficiently robust pedagogical content knowledge essential in teaching well. With relevant 21st-century skills gained through appropriate teaching approaches such as problem-based learning (PBL), this might in turn lead to self-directed learning, the focus of this study.

1.3 Significance of the Study

This study contributes to research related to improving Physical Sciences beginner teachers' use of problem-based learning (PBL) in teaching the particulate nature of matter (PNM) to promote 21st-century skills, namely, collaboration, critical-thinking, creativity and communication through workshops and other platforms. It also contributes to science education teaching methods. One aspect that makes this study unique is the promotion of 21st-century skills in teaching a specific topic of the Particulate Nature of Matter. The review of pertinent literature indicates that this is a difficult and challenging area yet to be explored, justifying therefore the undertaking of this study.

1.4 Theoretical and Conceptual Framework

A theoretical framework is an explanatory mechanism which guides the research process (Osanloo & Grant, 2016). Social interdependence theory is the theoretical framework that underpins this study. Social interdependence theory can be defined as shared influence between individuals in a small group (Johnson & Johnson, 1999, 2005, 2009). Similar to problem-based learning (PBL), social interdependence theory is associated with collaboration, small group-learning and cooperative learning. Social interdependence theory produces a two-dimensional realisation, positive (co-operative) and negative (competitive) interdependence (Deutsch, 1949b, 1962; Johnson & Johnson, 2003; Jongman, 2017). Social interdependence theory has three core tenets which may be linked to PBL, namely: psychological processes, group processing skills and social skills, all of which promote interaction (Deutsch, 1949a). This study adopted the PBL conceptual framework developed by Talat and Chaudhry (2014). Based on this framework, PBL has been credited for the promotion of 21st-century skills such as communication, collaboration, critical thinking, and creativity; and, social and personal developments. As a consequence, both 21st-century skills as well as social and personal developments lead to broad student creativity and competitiveness. The theoretical and conceptual frameworks are further discussed in detail and put into perspective in Chapter 2 of this study.

1.5 Purpose of the Study

According to Dudu (2016), teachers are most likely to improve their teaching approaches when they are sufficiently inducted into teacher professional development (TPD) that is aligned to their daily experiences and the content they teach. It is anticipated that participation of beginner Physical Sciences teachers and their full engagement in a problem-based learning TPD training could enhance their full application of PBL and the ultimate promotion of 21st-century skills such as collaboration, critical thinking, creativity and communication for realisation of SDL and academic achievements within their learners. The purpose of this study therefore is to enhance the utilisation of PBL by beginner Physical Sciences teachers in the teaching of PNM.

1.6 Research Questions of the study

The research questions that guide this study are as follows:

1. How can Problem-Based Learning (PBL) be enhanced to equip beginner Physical Sciences teachers in promoting 21st-century skills?
2. To what extent do beginner Physical Sciences teachers use Problem-Based Learning (PBL) in initiating and promoting 21st-century skills before and after a Teacher Professional Development (TPD) programme?
3. What Problem-Based Learning (PBL) principles of practice could be distilled for beginner Physical Sciences Teacher Professional Development (TPD) towards Self-Directed Learning (SDL)?

1.7 Delimitations of the Study

This study's delimitations are Problem-Based Learning (PBL) approach, beginner teachers of Physical Sciences, topic-specific Particulate Nature of Matter (PNM) in Grade 10 Chemistry, and the geographic area of the North-West Province, Ngaka Modiri Molema (NMM) district. This study is designed to establish and promote 21st-century skills that inform and enact Self-Directed Learning (SDL).

1.8 Explanation of keywords and phrases

Problem-Based Learning (PBL): According to Barrows 2015:251), PBL is “the learning that results from the process of working toward the understanding or resolution of a problem.” PBL commonly commences with an unstructured problem that has more than one answer which learners have to find collaboratively in groups. In this study, PBL is operationalised as a process where one group starts with a real-life or content-based ill-structured problem to achieve learning objectives.

Beginner Physical Sciences teachers: These are teachers with little experience in PCK; often teachers who have less than 2 years of teaching experience (Mahmoudi & Özkan, 2015). Beginner teachers have only recently started teaching Physical Sciences such that they have 5 years or less but possess relevant teaching qualifications such as a Bachelor of Education (B. Ed.), Post-Graduate Certificate in Education (PGCE).

Particulate Nature of Matter (PNM): The particulate nature of matter is a central topic in both primary and high school sciences curricula. PNM covers a range of phenomena such as states of matter, phase changes, properties of substances and kinetic molecular theory (Özmen, 2011; Harrison *et al.*, 2002; & Merritt, 2010). PNM is taken in this research report as a study of atoms (matter) that include illustrations such as representations, symbols and graphs.

21st-century skills: These are core competencies for learning in today's digitally and globally interconnected world (Howlett & Waemusa, 2019). The 21st-century skills in this study include collaboration, critical thinking, creativity and communication. This study concurs with Ongardwanich, Kanjanawasee and Tuipae (2015) that the 21st-century skills help learners become lifelong initiates who adapt to developments and enquiry all the time.

Self-Directed Learning (SDL): It is a process of analysing own learning needs, expressing the purpose for such learning and selecting accurate approaches for own learning needs by the students (Zainuddin & Perera, 2018). This study conceptualises SDL as the result of enhanced 21st-century skills where the learners collaborate and take charge of their own learning, think critically to solve problems. In the ultimate design, SDL allows learners to be creative and communicate with one another.

Teacher Professional Development programme (TPD): This is a structured professional learning activity that aims to alter and transform teachers' practices such that learning improves (Darling-Hammond, Hyler & Gardner, 2017; Bates & Morgan, 2018). This study identifies TPD as a launchpad for the beginner Physical Sciences teachers getting the necessary support for their appropriation and effective utilisation of PBL in the teaching of PNM.

1.9 Chapter Summary

Chapter 1: Introduction and background of the study – this chapter serves as orientation to the problem of the study. It covers the background, statement of the problem, purpose of the research, research questions, significance of the study, keywords and clarification, and chapter summary of the study.

Chapter 2: Literature review and theoretical framework - undertakes to examine and review the key theoretical constructs informing the study, including recent and relevant literature that is analysed critically.

Chapter 3: Research Design and Methodology - This chapter outlines and describes the methodology used to achieve the objectives of the study under the following topics: Research Design and Methodology, site, Participant selection, Data collection strategies, Data analysis, Trustworthiness, Researcher's role and Ethical considerations.

Chapter 4: Pre-Teacher Professional Development Results Presentation, Interpretation and Discussion - The results of data from the pre-professional development data are presented, interpretations and discussions are made.

Chapter 5: Results Presentation, Interpretation and Discussion – Presentation and discussion of data from participants obtained through the portfolio and interviews is reported in this chapter in relation to the research questions and literature.

Chapter 6: Summary, Conclusions and Recommendations – Conclusions and recommendations based on the results of the study are presented in this chapter. This chapter summarises the study with reference to the initial objectives as well as findings and recommendations proffered.

CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

The key terms, recent and relevant literature used in this study are explored in this chapter. The exploration captures a literature survey of contemporary practices in Problem-Based Learning (PBL). Logically, this examination of concepts culminates in the terms being operationalized. The major terms explored and operationally defined are: Problem-Based Learning (PBL), beginner teachers, Teacher Professional Development (TPD), Self-Directed Learning (SDL), 21st-century skills, and social interdependence theory. As this study is topic specific, the literature of the aforementioned concepts is discussed with reference to the teaching and learning of Particulate Nature of Matter (PNM), a topic in Chemistry. In addition, analysis of some major concepts regarding the theoretical and conceptual frameworks underpinning this study are interrogated.

2.2 Theoretical Framework

A theoretical framework constitutes the substance and knowledge foundations of a research study (Osanloo & Grant, 2016). Social interdependence theory underpins this study. Problem-Based Learning (PBL) is one of the learning approaches whose foundations are premised on the social interdependence theory (Torre, Vleuten & Dolmans, 2016). Given that tenets of PBL are aligned to the broader philosophy of the social interdependence theory, this study incorporates the former as a conceptual construct of the latter theory.

Formally coined by Deutsch (1949a) for the effect of co-operation and competitiveness upon small group functioning, social interdependence theory is defined by Johnson and Johnson (1999, 2005, 2009) as shared influence between individuals in a small group. Social interdependence theory is primarily associated with collaboration, small group-learning and cooperative learning. “Proving that cooperation could lead to effectiveness and efficiency is important for its real-world application” (Jongman, 2017:2). There is reported success of social interdependence theory when implemented in education (Slavin, 1988; Johnson & Johnson, 1974; 2009). This study utilised the small group learning approach with participants during its problem-based learning teacher professional development intervention programme

and problem-based learning classroom implementation to achieve its purpose by taking a leaf from Johnson and Johnson's (2009) pronouncement of the success of social interdependence theory in the field of education.

When applying the social interdependence theory, teachers ought to see a teaching-learning situation in terms of six principles:

- 1) Knowledge is constructed and extended by learners;
- 2) The learners are actively involved in constructing their own knowledge;
- 3) The teacher's effort must be aimed at developing and enhancing learners' skills;
- 4) Education is a personal transaction among the learners, between the learners and the teacher and work given;
- 5) Creating a conducive and cooperative atmosphere facilitates active mastery of concepts;
- 6) Considerable teacher training and continuous refinement of skills and procedures (Johnson, Johnson & Smith, 1995).

These six principles were infused in this study during the PBL classroom implementation and PBL TPD intervention. Learners had to construct knowledge by actively participating and deciding on their learning objectives and material with teacher's guidance which in-turn might have enhanced 21st-century skills within them. Extending the work of Johnson, Johnson and Smith, Jongman (2017), further identified several assumptions surrounding social interdependence theory namely; group structure, the rationality assumption, pure form, group size, the internal motivation, historical relations and equal power distribution. These assumptions were considered during both the PBL TPD intervention programme and implementation in the classrooms while teaching particulate nature of matter.

The exploration of the schools of thought regarding the core model of social interdependence theory produces a two-dimensional realization. First, positive interdependence (co-operative) and on the other hand, negative interdependence (competitive) (Deutsch, 1949b, 1962; Johnson & Johnson, 2003; Jongman, 2017). Positive interdependence exists when one member's actions foster the other member's goals to reach common goals in a small group (Johnson & Johnson, 2019). Each member in the group assumes a key role such that the success of the group work is based on whether everyone succeeds in their role (Li, 2017; Johnson & Johnson, 2019). Li further states that each member's responsibilities in the group increase since individual work influences overall group work success. In laymen's terms,

there is equitable division of labour in the small group. An examination of the social interdependence theory that has been described so far precipitates a broad concept of self-directed learning (SDL). To Torre *et al.* (2016), SDL originates from a group activity – a phase in the PBL process that is closely related to group learning, social interdependence, collective knowledge creation, achievement of group goals and can strengthen positive interdependence. Johnson and Johnson (2009) submit a few conclusions emanating from positive interdependence which are: increased achievement and greater productivity; motivates and individuals and develops new insights and more use of higher-level reasoning strategies; more willingness to work; and better collaborative and cooperative skills.

In contrast, negative interdependence occurs when one group member's actions impede the attainment of joint goals in a small group. Negative interdependence acknowledges that learners working in a small group do not always approach a given task collaboratively and may instead view it as competition (Haartman, 2017).

“Negative interdependence exists when there is a negative correlation among individuals' goal achievements; individuals perceive that they can obtain their goals if and only if the other individuals with whom they are competitively linked fail to obtain their goals” (Johnson & Johnson, 2009:366).

Conversely, competition can either be *destructive* where an individual or one group can be right or wrong or *constructive* where no group member or whole group is right or wrong (Deutsch, 2011). It is difficult to dismiss competition since it exists in real life day-to-day activities. Roseth, Lee and Saltarelli (2019) attest that different social interdependence results in different social interactions. There is a possibility of no-interdependence which occurs when individuals work independently instead of working together in a small group with shared responsibilities; where individuals abandon collaboration and cooperation with others (Johnson & Johnson, 2009).

This study sees less to no room for no-interdependence since its focus is on Problem-Based Learning (PBL). This finds support in the delineation of social interdependence done by Jongman (2017) who suggests that only positive and negative social interdependence are relevant to this theory since no-interdependence leads to no interactions. This study is therefore significantly influenced by positive interdependence. PBL implementation demands that every individual within a group is expected to contribute towards a common goal. In

playing the devil's advocate, this study does not abandon the possibility of negative interdependence where learners compete within the small group and between the groups for better understanding and presentation of the solution on the PBL problems set. Furthermore, there could also be positive social interdependence groups, negative social interdependence groups and no-interdependence groups within a PBL. Social interdependence theory guides this study by presenting how the use of PBL may be enhanced to promote 21st-century skills by beginner Physical Sciences teachers in selected South African schools while teaching PNM.

It is logical that in attempting to explicate the core tenets of social interdependence theory outlined by Deutsch (1949a) which may be linked to use of PBL in the classrooms by the beginner teachers, a description be given of each one of the core *namely*: psychological processes, group processing skills and social skills, and positive interaction. The **psychological processes** that may result from positive interdependence are substitutability, inducibility and positive cathexis (Deutsch, 1949a). *Substitutability* is defined as the feelings of responsibility and accountability of each member in a small group towards common goals (Albarracin, 2019). *Inducibility* is the willingness of all members to show openness in the relationship to influence one another (Albarracin, 2019). *Positive cathexis* is the mental energy and positive attitude invested in the group relationship to enhance the well-being of all group members (Deutsch, 1949a). These psychological processes were considered in this study since each member within the group had certain a role to play and responsibilities during PBL. Furthermore, teachers were expected to enable learners undertake to search for relevant solutions with a positive attitude and working with one another cooperatively during the teaching and learning process.

Group processing skills and social skills allow group members to assess individual contributions and promote their 21st-century skills in order to achieve the group goal (Li, 2017). To promote group processing, beginner teachers need to use PBL to allow members to discuss, to share, and to reflect upon ideas (Li, 2017:220; Rovers, Clarebout, Savelberg & van Merrienboer, 2018). "It is important for individuals in the group to gain social and interpersonal skills because it will allow the most effective functioning of the group" (Torre *et al.*, 2016:190). Interaction and cooperation could enhance both the interpersonal and social skills in a small group when engaged with each other on a specific task (Tran, Nguyen, Van De, Soryaly & Doan, 2019). To Johnson and Johnson (2009), it is in this tenet that group

members are expected to show respect for each other's efforts and contributions to achieve a common goal. These skills are the key components of social interdependence theory as they guide the individual development for a sustained relationship within a group (Sukrajh, 2018). Participating teachers in this study were encouraged to implement this tenet of group processing skills and social skills during teaching and planning sessions during the PBL TPD programme.

Torre *et al.* (2016:190) allude that, **promotive interaction** is “when individual members in the group facilitate the accomplishment of the goals of the group.” According to Li (2017), promotive interaction occurs in a face-to-face manner and encourages direct interaction with each other. It contributes to achieving group goals and personal development. Individuals within a small group achieve a promotive interaction by trusting and being trustworthy, communicating information, supporting one another, being motivated, advocating efforts, having low anxiety and stress levels, influencing each other's efforts, providing feedback and challenging one another's reasoning and conclusions. This could enhance the 21st-century skills which this study aimed to engender in the learners through teachers' instructional methods. In addition, during the face to face interaction, individuals support each other in order to achieve the group's shared goals (Tran, *et al.*, 2019).

Social interdependence theory also provides the context in which motivation takes place (Johnson & Johnson, 2003). According to Johnson and Johnson, motivation inherently occurs within a network of interpersonal relationships. Additionally, Johnson and Johnson (2003:140) states that “the latter is reflected in (1) the positive interdependence between one's goals and the goals of others (i.e. when one person takes action to achieve his or her goals, the likelihood of other people in the situation achieving their goals is affected); (2) other individuals observing and reacting to a person's attempt to achieve goals; and (3) the person being cognizant of other people's actual and potential reactions to his or her immediate and long-term attempts to achieve goals.” According to Van Mechelen, Zaman, Laenen, Abeele and Gielen (2014), the way in which interdependence is structured determines how group members interact resulting in the outcomes of the situation. Social interdependence theory maintains that when group members' goals are aligned, motivation increases and achievement improves as group members interact with each in ways that promote each other's success (Cockerill, Craig & Thurston, 2018). The most salient construct emanating from this section is that of collaboration.

Collaboration is one of the 21st-century skills this study aims to promote, and it is one main aspects to learning in PBL which makes intensive use of the concept of Zone of Proximal Development (ZPD). Vygotsky (1978:33) defines ZPD as “the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers.” The two main processes which facilitate the development of ZPD in the PBL approach are group-work and the feedback where both the facilitator and the learners are involved (Ansarian & Teoh, 2018). These two processes are categorised by Vygotsky (1978) as the level of potential development, which is realised when a learner is capable of problem-solving with the guidance from the teacher (facilitator) or collaboration with capable learners (group members). In other words, this level requires the teacher to employ an approach that allows the learner to learn through collaboration from others and guidance from the teacher – advocated through PBL in this study. The other level outlined by Vygotsky (1978) is the level of actual development where a learner’s capability of problem-solving is without the guidance from the teacher or collaborating with other learners. The level of actual development is not discussed in this study as it goes beyond the delimitation of this study. Within the ZPD the learner’s learning is scaffolded through mediation from the teacher (considered to be more knowledgeable) (Vygotsky, 1978).

Johnson and Johnson (2009) declare that social interdependence theory can guide an effective practice because it has sufficient precision and effective procedures for practitioners to use. Furthermore, Johnson and Johnson suggest that teachers should invest in understanding this theory because it provides them with a framework to organise what they know about cooperative learning, to guide their practices, and to integrate their new knowledge. From such benefits, this study adopted the social interdependence theory as a framework. Details on how the theory’s tenets are aligned and were utilised in this study are explicated in the following sections. The next section focuses on the conceptual framework which outlines constructs used in this study.

2.3 Conceptual Framework

According to Johnson and Johnson (1989, 2003), the basic foundation of social interdependence theory is that the way in which interdependence is structured determines

how individuals interact with one another and the situation or content to reach their outcomes. It is difficult to evaluate this interaction of individuals without exploring the area of problem-based learning. PBL is focused on enhancing group performance and effectiveness, fostering cooperation among learners, therefore, it is impossible to discuss PBL without interrogating the associated construct of cooperative learning. This study adopted the embedded PBL model (see Figure 2.1) developed by Talat and Chaudhry (2014:96) as a facilitation strategy where Physical Sciences beginner teachers engage in the topic of Particulate Nature of Matter (PNM) to enhance 21st-century skills. Although the framework by Talat and Chaudhry was based on Project-Based Learning, different authors (Swart & Havenga, 2019; Savery, 2019; Barneveld & Strobel, 2020) posit that both Problem- and Project-Based Learning share significant similarities. However, this framework upholds Problem-Based Learning (PBL).

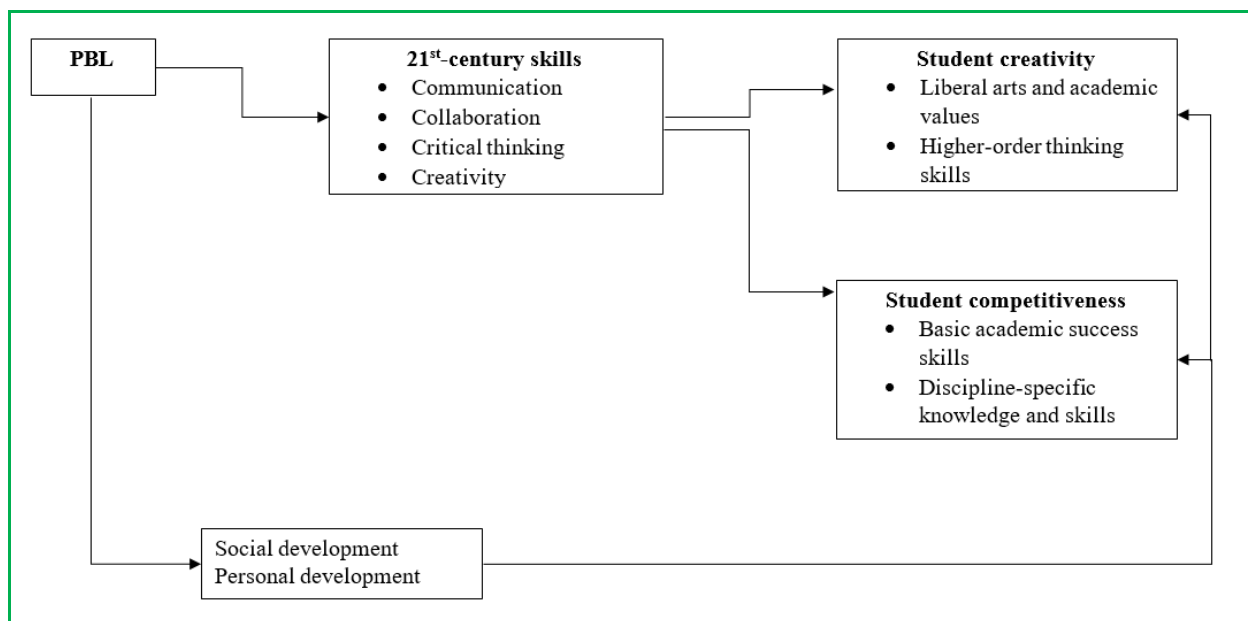


Figure 2.1: PBL conceptual framework developed by Talat and Chaudhry (2014:96)

Figure 2.1 outlines the conceptual framework where PBL leads to the promotion of 21st-century skills, namely: communication, collaboration, critical thinking, and creativity (Hidayati, Zubaidah, Suarsini & Praherdhiono, 2019). Rusmansyah, Yuanita, Ibrahim, Isnawati, Rizkiana and Kusuma (2020) state that PBL is capable of improving students' 21st-century skills including social and personal development. Talat and Chaudhry (2014) define *social development* as the ability to interact with others. By extension, *personal development*

is the ability to differentiate one's understanding from those of others in a group. As Oyibe, Edinyang and Effiong (2015:57) hint that critical thinking is not “hard” thinking but a personal development. In-turn, the 21st-century skills may result in students' creativity and competitiveness. *Students' creativity* includes benefits such as liberal arts (conceptual content or discipline understanding) and academic values; and promotion of higher order thinking. Jing and Tong (2018) concur with Talat and Chaudhry by mentioning that PBL improves learners' higher-order thinking, application of knowledge and motivation to learn. In the same vein, De Beer and Gravett (2016:42) extend this point and suggest that “developing critical thinking higher-order cognitive skills such as analysis, synthesis and evaluation” are most desirable. *Students' competitiveness* includes benefits such as educational success, and robust subject-matter knowledge. These traits and skills are anticipated from PBL approaches if properly implemented. One approach to properly implement PBL is group-work which may result in competitive learning, in-turn enabling completion of tasks successfully for the benefit of the group, for the enhancement of individual-worth and contributing to support within the group are then some of the factors that make competitive learning a constructive and useful process (Torre *et al.*, 2016). During collaboration, team members support one another and enhance one another's understanding (Havenga, 2018a). The above description knits the constructs which address the demands of the research questions posed in this study.

2.4 Problem-Based Learning

Yusof, Hassan, Jamaludin and Harun (2012) point out that PBL was originally coined as a response to medical education issues. However, Ansarian and Teoh (2018) argue that PBL was practiced long before it was even known as a “scientific” approach. When PBL was recognised as a “scientific” approach, Dewey was one of the leading proponents for an approach which could give learners the opportunity to reflect on their daily real-life experiences (Ansarian & Teoh, 2018; Delisle, 1997). This approach was PBL. Rifandi and Rahmi (2019) postulate that any learning approach that is given to learners should provide the skills needed in the 21st century. The Faculty of Health Sciences at McMaster University in Canada are pioneers of PBL who championed this approach in their curriculum in 1969 (Lee & Kwan, 2014; Savery, 2015; Havenga & Van Wyk, 2017, Servant-Miklos, 2019; Savery, 2019; Servant-Miklos, Woods & Dolmans, 2019; Servant-Miklos, Norman & Schmidt, 2019). The McMaster University believe that the students should be presented with the problem first, encouraging them to be hands-on in the teaching-learning process (Ansarian &

Teoh, 2018). PBL is implemented by many medical schools to promote problem-solving, critical-thinking and SDL (Kamin, O'Sullivan, Younger & Deterding, 2001). In this way, PBL is an innovative self-directed collaborative approach to learning which enables learners to apply their different skills working in small groups.

Literature is replete with definitions of PBL. For example, Overton and Randles (2015:251) defines PBL as “the learning that results from the process of working toward the understanding or resolution of a problem.” They extend this definition of PBL and argue that it commences with an unstructured problem that has more than one answer which learners collaboratively resolve. As mentioned earlier, learners collaboratively and cooperatively work in small group to achieve a common outcome. According to Jayaram (2013), given that learners work in groups during PBL, cooperative learning is involved. Saka and Kumaş (2009:1328) state that “while education process is carried out by PBL based application in cooperative groups; cooperative learning-based stages should be taken into account for the grouping and task sharing in terms of researching and implementing together within PBL.” Rovers *et al.* (2018:416) define PBL as follows: “Problem-Based Learning is a comprehensive educational approach that is based on cognitive theories of learning and has continued to be important in education curricula across the world.” To Loyens, Jones, Mikkers and van Gog (2015:35), PBL is “a teaching approach that is initially aimed at activating learners’ prior knowledge, facilitating critical analysis of arguments, and promoting deep understanding of the content.” In this study, PBL is operationalised as a process where one/group starts with a real-life or content-based ill-structured problem to achieve learning objectives. It is difficult to achieve learning objectives in PBL without cooperative learning. Another definition by Jonassen (2011), Havenga and Van Wyk (2017), submits that PBL is an instructional methodology that is: problem focused; student-centred; self-directed; and self-reflective with teachers as facilitators. Jonassen (2011) further states that during PBL approach, learners are required to have a problem-solving skill. However, Wood (2003:328) argues that “PBL is not about problem solving per se, but rather it uses appropriate problems to increase knowledge and understanding.”

A common denominator from the definitions of PBL given so far align with Yew and Goh’s (2016) view who see PBL as a worthier and more potent teaching strategy to train educational practitioners and to promote long-term retention of knowledge and skills.

Havenga (2018a:262-263) validates this observation and states that “PBL has the potential to foster active learning, supports knowledge construction and is useful for developing crucial employability skills”, attributes which one may see as the 21st-century skills. Furthermore, Havenga (2018b) suggests that learners working in groups for the first time may encounter challenges such as time constraints, problems with communication and staying focused. However, communication is a skill that if acquired, lowers conflicts within a group (Havenga, 2015a:151). Against this assertion, Golightly and Raath (2015), argue that PBL may enhance 21st-century skills by suggesting that learners during PBL take ownership of their learning, select and apply their own learning resources, discuss the information within their groups, and reflect on their solving the problem skill process. This section of definitions maybe summed in stating that though there are diverse definitions of PBL cited in literature (a few proffered above), one can infer that most of the definitions slightly differ in semantics but bear the same ideas and principles.

2.4.1 PBL formats (pure PBL, hybrid PBL, integrated PBL and embedded PBL)

According to Golightly (2016), there is little information available in literature regarding the scope of use of pure PBL, hybrids PBL and integrated PBL in science education courses and curricula. This resulted in this study consulting literature from other disciplines such as health and engineering sciences. There are “various PBL models emerging from the McMaster University PBL model which organise teaching and learning elements differently” (Baresh, Ali & Darmi, 2019: 11).

To Baresh *et al.* (2019), there are two formats of PBL namely, the pure and hybrid formats. The pure PBL model refers to the one implemented in fully problem-based methodology and based on the McMaster Medical School PBL model. The implementation of pure PBL model is generally without any lecturers or tutorial sessions, and students typically work in small groups. On the other hand, the hybrid PBL model is, embedded within lecturers and tutorial sessions to support students’ learning. The hybrid PBL model is an integration of the pure PBL and traditional approaches (Baresh *et al.*, 2019). The hybrid PBL model is utilised to enhance the learners’ understanding of the lecture content materials. According to several authors (see, for example, Lim, 2012; Bachtiar, Zubaidah, Corebima & Indriwati; 2018; Tortorella & Cauchick-Miguel, 2019; Servant-Miklos *et al.*, 2019), the hybrid PBL model effectively integrates teacher-centred approach, laboratory sessions, and other instructional

activities into the active PBL discussions in various curricula outside of medicine. To Tan and Shen (2019), the hybrid model PBL approach is developed in a way which incorporates both the traditional teacher-centred and the pure PBL approaches, hence the term *hybrid*.

Regarding the integrated PBL, a plethora of authors (see for example, Ibrahim, Arshad & Rosli, 2015; Ibrahim, Arshad, Rosli, Nurbiha & Shukor, 2017; Dawilai, Kamyod & Prasad, 2019); Ibrahim & Jamaludin, 2019) see this as an approach supported by online technology whilst discussing problem-based blended learning (PBBL). Dawilai *et al.* (2019) argue that technology has become a part of learners' daily lives including learning, as a result, technology enhanced learning is important for learners since they have more choices to communicate and work with one another through technology like mobile application and web-based technology. In order to solve the problem provided, learners are permitted to work across distances by employing online technology such as group chat, video conference, web-board, group post, and blog. "This approach has three components: the mentor or teacher, online learning materials, and the skills developed during the classroom experience" (Dogan, 2017:102). It is argued that PBBL provides learners with the learning space anytime suitable and at one's own place of comfort.

The embedded PBL is another model that can be adopted in various disciplines, however, there is a limited literature regarding this model. Botelho (1999), discuss the embedded PBL model as one that can be implemented in a course for a short while for a particular intention and returning to usual approaches. The learning principles for embedded PBL is similar to that of other models. During the embedded PBL, continuous assessment is used to evaluate learners' contribution and participation; learners' collaboration, communication, critical and creative skills and feed-back sessions. From the descriptions given above, this study adopted the embedded PBL model for the reason that it can be implemented for only a few lessons for a specific purpose. In this study, PBL was embedded in the few Chemistry lessons to promote the 21st-century skills for SDL by beginner teachers in the teaching of PNM confronting learners with problem scenarios. Post a short curriculum-based PBL implementation, the teachers may continue with using PBL to teach various topics in their physical sciences classrooms or return to their usual approaches respectively.

2.4.2 PBL process

“In the PBL process, an ill-structured, real-world problem (one to which there are many possible solutions) is presented to the students first” (Petersen, Golightly & Dudu, 2019:154). PBL is a teaching methodology that primarily begins with a problem where a group of 4-6 learners should solve with the help of the tutor facilitating group learning (Moutinho, Torres, Fernandes & Vasconcelos, 2015; Havenga & Van Wyk, 2017; Weiss & Belland, 2018). The PBL process further proceeds to introduce and explain concepts on the subject matter where ill-structured problem statement is introduced in the form of a real-life situation to be solved by the learners (Abbey, Dowsett & Sullivan, 2017). The introduction of ill-structured real-life problem of PBL makes it a significant approach, for example in a Chemistry classroom given that it allows the learners to be involved and participate rather than silently learning facts from the teacher and the few active learners. Suastra, Suarni and Dharma (2019) maintain that the problems during PBL approach can train and develop critical thinking skills and learning autonomy. This approach’s emphasis on the teamwork is designed to boost learners’ 21st-century skills, thus fostering self-directedness. Real-life problem-solving creates the foundation in which learners can engage in self-directed learning by collaborating and communicating (Stehle & Peters-Burton, 2019). Collaboration and communication are 21st-century skills important to a successful deployment of knowledge construction and real-life problem-solving. This study finds PBL to be what Grimus (2020) calls an open-minded approach from the teacher in the promotion of critical and creative thinking. The learners work together to plan and discuss the solutions through a seven-step method, namely: (1) defining concepts in the problem, (2) delineating and defining the problem, (3) analysing problems, (4) looking for explanations, (5) formulating learning objectives or issues, (6) searching additional information, and (7) preparing a report that provides a solution (Bilbao, Varela, Rebollar, Bravo & García, 2018).

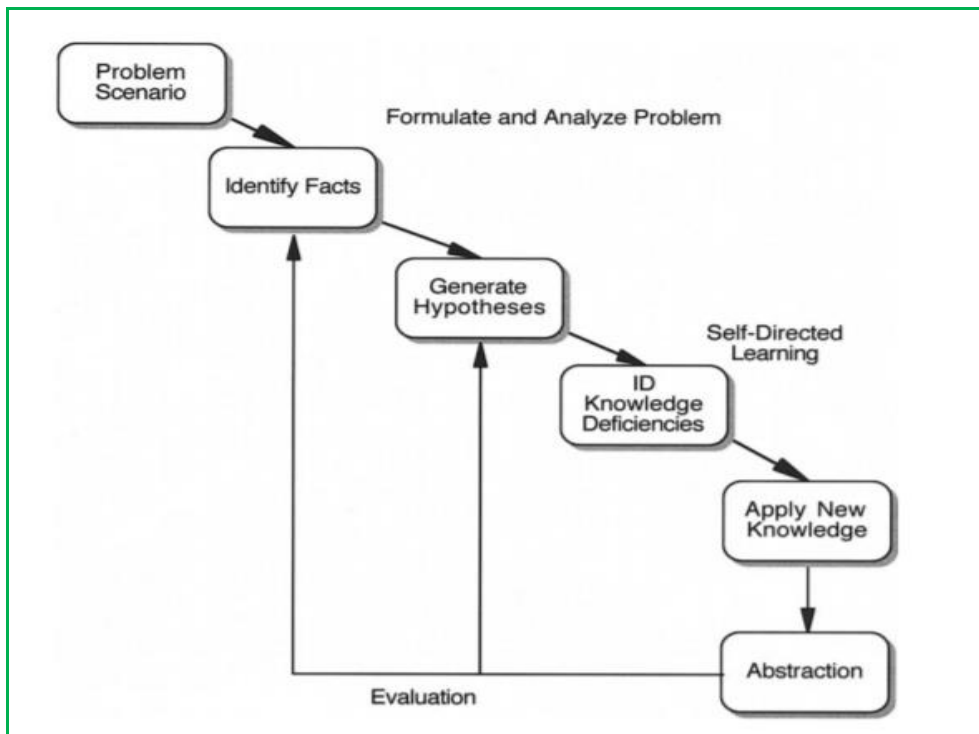


Figure 2.2: Problem-Based Learning (PBL) process. Adopted from Hmelo-Silver (2004:237)

As shown on Figure 2.2, in the second step the learners begin to evaluate the problem in order to generate ideas for possible solutions where each learner is expected to contribute. The following step involves formulating learning issues/objectives for SDL, researching and filling-in gaps in knowledge through SDL, and finally sharing findings within a group submitting possible solutions to the problem. It is from this point that the learners are afforded with collaboration, one of the skills this study ought to promote. During the PBL approach implementation, traditional lectures are either totally eliminated or reduced in order to allow SDL (Tan & Shen, 2019). Ansarian and Teoh (2018) argue that the problem should be designed at the learners' level and according to the learners' ability to boost their confidence and motivation. Working co-operatively within a group provides the learners with various learning opportunities, such as the ability to actively communicate, critical thinking and analysing (Ansarian & Teoh, 2018). PBL is designed with several goals to help students: construct an extensive and flexible knowledge base; develop effective problem-solving skills; develop self-directed, lifelong learning skills; become effective collaborators; and become intrinsically motivated to learn (Hmelo-Silver, 2004:237), as outlined in Figure 2.2 (the PBL process).

2.4.3 Role players in PBL (facilitator, group leader, scribe & group members)

During implementation of PBL learners are required to assume full responsibility for their own learning within their groups in collaborating, researching, communicating and independent study (Abbey, Dowsett & Sullivan, 2017:62, Johansson & Svensson, 2019). PBL encourages the learners to engage in one of active learning strategies such as Self-Directed Learning (SDL) (Ali, 2019). This implies that the roles of both the teacher and learners should be clearly defined.

Teacher's role:-During PBL, the teacher's role is to facilitate collaborative knowledge construction in the learners within their groups (Ansari, Rahman, Badgujar, Sami & Abdullah, 2015; Dolmans, Wolfhagen & Ginns, 2010). The role of the teacher is to coach, encourage thinking and inquiry for the deeper levels of understanding (Etherington, 2011; Plucker & Nowak, 1999). The teacher is the facilitator and responsible for designing and identifying problems that are complex and vague thus encouraging the learners in a group to inquire about them (Ali, 2019). As the facilitator, the teacher must coach the learners to work in their respective groups collaboratively.

Hmelo-Silver and Barrows (2015) suggest that the interventions of the PBL teacher as the facilitator should diminish as the learners' progress into taking responsibility of their own learning. During the PBL lesson, facilitator asks probing questions that foster critical thinking and application of prior knowledge (Ayyildiz & Tarhan, 2018). Furthermore, the facilitator promotes learning and critical-thinking by modelling good learning and reasoning strategies such as leading learners to of the range of questions they should be asking themselves (Hmelo-Silver & Barrows, 2015); Hmelo-Silver, Bridges & McKeown, 2019). As mentioned earlier, during PBL implementation in the classroom the teacher facilitates learning amongst small groups putting responsibility on the learners. The teacher walks around the classroom, observing learners' interactions and asking probing questions.

Learners' roles within a PBL group:-The learners work in small cooperative groups (Baran, 2016). Learners take up different roles such as being the group-leader, scribe and only group member; however, each member in the group has an opportunity to present the solution to the rest of the group with the supporting material. According to Ansari *et al.* (2015), groups may choose a leader who makes decisions if the group struggles to reach a

consensus or may use a democratic strategy where decisions are made by majority vote. Learners are required to do the research and generate reasonable solutions and conclusions (Ali, 2019). During PBL, learners are active participants solving the problems, self-directed in structuring their own learning, and develop the 21st-century skills (Cilen & Yiğitalp, 2016). The learners are required to ask questions and express opinions, search for relevant information in order to effectively solve the problem (Suastra *et al.*, 2019).

2.4.4 Advantages of PBL

According to Koh and Chapman (2019:75), “PBL is an effective pedagogical approach that enhances authentic learning and development of disciplinary knowledge and professional competence (critical thinking, creativity and innovation, complex problem solving, self-directed learning, collaboration, and communication) from the school level (kindergarten-grade 12) to the tertiary level.” Wood (2003), adds that PBL facilitates acquisition of content knowledge, communication, teamwork, problem-solving, independent responsibility for learning, sharing information, and respect for others. The students taught through PBL approach exhibit better understanding of Chemistry concepts, better attitude towards learning Chemistry and prove to have acquired critical thinking and problem-solving skills (Ayaz, 2015; Awan, Hussain & Anwar, 2017). According to Plucker and Nowak (1999), implementation of PBL should encourage critical thinking. It is submitted here that one of the greatest benefits of PBL implementation is improvement of learners’ real-life problem-solving skills. One other benefit of PBL approach related to ill-structured real-life problem is suggested by Gonzalez (2019) who states that the PBL approach increases learners’ motivation. Baran (2016:289) states that “PBL helps students to use their transferable skills, such as intra-group and inter-group communication, delivering presentations, problem-solving, reporting, and self-regulated learning.” Gilbert and Afonso (2015:124) assert that “successful implementation of approaches that focus on using problems, scenarios and real-life events ought to improve learners’ life-long learning.” Benefits emerging from the application of PBL include: enhanced skills to search relevant information, involving the real world in a learning situation, encouraging and motivating learners to learn, encouraging learners to be responsible for the development of other skills and attribute, learning and retaining information better and longer, higher academic achievement, and improved 21st-century skills (Nariman & Chrispeels, 2016; Dmitrenko, 2017; Ali, 2019). Ali further posits that critical thinking, problem-solving, and communication are generated from PBL. These

are some of the skills that this study strives to promote as the 21st-century skills cited in the literature.

Ceker and Ozdamli (2016) suggest that PBL has both advantages and disadvantages in different disciplines such as Medicine and Chemistry among others. In Chemistry, the advantages of PBL include: “assistance to develop teamwork skills within groups; assistance to develop problem solving skills; promoting long-life learning and remembering; help to build individual learning skills; help to achieve collaborative learning skills; help to build positive motivation; helps learners to build communication skills; and that PBL helps learners increase their skills of using resources” (Ceker & Ozmalı, 2016:198). One school of thought posits that learners taught through PBL possess several positive attributes such as integrating knowledge, addressing problems, interpreting and evaluating more objectively than those taught through traditional methods (Krenik, 2014). The argument further states that PBL has many desired outcomes that teachers seek such as learners that are resourceful in addressing problems, self-directed learners, improved scores, and enhanced knowledge application. To Ali (2019), Wood (2008), learners taught through PBL become actively involved in a teaching-learning situation and can deal new situations and develop life-long learning skills. Ansari *et al.* (2015) concurs, the PBL approach promotes meta-cognitive skills, learning responsibilities, life-long learning and SDL amongst the learners. Stihle and Peters-Burton (2019) links the advantages to 21st-century skills and argues that placing learners to work in groups, providing peer feedback, and having learners solve a problem for a particular situation provides opportunities for learners to practise 21st-century skills. It is evident that there are myriad benefits associated with PBL. Considering that this study aims to enhance beginner teachers’ use of PBL in teaching the PNM, PBL benefits that are of interest are promoting the 21st-century skills, thus, affording SDL amongst the learners.

2.4.5 Disadvantages in PBL

Ansarian and Teoh (2018), Hung (2011) mention that one of the main challenges of implementing PBL is formulating or/and defining the learning problem to engage the learners. Joham and Clark (cited by Johansson & Svensson, 2019) identify one of the challenges of PBL as the struggle in providing instruction design and tools that support some of the 21st-century skills such as creativity and critical thinking to achieve SDL amongst the learners. PBL places significant responsibility and accountability equally on both the teacher (facilitator) and the learners (Ayyildiz & Tarhan, 2018). Some of the challenges with the

implementation of PBL include groups finishing their task earlier or later, requirement of rich learning material, difficulty of implementation in all classes since it requires learners to understand the scope of the problems with social content, and difficulty to assess learning (Tandogan & Orhan, 2007). Some of the disadvantages mentioned by Wood (2008) are: PBL may be inefficient with larger numbers of learners in a classroom; formulation of the problems; and facilitator's lack of control. The disadvantages of PBL in Chemistry outlined by Ceker and Ozdamli (2016:197) include: "difficulties for teachers in implementing PBL during their teaching; difficulties for learners in using PBL during their learning; less knowledge is acquired during the use of PBL; and that more time is required for learners during the use of PBL."

During implementation of the modified model of PBL called Problem-Based Service-Learning, Aker and Pentón-Herrera (2020) state the problem to be that of lack of time. The relationship between time and any teaching method is unavoidable. Some of the problems related to implementation of PBL include unsatisfactory work and self-studies regarding the problem given to the learners (Hung, 2011). After nearly a decade of implementation of hybrid PBL approach at the University of North Dakota School of Medicine and Health Sciences, Vogeltanz-Holm, Olson, Borg and Hill (2014) submit that students were not satisfied with the PBL activities and showed less collaboration as they preferred individualised study. Participating teachers in the current study were made aware of PBL pitfalls during the intervention phase so that they could be alert to the disadvantages and circumvent them (disadvantages) during the teaching and learning process.

In a study conducted in Latvian basic and secondary schools, Zhukova (2017:906) states that "more than a half of those participating in the survey admitted that they had tried using problem-based activities in their EFL classrooms, but they seemed to be of little effectiveness due to various reasons. Most often the teachers mentioned that (1) it is often difficult to control the students and maintain the discipline in the classroom (2) such activities required too much time for instruction and explanation of tasks and did not give the students sufficient opportunity to practice; (3) such activities might be inappropriate for mixed ability classes and for weak students or for students with lower levels of language skills; (4) it is often difficult to encourage students to use the target language rather than their native language in group discussions. Zhukova's purpose was to explore 25 novice teachers' pedagogical beliefs and challenges regarding the implementation of a problem-based learning (PBL) approach in

English as a foreign language (EFL) classroom. The purposive sample of the novice teachers was from the urban public-schools in Riga and Daugavpils. Qualitative data was generated from face-to-face individual semi-structured interviews and classroom observations. The major findings were that the frequency and effectiveness of the use of PBL depends on various factors such as teachers' beliefs about the nature of teaching and learning; beginner teachers report being afraid of losing control in the classroom and struggling with discipline and behaviour issues due to lack of confidence in implementing PBL; and that beginner teachers find implementation of PBL time consuming since they are under pressure to complete the curriculum and prepare learners for standardized assessment (controlled term tests and examinations).

In juxtaposing these two studies, both qualitative studies explored the classroom implementation of PBL by beginner teachers. Zhukova's focus was on English subject whereas this study is topic-specific on Physical Science's PNM. The current study first employed open-ended questionnaire whereas Zhukova's study conducted face-to-face semi-structured interviews. With the aim to enhance PBL, this study conducted a TPD training beginner teachers before data was collected from their classroom implementation, this was to familiarise beginner teachers with PBL to avoid or rather minimise challenges and ineffectiveness. Contrary, Zhukova collected classroom implementation data without having conducted a TPD for novice teachers, which might have hindered with the PBL implementation. Classroom implementation of PBL in this study was collected through a reflective portfolio and a classroom observation in Zhukova's study.

2.4.6 Assessment in PBL

The South African National Protocol for Assessment (NPA) Grades R – 12 states that "assessment is a process of collecting, analysing and interpreting information to assist teachers, parents and other stakeholders in making decisions about the progress of learners" (Department of Basic Education, 2012:3). According to the NPA document, the classroom formal and informal assessment should provide learners' achievements in the most effective and efficient formats in order for the learners to identify what knowledge and skills are being assessed thus providing feedback to learners. Budiastira, Erlina and Wicaksono (2019) define assessment as a structured activity that a teacher must carry out comprehensively and integrate with the learning process. Before deviating into assessment in general, this section discusses the literature in assessing PBL. Koh and Chapman (2019) state that assessment in

PBL is a prerequisite to learning and development of professional competencies. Unfortunately, adopting and implementing an assessment on a PBL approach in the classroom is a challenging process (Dillon, McDonnell, Murphy & White, 2018; Johansson & Svensson, 2019). PBL assessment may be a challenge since PBL focuses mainly on the learning process (Lee, 2013). A PBL assessment must comprise learner-based assessment (self- and peer-assessments) and teacher-based assessment (facilitator-assessments) promoting SDL within the learners (Ansari & Rahman, 2015). It is a standard practice in PBL for learners to be assessed on the basis of their participation and contributions to the group (Alias, Masek & Salleh, 2015).

Self-assessment is a process of learners evaluating their own work against particular criteria on a specific task (Alias, et al., 2015; Adachi, Tai & Dawson, 2018). According to Khoiriyah, Roberts, Jorm and Vleuten (2015:2) “Self-assessment is ... a comparative process, with the student comparing their own performance to specific standards or to previous performances or to the performance of others.” Self-assessment can have a positive or negative impact on the learners’ learning (Andrade & Brown, 2016). Self- and peer-assessment are often combined and called learners-based assessment (Papinczak, Young, Groves & Haynes, 2007; Ghahari & Farokhnia, 2017).

On the other hand, peer-assessment is defined a process of learners evaluating and in turn being evaluated by their peers in a classroom (Li, Xiong, Hunter, Guo & Tywoniw, 2020). Peer-assessment can be used across educational levels and its scope of feedback can be written or oral comments and replies, instead of or in addition to scoring (Strijbos & Wichmann, 2018). Peer-assessment within PBL is important for developing 21st-century skills, promoting SDL and fostering personal development within the learners (Roberts, Jorm, Gentilcore & Crossley, 2017). Peer-assessment can be used in large classrooms to decrease the teacher’s workload (Li, et al., 2016; Kitchen, Bethell, Fordham, Henderson & Li, 2019).

Self- and peer assessments must be mixed with teacher-assessment for validation. Teacher-assessment strengthens the knowledge, skills, dispositions, and personal development of the learners (National Education Association, 2010). Teacher-assessment can be both summative and formative intended to provide timeous feedback to the learners (Stojcevski & Du, 2020). The aforementioned assessments can be in writing workshops, classroom discussion (whole-class or small-group), reflection logs, weekly self-evaluations, checklists and tick-box

rubrics, Likert scale rubrics and ratings, and interviews (Brantmeier, Vanderplank, & Strube, 2012; Salinitri, Lobkovich, Crabtree & Wilhelm, 2019).

The three “basic” PBL assessment processes discussed enhance social team interactions and productivity, thus, preparing students for the future (Mota, Santos, Esperto & Coutinho, 2019). Some of PBL related assessment models that have been used include portfolio, triple jump, group presentation, individual presentation, tripartite assessment, reports, *viva voce* examination, open group assessment and reflective (online) journal (Bilbao *et al.*, 2018; Silva, Bispo, Rodriguez & Vasquez, 2018; Chian, Bridges & Lo, 2019). Both self- and peer-assessments are arguably a solution to lower educational achievement and improving understanding of the concepts since they involve learners (Wuli, Susilowati & Prasetyo, 2017). Li, Xiong, Zang, Kornhaber, Lyu, Chung and Suen, (2016) posit that more than one type of assessment could result in some inconsistencies such that learners’ and teachers’ ratings differ significantly. Moreover, findings reported by Prasetyo and Hima (2019) show that the self- and peer-assessment scores by learners were higher than those from facilitator’s assessment. Golightly (2020) reports differences between the self- and peer assessment in a study conducted with Geography students in South Africa. However, Lee and Fu (2019) argues that assessment challenges can be overcome by providing learners with proper guidance. In PBL, there has to be association between learner-based assessment (self- and peer-assessments) and facilitator’s assessment to ensure that learners and teacher are looking at and for same concepts (Ghahari & Farokhnia, 2017). It is worth noting that this study utilised both learner-based assessment and teacher-based assessment for consistency.

2.4.7 Related studies of Problem-Based Learning (PBL) in schools

PBL can be utilised in all disciplines to accomplish an effective and conducive teaching-learning situation (Jing & Tong, 2018). Nonetheless, this section focuses on studies related to PBL implementation in Grade R – 12 classrooms on various contexts. Successful implementation of PBL in Grade R – 12 contexts can foster skills for both learners and teachers (Grant & Tamim, 2019). Interestingly, utilisation of PBL in schools improves learners’ academic achievement (Merritt, Lee, Rillero & Kinach, 2017).

Aidoo, Boateng, Kissi and Ofori (2016) conducted a study in KwaZulu Natal, South Africa investigating the effect of PBL on students’ achievement in Chemistry. The current study

aims to enhance Physical Sciences beginner teachers utilising PBL to promote 21st-century skills for SDL in the teaching and learning of PNM. The PNM that the current study focuses on are the phases of matter and Kinetic Molecular Theory. Chemistry concepts such as rates of chemical reaction, reactions of organic compounds, chemical equilibrium, acid, bases, and salts are the focus in Aidoo *et al.*. This current study used qualitative methodology and had a sample of 5 beginner physical sciences teachers who were purposively sampled and one each of their Grade 10 classes while Aidoo *et al.*'s study had a sample of 102 Grade 12 learners used convenience sampling. In their study, Aidoo *et al.* randomly selected the learners into the control and the experimental groups equally and provided them with pre-test experimental design to assess their problem-solving, critical-thinking skills and content knowledge. In the current study, critical thinking is one of the (21st-century) skills observed. While in Aidoo *et al.* PBL was implemented on the experimental group while the control group was exposed to the traditional teaching method, the current study implemented PBL in all the 5 teachers' Grade 10 classes – both studies allowed learners to assess themselves using rubrics. The post-test results of their study show a significant difference in the achievement between the students' performance after being exposed to PBL and traditional teaching approaches of teaching Chemistry. The students in the experimental group performed well after the study compared to the control group and it showed that the students' problem-solving and critical thinking skills were improved. The findings presented by Aidoo *et al.* are unsettling given that the current study suggests that PBL implementation in a Chemistry classroom might result in enhanced 21st-century skills and promote SDL amongst the learners. It is yet to establish if similar or different findings emerge from the current study and to what extent PBL is implemented.

A study by Thakur, Dutt and Chauhan (2018) implemented PBL in a 9th grade Biology class in New Delhi, India. With reference to the current study, the purpose was to enhance beginner teachers to implement PBL in their Chemistry classrooms while teaching PNM. The purpose in Thakur *et al.* was to investigate the learners' perceptions towards PBL in learning Biology. Their sample was 93 students who had recently passed from 8th class and were moving into 9th class in a government school, whereas the current study purposively sampled 5 beginner teachers to explore PBL with their learners. Thakur *et al.* divided students into control and experimental unequal groups wherein, the experimental group PBL was implemented and the control group was taught through traditional lecture method. During teaching, the students were further grouped into 4. After PBL implementation, questionnaires

were administered to the experimental group students to analyse their perceptions of the PBL strategy in learning Biology. The current study required participants to submit a portfolio reflecting the material used and activities that occurred during the PBL implementation. The questionnaire evaluating PBL on the basis of content and level of the modules; positive attitude towards learning; integrating new and old knowledge; understanding of the concepts; principles of self-learning; and etc., used a four point Likert scale ranging from strongly agree to strongly disagree. In contrast, the portfolio submitted by beginner teachers in the current study included teacher's reflections and rubrics aimed at observing 21st-century skills that were appropriated by learners during PBL implementation. With regard to their results and interpretations, Thakur *et al.* support that PBL is a one of the best strategies that motivates, interests and encourages learners. The Likert scale respondents' views confirmed the following about PBL, to name a few: it makes learning an enjoyable experience; it helps in discovering new things; it creates a tension free environment as we can work out beyond the boundaries of classroom environment; it creates a challenging atmosphere; it develops self-confidence within them; it promotes scope for social interaction; it promotes communication skills; it promotes discussion and sharing of ideas; it motivates; it makes learning more meaningful; it creates curiosity among learner; it promotes active learner participation; it promotes critical thinking; it promotes collaboration; it promotes decision making; and etc. It is significant that the findings presented by Thakur *et al.*, promoting and affording the learners with the 21st-century skills and reflecting the elements of SDL, are perfectly aligned with the aims of the current study.

Valdez and Bungihan (2019) studied effectiveness of PBL approach in enhancing the problem-solving skill in Chemistry of Grade 9 learners in a public high school in the Philippines. Comparably, the current study implemented PBL to enhance 21st-century skills such as critical thinking, creativity, communication and collaboration in Grade 10 Chemistry in a public high school. This mixed method study was conducted on four randomly selected classes where two non-PBL group consisted of 50 learners each and two PBL group consisted of 46 learners each. The classes were carried out for 4 sessions per week and 60 minutes per session and were handled by different teachers. The subject matter that was applied during this study were: a) Electronic Structure of the Atom, b) Chemical Bonding c) Carbon Compounds and d) The Mole Concept –are also defined as PNM.

Valdez and Bungihan (2019) employed a descriptive-comparative research and pre- and post-test on the experimental designs. The comparative part involved the comparison of their levels during the pre- and post-test. The experimental part of the study involved the students' performance in Chemistry after exposure to PBL. In contrast, the current qualitative study purposively sampled 5 novice teachers and administered open-ended questionnaires, conducted a TPD intervention programme and required submission of a portfolio post PBL implementation. Valdez and Bungihan's (2019) research instruments were a PBL Matrix containing the learning competencies for the different topics, activities and assessment; a PBL Teacher's Guide which consisting of lesson plans; PBL Chemistry Content Material; and Open-ended Problem-Solving Skill Test (PSST) for assessing learners' problem-solving skills. The findings of this study showed that: PBL approach significantly enhanced problem-solving skill within learners; PBL approach may have enhanced judgement skills in choosing the best solution for the identified problem; the training provided to learners during the teaching-learning situation may enhance problem-solving skill; and lastly, PBL approach can be affected by the size of the class – larger classroom might experience challenges in implementing PBL approach and achieving desired outcomes. Interesting findings indeed which this study was to establish if they also apply to the current study.

In West Nusa Tenggara, Indonesia, Nursa'ban, Masykuri and Yamtinah (2019) implemented PBL in a Grade 11 Natural Sciences classroom. The purpose was to examine the effectiveness of PBL-based modules in science learning. Equally, the current study implemented PBL in a Grade 10 Physical Sciences classroom with the aim to enhance 21st-century skills for SDL. Nursa'ban *et al.* conducted a qualitative descriptive study with all the Grade 11 learners and sampled Natural Sciences teachers. Data generation of this study followed a PBL-based module implementation, and finally a test which consisted of 15 multiple-choice questions. Results of the descriptive analysis shows an average difference between the pre- and post-test with an N-gain score of 0.74. The N-gain score indicates a significant difference between the pre- and post-test averages so that an inferential statistical test is necessary. The dependent t-test analyse showed that between pre-test ($M = 39.167$, $SD = 10.307$) and post-test ($M = 83.917$, $SD = 6.071$) had a significant difference [$t(23) = 25.848$, $p < 0.05$]. Therefore, implementation of PBL-based modules can improve learning outcomes of students. The implementation carried out consistently is able to improve students' critical thinking skills and SDL. The findings presented by Nursa'ban *et al.* (2019) are undoubtedly reassuring of the use of PBL in a science classroom.

A study by Li and Tsai (2017) focused on the primary school students' experiences after PBL implementation in their Mathematics classroom in central-west of Taiwan. Conversely, the current study is focused on enhancing the PBL use by beginner teachers and thereof relies on the responses they submit post PBL implementation with their Grade 10 Physical Sciences learners. In their study, Li and Tsai (2017) conducted a TPD for the class teacher of the 35 public primary school students that the study is focused on. Similar to the current study, Li & Tsai, (2017) TPD was aimed at enhancing the class teacher's PBL instruction skills before implementation since the teacher had no prior experience with PBL. Furthermore, the class teacher had 8 years of primary school teaching experience. In contrast, the current study was conducted with beginner teachers who possessed less than 5 years of teaching experience. Once again, like the current study, the study by Li and Tsai was topic specific focusing on Fractions in Mathematics. In Li & Tsai, (2017) PBL was implemented on 19 lessons about the fractions for the whole year. Contrary, in the current study PBL was implemented on the maximum of 3 lessons through a week. Nonetheless, throughout the study, there was a prolonged engagement with the teacher participants to ascertain their teaching strategies and guide them in the role of a critical friend. In their study (Li & Tsai), all the PBL lessons were observed recorded by the class teacher using three sets of videotaping equipment. Contrary, the current study employed a portfolio reflecting PBL implementation including learners' activities and rubrics, and was submitted at the end of all PBL lessons. Li and Tsai captured learners' experiences during the PBL implementation through semi-structured interviews and post-implementation open-ended student questionnaire.

Similarly, the current study captured learners' progress on the 21st-century skills but employed open-ended questionnaire before the TPD programme and PBL implementation. Li and Tsai further administered two kinds of researcher-designed 30 minutes written tests which were used as follows: (i) a Post-Topic (PT) test administered upon completion of the sequence of lessons within each of the four main topics and (ii) a Post-Implementation (PI) test that was administered 27 calendar days after the completion of the intervention. Li and Tsai (2017) reports findings that are undesirable: that learners kept asking the teacher for direction, learners were competing, learners were simply giving answers without explaining, more than half of group members positively had discussions and helped one another, none of the group members tried to solve the problem, some learners discouraged others with negative feedback, and etc. It is undeniable that the findings of the study by Li and Tsai

(2017) are unsettling. Furthermore, the methodology employed in their study lacks clarity if one is to replicate the research methods. Though unsettling, Li and Tsai's findings are seminal in cases where teachers try to implement PBL, especially inexperienced teachers. The current study strove to establish similar findings in the South African context.

Wahyu and Syaadah (2018) conducted a study in West Java, Indonesia aimed to investigate the implementation of PBL to improve student's academic achievement and creativity on the topic of electrolyte and non-electrolyte solutions. It is noteworthy to mention that creativity, as investigated by Wahyu and Syaadah (2018), is one of the 21st-century skills explored by the current study. Furthermore, both studies focus is on implementation of PBL in a topic-specific Chemistry classroom. Their study was conducted as a descriptive case study design method with 30 students in the class X one of the vocational school in Bandung studying electrolyte and non-electrolyte solutions. The data on their (Wahyu & Syaadah, 2018) study were collected by test, observation worksheet, guided interview, and questionnaires. Their study started by giving the students a multiple-choice pre-test of electrolyte and nonelectrolyte solutions. The test was divided to four concepts such as electrolyte and non-electrolyte, classification of strong and weak electrolyte solution, degrees of dissociation, and ionization reaction. The second stage of this study was implementation of PBL in a classroom. Finally, students were given a post-test and a questionnaire intended to measure their potential development. Their findings showed an academic achievement increase from the pre- and post-tests.

It is therefore undeniable that their study (Wahyu & Syaadah, 2018) validates that PBL is one of effective instructions. Interpretations submitted by Wahyu and Syaadah (2018) showed that students can easily understand the topic due to many phenomena in daily life experience brought by PBL. Furthermore, their findings further showed a regress on the concept of ionization reaction. Student's creativity in generally was found to be at 80.69%. Wahyu and Syaadah (2018) further suggest that although all students' creativity is enhanced, students with stronger basic conceptual understanding are most likely to enhance their creativity skill. Finally, their study reported a correlation of 0.413 between student's academic achievement and creativity. The findings by Wahyu and Syaadah are settling given that creativity can be enhanced by PBL regardless of learners' conceptual understanding. In contrast, the current study does not utilise the quasi-experimental design followed in Wahyu and Syaadah's study but takes path of a qualitative design.

In corroboration with the current study, and other reported PBL studies described above (Aidoo *et al.*, 2016; Thakur *et al.*, 2018; Wahyu & Syaadah, 2018; Valdez & Bungihan, 2019; Nursa'ban *et al.*, 2019), Sekarini, Wiyanto and Ellianawati (2020) recently conducted a study in Semarang, Indonesia to determine the effectiveness of PBL aided mind mapping to increase the 21st-century skills such as creative thinking and collaboration skills. In their exploratory qualitative study, Sekarini *et al.* (2020) used a random cluster sampling technique, to select 30 grade 8 learners. The findings presented by this study validates the results by the aforementioned studies about implementation of PBL. The findings reported by Sekarini *et al.* showed that an increase in scores obtained by students in creative thinking and collaboration skills. Sekarini *et al.* further suggest implementation of PBL to provide effective learning model reference to be used in developing the 21st-century skills. It is therefore evident that regardless of the purpose of the study, implementation of PBL in schools may enhance and promote the 21st-century skills. This study aims to enhance PBL use by beginner teachers and thereof relies on the responses they (teacher participants) submit post PBL implementation with their grade 10 Physical Sciences learners

2.4.8 Illustration of Problem-Based Learning Chemistry Examples

This section presents a selection of PBL examples related to the Chemistry education discipline. In corroboration with the PBL process discussed above, during PBL, problems-driven learning starts to afford the content knowledge to be studied (Hung, 2019). Hung further states that a PBL problem must contextualise abstract content knowledge to practical, meaningful working knowledge. “The effectiveness of problems determines the effectiveness of PBL curriculum. The quality of PBL problems affects not only various aspects of student learning but also academic achievement” (Hung, Jonassen & Liu, 2008:496). The selected Chemistry problems are outlined by Poë (2015:285-287) as follows:

- **Descriptive Chemistry of Metals**

You are an aircraft engineer examining the materials used in the construction of the exterior of a plane. The principal metal used is aluminium. In the aerospace industry, primer paints containing dichromate pigments are used to inhibit corrosion on aluminium. Despite the high toxicity of these primers, the aerospace industry still prefers to use them rather than alternative nontoxic substitutes. How would you explain to representatives of the Ministry of Labour why the industry is so strenuously resisting the move away from the use of these dichromate-based paints?

This problem was used to teach the descriptive chemistry of metals and their binary oxides. In its application, cost effectiveness, chemical toxicity, environmental concerns, and political factors must be considered. The report requires providing an explanation of scientific data to non-scientists.

- **Organic Chemistry**

Devise a reaction scheme by which 3-ethylpent-2-ene could be synthesized from ethanol as the only source of carbon atoms.

This type of problem, presented after students have studied atomic and molecular structure but before any study of organic chemistry, makes a good introduction to the topic. The class, working as a group of the whole, can compile a list of what knowledge they would need in order to address the problem (one of the key cognitive steps in the process):

- 1) Organic nomenclature, in order to know what 3-ethylpent-2-ene is;
- 2) How to make carbon–carbon bonds, in order to build up a seven-carbon compound from a two-carbon compound;
- 3) How to break carbon–carbon bonds, in order to make a compound with an odd number of carbons from one with an even number;
- 4) How to eliminate the OH-group;
- 5) How to generate the carbon–carbon double bond (related, of course, to 3 above).

From the examples given above, it is evident that PBL represents a major development in educational practice that continues to exert an impact on courses and disciplines across the curriculum (Phungsuk, Viriyavejakul & Ratanaolarn, 2017). It is evident that Problem-Based Learning can be effectively implemented in chemistry education (Zejnilić-Hajrić, Šabeta & Nuić, 2015; Wahyu & Eli, 2016), and this study implemented PBL in the topic of the Particulate Nature of Matter (PNM) in its inception and extension of 21st-century skills such as collaboration, critical thinking, creativity and communication. As Ansari *et al.* (2015:263) encourage, “PBL should be implemented to achieve critical thinking, scientific thinking, leadership qualities and managerial skills among students.”

2.5 21st-Century Skills

The South African Physical Sciences curriculum aims to produce learners who can: “identify and solve problems and make decisions using critical and creative thinking; work effectively as individuals and with others as members of a team; organise and manage themselves and their activities responsibly and effectively; collect, analyse, organise and critically evaluate information; communicate effectively using visual, symbolic and/or language skills in various modes; use science and technology effectively and critically showing responsibility towards the environment and the health of others; and demonstrate an understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation” (Department of Basic Education, 2011:5).

In corroboration to what is mentioned in Chapter 1, 21st-century skills are core competencies that could assist learners to face and survive today’s ever-changing and globally interconnected world (Partnership for 21st Century Skills, 2009; Taylor, 2016; Rifandi & Rahmi, 2019; Howlett & Waemusa, 2019). Amongst others, these skills include collaboration, critical thinking, creativity and communication which are explored in this study. According to Grimus (2020:130) “Twenty-first-century (learning) skills are outlined as a set of abilities that students need to develop in order to succeed in the information age”. As mentioned in Chapter 1, the learners must be encouraged to collaborate with friends and think critically (Wyness & Dalton, 2018). It is clear that the aims of the South African curriculum and the 21st-century skills discussed in this study are undeniably aligned.

21st-century skills provide a framework that captures four clusters: (a) key subjects and themes (e.g. global awareness and multiple literacies, such as financial, civic, health and environmental); (b) learning and innovation skills (e.g., creativity and innovation, critical-thinking and problem-solving, communication and collaboration); (c) information, media and technology skills (e.g., information, media and ICT literacy); and (d) life-long learning and career skills (e.g., adaptability, initiative, social skills, accountability and leadership). It is important to note that this study focuses on the 21st-century skills of cluster (b) learning and innovation skills as stated in the preceding statement (Greenhill, 2010; Partnership for 21st Century Learning, 2016, 2019; Spector *et al.*, 2016). Specifically, the focus is on cluster (b) 21st-century skills that include *collaboration, critical thinking, creativity and communication*. Acquiring such skills of the 21st-century, learners might be ready to face complex real-life situations such as work experiences and day-to-day survival (Al Kandari & Al Qattan, 2020). During the Coronavirus (COVID-19) global pandemic, the Ministry of Education of the People's Republic of China emphasised on the 21st-century skills discussed in this study among their learners, teachers and parents being necessary for a successful learning while learners learn from homes (Cheng, 2020).

According to Stehle and Peters-Burton (2019:4), “collaboration is an important skill to enhance Self-Directed Learning (SDL).” In order to accomplish a high level of collaboration, roles in the group must be defined, learners must be provided with explicit instructions on how to share responsibility, and evidence of interdependence. Erkens and Bodemer (2019) outlines two prerequisites are essential for collaboration as (1) learners must be aware of their peers' knowledge in the group, and (2) learners must activate their prior knowledge in dealing with the problem. Collaboration can focus on the quality of the group outcome and its process measuring the group success (Collazos, Guerrero, Pino, Renzi, Klobas, Ortega, Redondo, & Bravo, 2007).

Aker and Pentón-Herrera (2020) posit that in the real-world today, professionals must communicate information and collaboratively learn with and from one another. Landon (2019) asserts that acquiring communication skill does not mean learners can communicate effectively across all forms; however, learners must at least perform interpersonal, written, and oral communication in order to participate globally – out of their usual context. In addition, Landon (2019) argues that affording learners a skill such as communication should certainly rank high for technological skills. The ability to communicate and collaborate is

important because students are required to be part of the community. This is reasonable because in social life where students must criticize and solve the problem. Solutions will be designed and implemented by people who are creative and able to think critically (Al Kandari & Al Qattan, 2020).

Grimus (2020) defines critical thinking as the ability to think clearly and rationally in order to analyse and combine acquired information to develop own interpretations, learning and critiquing facts. Critical thinking is triggered by a working on a problem through collaboration and reflection (Kamin *et al.*, 2001). According to Brown (2018:42), “critical thinking pertains to the ability to apply cognitive thought to new or known information”. In clinical nursing, “critical thinking has been closely associated or even considered synonymous with the nursing process, clinical judgment, and problem solving” (Cise, Wilson & Thie, 2004:147). Critical thinking is an activity that does not rely much on the memorised (or learned) and prior knowledge but on the ability to connect relevant information (Wagner, 2015). The aforementioned citations imply that critical thinking is a skill that must be taught through PBL. It is not surprising when Al Kandari and Al Qattan (2020) declare that critical thinking occurs when learners are triggered to think outside of their usual thinking habits by fostering new ways of thinking and conveying new ideas and solutions. Critical thinking skill prepares the learners to be able to respond to the changes and new challenges arising and promotes self-insight and awareness of the societal frames, thus, personal development (Zabit, 2010). Malmir and Shoorcheh (2012:609) outline some of the characteristics of a critical thinker which are independent of the definition chose, those are: Asks relevant questions to the issue; Assesses arguments which are made; Admits a lack of understanding; Has a sense of curiosity; Analyses the interpretations and claims made; Analyses the problems; and Is eager on finding new solutions.

Creativity is defined as offering new perspectives, generating novel and meaningful ideas, raise new questions, and coming up with novel solutions to ill-defined problems in specified contexts of value (Beghetto, 2006; Morris, 2020). As in the PBL process, creativity is more about allowing learners the freedom to make mistakes while thinking divergently rather than accuracy and the solution. To Alshammari (2019), creativity is the ability to refine existing or generate new ideas; to be open-minded and courageous to explore; work creatively with others; and creative and innovative production. Creativity provides learners with the ability to imagine new designs and new ways of doing things (Partnership for 21st Century Learning,

2011; Usmeldi, Anggreini & Amini, 2019). Hamid (2018) argues that critical thinking and creative skills are the two skills that are inseparable because they sharpen one another. These four 21st-century skills were investigated in this study as part of the PBL process.

2.5.1 Why are 21st-century skills important?

Our increasingly globalized world brings people from different parts of the practice and different beliefs and ideas to participate (Ansarian & Teoh, 2018). It is therefore only fair that science learners are prepared for the 21st-century skill so that they can participate in both the local and global platforms effectively. Grimus (2020) says these 21st Century skills build the connections between classroom and real-world learning. If learners are afforded these skills, they can apply them to solve problems in their everyday life and may be aligned with current work demands (Rifandi & Rahmi, 2019). A recent good example is in the declaration of national state of disaster in South Africa due to Coronavirus (COVID-19) epidemic outbreak, the President of the Republic, Cyril Ramaphosa on March 15th, (2020) stated that the national emergency demands citizens to communicate effectively, collaborate with one another and the government, and extraordinary response to limit the spread of the virus. One could argue that an extraordinary response, therefore requires critical thinkers who are creative in dealing with this outbreak. It is evident that these 21st-century skills are important for the survival and managing day-to-day activities in real-life situations.

Oyibe, *et al.* (2015) state that critical thinking engages learners in making reasoned judgments that are logical. Bailey and Mentz (2015) argue that learners must be able to evaluate and criticise information and make informed judgements. Critical thinking and problem-solving are essential for learners who have to communicate ideas, make decisions, analyse and solve problems. It is therefore critical to enhance 21st-century skills such as critical thinking as Havenga (2015b) suggests that without a fundamental level of reasoning, comprehension and problem-solving, students cannot direct their knowledge in a constructive manner. Bilbao, *et al.* (2018) argues that a teaching approach should promote critical thinking for a significant and improved learning to take place. It is not surprising when Havenga (2018a) emphasizes that, collaboration is a necessary skill within a group when solving a real-world problem since it is one of the ways to instil professional practice. Havenga further states that collaboration is enhanced by using small groups when utilising PBL. Collaboration facilitates learners working together in small groups to achieve a common goal, and this has been used wide range of physical classroom practices in teaching and in online learning

(Chen & Kuo, 2019). In addition, collaboration benefits learners in terms academic success, motivation, and social development skills. Talat and Chaudhry (2014) found that there is a significant relationship existing between the constructs – the PBL model supports the 21st-century skills along with personal and social development. The importance of creativity skill is to ease the process of managing the complexities of globalization and social justice (Nganga, 2019).

2.5.2 How are 21st-century skills enhanced?

The 21st-century skills can be enhanced by using an effective teaching-learning approach that offers more creative approaches (Elsafi, 2020). Teachers must employ teaching approaches that fulfil the 21st century education thus effectively fostering the 21st-century-skills such as the 4Cs in their classrooms (Rusdin & Ali, 2019). According to Care, Kim, Vista and Anderson (2018), curriculum, pedagogy and assessment are delivery mechanisms that should be considered to successfully enhance the 21st-century skills. According to Alismail and McGuire (2015), some of the many teaching approaches that can enhance 21st-century skills and content knowledge include PBL, cooperative learning, and technological tools such as WebQuests, Guizzes, Wiki, Google site, Digital Storytelling, ePortfolios, and SoftChalk LessonBuilder, Blog, and among others. Moreover, Rusmansyah, Yuanita, Ibrahim, Isnawati and Prahani (2019) and Ismail (2019) suggest that PBL is a relevant teaching approach that may enhance the 21st-century skills since it emphasizes personal experience through observing, asking, reasoning, trying, problems solving, and working in small groups. Saavedra and Opfer (2012a; 2012b) outline the nine lessons that can enhance the 21st-century skills. The nine lessons include: making the curriculum relevant to learners' daily lives; teaching 21st-century skills through various disciplines; teaching demanding concepts to learners; encouraging learners to apply the knowledge and skills learned on other disciplines; teaching SDL to the learners; addressing the alternative conceptions; encouraging and assessing team-work amongst learners; employing technology to support learning; and teaching and assessing creativity. The utilisation of PBL by the beginner physical sciences teachers agrees with the nine lessons as listed on the preceding statement to a large extent. The beginner physical sciences teachers' instructional practices are enhanced in this study to use PBL while teaching PNM in order to promote the 21st-century skills in the Chemistry Education discipline.

The employment of ill-structured real-life problems that are PNM related makes the curriculum more relevant to learners' daily lives. The ill-structured real-life problems given to the learners during the implementation of PBL are demanding to the learners as they define the problem, identify lesson objectives (what they need to know to solve the problem), and search for most probable solutions. As the result of being exposed to PBL and acquiring the 21st-century skills, SDL might be fostered and therefore learners may apply these skills on other disciplines. During the PBL implementation, as learners collaborate in a small-group and communicate ideas their alternatives concepts may be dealt with. Researching of the information from their textbooks and the internet may assist by employment of technology and creativity. Group-work is an essential aspect of Problem-Based Learning since it enhances learners' communication skills (Jing & Tong, 2018). Furthermore, Narmaditya, Wulandari and Sakarji (2018:384) found that "learners' critical thinking skills were enhanced dramatically after the implementation of PBL in a lesson." In sum, PBL increases ability to solve problems and make conclusions through critical thinking.

Arevalo and Ignacio (2018) conducted a study in the Philippines to determine if the 21st-century skills constructs such as digital age literacy, inventive thinking, effective communication, and high productivity were significant drivers of students' science achievement. In contrast, the purpose of the current study is to enhance Physical Sciences beginner teachers to utilise PBL in enhancing 21st-century skills in order to promote SDL in the teaching and learning of PNM. In addition to two (critical-thinking and effective communication) of the 21st-century skills investigated by Arevalo and Ignacio, this study looks at collaboration and creative thinking but does not focus on digital age literacy, and high productivity as the other study did. Arevalo and Ignacio's study utilized an exploratory, descriptive, and causal-comparative design involving four sections of Grade 10 students enrolled in Science Grade 10, AY 2016 – 2017. The current study utilised the qualitative study and five beginner physical sciences teachers and one of their Grade 10 classes enrolled for physical sciences. In the Arevalo and Ignacio's study, two instruments were used in the study, the 21st-century skills of Science Students (21CSSS) and the Science Achievement Test (SAT). However, no instrument specifically for 21st-century skills was used in the current study as focus was on enhancing Physical Sciences beginner teachers to utilise PBL in enhancing 21st-century skills in order to promote SDL. Results from Arevalo and Ignacio's study revealed that majority of the Grade 10 students both male and female have an average level of 21st-century skills constructs and achievement in science.

Also, results showed that Digital Age Literacy (DAL) and Inventive Thinking (IT) skills significantly affect the science achievement of the students, this is significant at 0.05 level and could be generalized onto the entire population of Grade 10 students. It is noteworthy to mention that the current study does not focus on 21st-century skills as significant drivers of students' science achievement hence statistical findings are not expected as the current study's design is purely qualitative and not causal-comparative.

Tipton (2019) explored how the 21st-century skills for learners with special needs are built through PBL by home-school teachers in United States of America (online archives). Contrary, this study based on implementation of PBL on the normal secondary school learners in South Africa, North-West province. Tipton's 21st-century skills framework included communication and collaboration, problem-solving and critical thinking, and cross-disciplinary knowledge. The current study also looks at the promotion of the 21st-century skills such as collaboration, communication, critical thinking and creativity rather than cross-disciplinary knowledge, however, problem-solving is incorporated within these skills and PBL approach itself. Tipton generated data from 20 blog sites that were each written by a home-school teacher of at least 1 learner with special needs; the sites had a minimum of 3 blog posts that referenced teaching and learning that aligned with the fundamentals of PBL. Therefore, the methodological approach for this qualitative study was deductive-dominant content analysis. The home-school teacher blog sites were purposefully selected. A minimum of three blog posts from each of the 20 teachers was selected as they referenced the use of PBL strategies. The current qualitative study, like Tipton (2019), equally employed purposive sampling of participants. Rather than employing only one instrument (content analysis) for data generation (Tipton, 2019), the current study employed open-ended questionnaire, portfolio and interview. Tipton (2019) showed that although more home-school teachers emphasized the skill of communication, both skills were reflected in PBL implementation. Furthermore, the 21st-century skill such as problem-solving and critical-thinking were most reflected by learners in PBL. Another skill reflected by learners during PBL was cross-disciplinary knowledge where learners can integrate multiple subjects. Arguably, cross-disciplinary knowledge is based on SDL. It is anticipated that with implementation of PBL by beginner teachers, the learners will reflect the 21st-century skills discussed as alluded by Tipton (2019). Furthermore, this study acknowledges the difference in the learning context of the learners and the number of learners exposed to PBL in Tipton's study.

2.6 Self-Directed Learning (SDL)

According to Knowles (1975:18), “self-directed learning in its broadest meaning describes a process in which individuals take the initiative, with or without the help of others, (1) in diagnosing their own learning needs, (2) formulating learning goals, (3) identifying human and material resources for learning, (4) choosing and implementing appropriate learning strategies and (5) evaluating learning outcomes.” To Robinson and Persky (2020), SDL can be described in the process of six steps, namely: developing goals for study; outlining assessment with respect to how the learner will know when they achieve those goals; identify the structure and sequence of activities; lay out a timeline to complete activities; identify resources to achieve each goal; and locate a mentor/faculty member to provide feedback on the plan. Arguably, the preceding SDL descriptions echo the elements of PBL. According to Robinson and Persky (2020), SDL can be assessed through problem-solving, collaboration, communication, self-awareness, innovation and professionalism. Capon and Kuhn (2004), Evensen and Hmelo-Silver (2000) submits that success of SDL is when PBL learners are able to integrate new knowledge into prior-knowledge.

Rana, Ardichvili and Polesello (2016) also state that SDL can be promoted through skills such as communication, collaboration, interaction and teamwork; and the use of relevant technologies. Collaboration and communication are two of the four 21st-century skills mentioned by Rana *et al.* (2016) which this study aims to promote through PBL for SDL. Ansari *et al.* (2015), Morris (2019a) define SDL as the learners’ ability to formulate learning goals, identify resources and knowledge or skills for learning, choose relevant and appropriate strategies for learning, and evaluate the learning outcomes for their task. To Ansarian and Teoh (2018), SDL is addresses problem-based learners to become therefore self-directed learners. During the process of PBL where learners discuss and formulate their learning objectives from a problem, this is synonymous to SDL (Loyens, Rikers & Magda, 2008). Loyens *et al.* further state that SDL is about assessing learning needs, planning, time management and evaluation of information. As Zainuddin and Perera (2018) postulate, SDL is a situation where learners determine the key issues of learning and solve real-world problems within a problem-based learning environment. According to Grow (1991), learners exhibit SDL when: (1) they are not dependent on the teacher; (2) they are interested and motivated; (3) they have skills and knowledge and see themselves as owners of their education; (4) they can set their own goals and standards without the help of the teacher.

Grow states that SDL being exhibited in four stages, stage 1 is the lowest and stage 4 the highest. It is therefore with this knowledge that this study anticipates that utilisation of PBL while teaching will result on learners becoming self-directed learners.

2.6.1 Why is SDL important?

Morris (2019b:640) states that “Self-Directed Learning empowers adults to adapt to fluid and complex social contextual changes – rendering it an essential competence for living and working successfully in our modern world.” Individuals who are afforded self-directed learning in this ever-changing world where workplace and profession often change due to the economic instability, are most likely to adapt by learning more for their personal development (Aoki, 2020). Learners must be prepared for SDL to keep up with transformations in work and workplaces. Curran, Gustafson, Simmons, Lannon, Wang, Garmsiri, Fleet and Wetsch (2019) argue that SDL is effective when the socio-political context and the learning-learning situation favour the learner. Sebotsa, De Beer and Kriek (2019) argues that the concept of SDL is not known to teachers, as a result, they are often not self-directed and do not enhance self-directed learning in their classrooms. SDL can encourage learners of varying readiness and willingness to take ownership of their learning (Bosch, Mentz & Goede, 2019).

Linked to SDL is the construct of Andragogy. Andragogy was coined and defined by Knowles (1980:43) as “a normal aspect of the process of maturation for a person to move from dependency toward increasing self-directedness.” Andragogy implies that the foundations of life-long learning should be founded both by the school system and progressively by enhanced experiences in life (Gilbert & Afonso, 2015; Knowles, 1973). There are five assumptions underpinning Andragogy which describe the learner as: (1) an independent self-concept and who can direct his or her own learning; (2) an accumulated a reservoir of life experiences that is a rich resource for learning; (3) owning learning needs closely related to changing social roles; (4) problem-centred and interested in immediate application of knowledge; and (5) motivated to learn by internal rather than external factors (Merriam, 2001). Wark and Ally (2020) posit that in the Andragogical teaching-learning situation collaboration is a key aspect where learning is teacher-learners shared process involving formulation of learning needs, planning and problem-solving.

Penn and Arshad (2017) conducted a qualitative case study in Malaysia to investigate the types of PBL collaborative and self-directed processes during problem analysis phase utilizing the FILA-MMS chart in a secondary school classroom. Sampling in that study included a Grade 10 Chemistry class of 35 learners and their teacher, and they were all new to a PBL exposure. In the current study, PBL was implemented to promote 21st-century skills through SDL. Compared to the study conducted by Penn and Arshad (2017), the sample of the current study also involved a teacher and his/her respective Grade 10 Chemistry learners who were new to PBL exposure. Penn and Arshad observed the PBL implementation and recorded each group's verbal interaction using an audio recorder. They randomly selected two groups' audio-recording for transcription and analysing the learning processes such as collaborative and self-directed process. In contrast, the current study used portfolios submitted by teachers where in the PBL lesson was captured. The findings reported by Penn and Arshad showed that both collaborative and self-directed processes occurred within groups during PBL implementation. The results presented by Penn and Arshad (2017) report that participants showed comparatively high occurrences of collaborative process but a lower self-directed process. Although learners showed a lack of self-directed learning process, they managed to complete their task. The overall picture of these findings show that learners have the potential to adapt to the new active learning environment such as PBL and enhance SDL.

“A Study on the Relationship between Self-Directed Learning and Achievement in Information Technology (IT) of Students at Secondary Level” was conducted by Jaleel and Anuroofa (2017:1849) in India. Contrary, the current study, through chemistry teaching, associates SDL with the 21st-century skills rather than learner achievement. The sample of 150 standard 9 learners from various secondary schools in Ernakulam District was selected using stratified random sampling technique. Although learners' responses are looked into, the current study's main focus is on beginner teachers. Two instruments used by the study included Self-Directed Learning five point Likert scale and an Achievement Test in Information Technology that was prepared by giving weightage to six domains in the revised Bloom's taxonomy of Educational objectives namely, Remembering, Understanding, Applying, Analysing, Evaluating and Creating. In the current study, a 21st-century skills rubric found inside the portfolio is used to assess their manifestation. The findings of the study showed that there is a significant positive correlation between Achievement in Information Technology and SDL of secondary school learners. Moreover, the findings of their study imply that Teaching and learning activities in IT classrooms should focus on the

ways for enhancing the Self-Directed Learning capacity of the students. The activities in the IT classrooms must be properly designed to enhance the Self Directed Learning of the students and also, the teachers should motivate the students to improve Self Directed Learning capabilities, which gains momentum in the 21st-century classrooms especially in technology-based classrooms. Based on Jaleel & Anuroofa, (2017) findings, it could be equally argued that activities in the Chemistry classrooms must be properly designed to enhance SDL.

2.7 Traits of Beginner Physical Sciences Teachers

Although literature on ‘beginner teachers’ in school science is both extensive and intensive, none of that surveyed has made an effort to give precise definitions of the terms in usage. Scholars have used the terms, novice teachers, new teachers, neophyte teachers, newly qualified teachers, and beginner teachers (which this study adopts) interchangeably. The definition for beginner teachers varies from one scholar to the other. A precise definition of terms is a discursive necessity and not just about satisfaction of an appetite for semantics. Although the definition of beginner teachers varies, the idea is mainly about the teachers who have recently qualified from high institutions and entered the education system to practice. In addition, one contrasting idea on the definition of beginner teachers may denote teachers who have many years (more than five years) in the education system and experienced but recently (less than five years) started teaching a particular subject. Mahmoudi & Özkan, (2015) says beginner teachers have little or no mastery experience; often teachers who have less than two years of teaching experience. Beginner teachers in this study refer to those who have recently started teaching Physical Sciences such that they have five years or less and possess relevant teaching qualifications such as a Bachelor of Education (B. Ed), B. Ed Honours and Post-Graduate Certificate in Education (PGCE).

Beginner teachers are most likely to use teaching approaches they have been exposed to; maybe it worked for them as learners and they had a positive experience with it (Cox, 2014; Owens, 2013). According to Kaptan and Timurlenk (2012), most science teachers start their practice with some relatively good content knowledge. Van Heerden (2019) argues that beginner teachers are new to teaching and the classroom, therefore their pedagogical content knowledge (PCK) is at the ‘novice’ level. However, it is anticipated that although beginner teachers might have an understanding of the science content knowledge, they have limited

knowledge on the PCK. The concept of PCK is popular in science education research. The PCK concept was established by Schulman (1986) along with other knowledge bases such as curriculum knowledge; learners and their characteristics; educational contexts; and educational purpose. There has been great development and modification of PCK for a wide range of science concepts, however, originally Shulman (1986) established this concept of PCK defined it as the form of knowledge required by teachers when teaching to transform content knowledge into a teachable form. Van Driel, Verloop, and de Vos (1998) conceptualise PCK as teachers' interpretations and transformations of subject-matter knowledge in the context of facilitating student learning. PCK involves the presentation and articulation of content knowledge, pedagogical strategies, and knowledge of what makes content difficult or easy to learn.

Robson and Mtika (2017) posit that beginner teachers often face complex and dynamic challenges such as personnel, organisations and environments. Chaves (2018) conducted a doctoral qualitative phenomenological study in Massachusetts, United States of America, investigating novice (less than five years of teaching experience) elementary teachers' experiences and preparedness to teach mathematics. The purposeful sample size of this study was 11 novice elementary teachers from various schools in the Southeastern Massachusetts Public School District. Data was collected through a demographic survey, Teacher Efficacy Scale, virtual writing prompt, and audio recorded individual interviews to explore the phenomenon of novice teachers' preparedness and mathematics. The current study employed open-ended questionnaire to five Chemistry beginner teachers to fathom their teaching approaches, their knowledge about the 21st-century skills, and PBL implementation to inform the nature and type of PBL TPD programme. Chaves found that teachers coming fresh out of their teacher training programme are expected to be ready to handle teacher-work, but oftentimes, they are not. The findings in Chaves (2018) showed few traits of beginner teachers such as: struggling to make their subject fun; under-preparedness in terms of teaching techniques and approaches; and struggling with some content knowledge. Surprisingly, over a decade later, Chaves (2018) corroborates Davis, Petish and Smithey (2006) who submitted that science content and discipline; learners; approach; learning environment; and professionalism are the five key challenges that most beginner science teachers encounter. It is clear that most beginners, amongst other challenges, struggle with delivering content effectively.

Boakye and Ampiah (2017) in the central region of Ghana conducted a qualitative multiple case study that investigated the challenges faced by newly qualified teachers (NQT) in the teaching and learning situation and with the interest of addressing those challenges. Their selection of five beginner teachers was based on the following reasons that they: attended a certain College of Education, which was equipped for the specialist science programme; had taught science at the Junior High School level for more than a year; and were willing to participate in study. Contrary, the current study sampled five beginner teachers through a snowball method, and the teachers had to possess a teaching qualification from any tertiary institution, must have less than five years of Chemistry teaching experience and willing to participate. All the teachers taught in public Junior High Schools in different districts except two schools, which were in the same district. Their data generation methods were semi-structured interviews which were audio recorded, lesson observations and content analysis which included: *The guidelines for making the NQTs' observation protocol* based on the goals of the integrated science syllabus for basic schools in Ghana; and NQTs lesson plans. The findings of this study showed that all the NQTs faced challenges in teaching integrated science at their various high schools. "The areas in which the NQTs faced challenges are (a) time management, (b) content knowledge, (c) teaching and learning resources, (d) student understanding, (e) lesson note conflict/writing, (f) student punctuality, (g) class management, (h) student's interest in science, (i) getting sources of information, (j) workload, and (k) weak background of students" (Boakye & Ampiah, 2017).

In corroboration, findings of a Masters study with English novice (beginner) teachers (1-3 years teaching experience) in Turkey report that beginner teacher struggle with "classroom management, following the curriculum, their high expectations, mismatch between ideals and actuals, teaching materials, technological issues and testing" (Bekdemir, 2019:47). It is evident that beginner teachers face more or less same challenges regardless of their context.

Another study is by Zhukova (2017) who investigated '*novice teachers' beliefs about problem-based learning approach, and teaching practices*' in the Republic of Latvia. Twenty-five novice teachers with up to 3 years of basic and secondary teaching experience participated in the study and the data was generated through a face-to-face semi-structured interviews and classroom observations. Zhukova (2017) ultimately establishes that "majority of the teachers surveyed tend to believe that students have to be actively involved into the learning process and take responsibility for their learning; 78% of the novice EFL teachers

affirmed that students' achievements in language learning and their future success are largely dependent on their commitment, active involvement and participation in the learning process, as well as on teacher's professionalism." When asked about student motivation, more than a half of the novice teachers pointed to the importance of creating such learning environment where their students feel secure, supported, valued, and respected; according to the teachers, their role is not to force students to learn, but to help them discover their true interests and strengths, boost their curiosity and willingness to learn and create. Furthermore, "the interviews data also show that a lot of novice teachers report being afraid of losing control in the classroom and struggling with discipline and behaviour issues" (Zhukova, 2017:905).

Other significant findings from the classroom observations confirm that most novice teachers struggle with promoting SDL by allowing learners to independently use the information provided to construct their own knowledge and understanding. Rather, novice teachers tend to use teacher-centred and direct teaching approaches more often abandoning PBL. Zhukova's (2017) study purpose slightly differs from this current study which does not focus on beliefs but on how Problem-Based Learning (PBL) can be implemented to equip beginner Physical Sciences teachers in promoting 21st-century skills *namely*, collaboration, critical thinking, creativity and communication. The current study uses a smaller sample of 5 teachers in line with the qualitative approach. Unlike Zhukova's (2017) study whose participant teachers had taught for up-to 3 years, the current study beginner teacher participants had up-to 5 years of basic and secondary teaching experience. Interesting findings were reported from Zhukova's (2017) study and it is interesting to see if similar findings can be found in this current study given the different contexts the two studies were conducted.

2.8 Particulate Nature of Matter (PNM)

As mentioned in Chapter 1, Physical Sciences comprises of Physics and Chemistry (Ogegbo *et al.*, 2019; Samuel & Dudu, 2018). According to Hlabane (2016), Physical Sciences is generally difficult for learners, therefore critical-thinking, creativity, communication and problem-solving are the skills learners need to learn the subject effectively. The National Senior Certificate examination report 2019 (DBE, 2020) shows a decline on the number of learners enrolling for Physical Sciences in the past 5 years in the North West Province. The particulate nature of matter (PNM) is one of the fundamental concepts in science for one to

understand subsequent topics in Chemistry. As mentioned in Chapter 1, PNM presents multiple teaching challenges (Harrison & Treagust, 2002; Pitjeng, 2015). Yakmaci-Guzel and Adadan (2013) state that PNM is part of basic concepts in school science curricula worldwide from Grades 6 to 12 where learners are exposed to the structure of matter and three physical states, classification the matter, different representational levels and Kinetic Molecular Theory. Chua and Karpudewan (2020) posit that learners have difficulties in understanding various Chemistry concepts especially PNM and it is a great concern in Malaysia. Some scholars (Chua & Karpudewan, 2020) argue that poor understanding of PNM might result in difficulties in understanding other concepts in Chemistry. Merritt and Krajcik (2013) states that learners are unlikely to develop appropriate ideas in chemistry if they never apply and reapply these ideas to explain phenomena in their context.

As a result, Chua and Karpudewan (2020) argue that emphasis on a teaching approach that results in the learners doing more work could lead to learners' understanding of Chemistry concepts. Since Merritt and Krajcik (2013) point out that learners' PNM originates from daily experiences and classroom instruction, this study proposes the utilisation of PBL which allows integration of real-life and class-taught content. Penn and Ramnarain (2019) maintain that positive attitude and conducive environment are important factors for the teaching-learning situation. Alamina and Etokeren (2018) state that utilisation of visual materials (such as models and simulations) and imagination stretch teaching strategy into the secondary school Chemistry teaching has a potential to make learning and teaching easier. This suggests the importance of using analogies and visual materials in a teaching-learning situation of Chemistry since it is an abstract subject (Kawedhar, Mulyani & Indriyanti, 2019). Implementation of active learning in teaching chemistry may results in a deeper understanding of a subject matter (Summerton, Hurst & Clark, 2018). This is because active learning methodologies such as project-based learning, inquiry-based learning, experiential learning, just-in-time teaching, contextualised learning and cooperative learning may foster social learning experiences by embedding group work throughout the sessions.

2.9 Teacher Professional Development (TPD)

Teacher Professional Development (TPD) is a structured professional learning activity that aims to change or improve teachers' practices such that learning improves (Darling-Hammond *et al.*, 2017; Bates & Morgan, 2018). Darling-Hammond *et al.* (2017) further

states that a TPD should be linked to teachers' experiences and teaching standards. Dudu (2014) reported that South African Physical Sciences teachers acknowledged that TPD improved their teaching approaches and content knowledge since it was directly linked to their daily experiences. In order to ensure positive learning outcomes, particularly 21st-century skills and knowledge on the learners, teachers must be supported to: align content and pedagogy; balance teacher-centred approaches with learner-centred approaches; employ various assessment strategies to evaluate learner performance; and participate actively in the community of practice (Greenhill, 2010). A South African study by De Villiers, De Beer and Golightly (2016) conducted with seventy-five Life Sciences teachers from two provinces reports that only a few of the teachers admitted to only knowing about PBL approach although they did not know how to use it. The study further reports that while other teachers are knowledgeable about PBL, most confirmed to be clueless about it. This is alarming, thus dictating the need for the PBL TPD programme. Moreover, Lee and Blanchard (2019) report that PBL TPD increases teachers' intention to implement PBL in their classrooms. Darling-Hammond et al. (2017) and Bates & Morgan (2018) outlines that effective TPD has seven characteristics, *namely*:

1. Is content focused,
2. Incorporates active learning utilizing adult learning theory,
3. Supports collaboration, typically in job-embedded contexts,
4. Uses models and modelling of effective practice,
5. Provides coaching and expert support,
6. Offers opportunities for feedback and reflection, and
7. Is of sustained duration.

TPD remains an important factor in maintaining a strong workforce and keeping up in the 21st century (Wozniak, 2020). This is because there are skills required to survive in the world today for people to either get or secure jobs and as stated by Hunter and Molapo (2014), when the departments or educational systems adopt a new curriculum or teaching approach teachers in the field certainly require training. Furthermore, Christiansen and Bertram (2019) assert that TPD for in-service teachers is an important factor in improving South African education and improving teachers' confidence in teaching-learning situation. In countries such as New Zealand and Scotland, it is mandatory that beginner teachers go through a TPD programme before attaining the status of fully qualified teachers (Robson & Mtika, 2017).

This is mandatory since it is widely acknowledged that TPD during early career years can positively affect the quality of practice of teachers. Pretorius, De Beer and Lautenbach (2014) laments that South African sciences teachers need TPD in science pedagogy. However, Pretorius (2012) posits that TPD workshops are perceived negatively by most teachers since they do not address their needs. Selvaratman (2011:7) recommends that “Workshops should be conducted for teachers to increase their competence in intellectual skills and strategies. Universities in each province should be entrusted with the task of conducting workshops in that province because many workshops will generally be needed to ensure acquisition of intellectual abilities. The progress of teachers must also be continuously monitored.”

Dudu (2017) conducted a study to explore encounters and experiences of Experimento multipliers in one province running a TPD programme in facilitating small-scale implementation of inquiry-based teaching in various schools of South Africa. The sample of the study were 37 Physical Sciences teachers from 37 various high schools in Gauteng province selected by one of the multipliers. Teachers’ professional teaching experience ranged between 4 and 30 years. These were trained in three groups at different times due to space limitations in the laboratory. The main data sources analysed in the study were questionnaire, semi-structured individual interviews, observations made during school visits to check on the state of the Experimento 10+ kit and researchers’ field notes. Additional data generated from field notes written by the multipliers as they visited schools to observe the enactment of science activities in teachers’ classrooms. Generally, results show that teachers were confident in designing practical activities as well as allowing their learners to perform practical activities. Overall, findings indicated that teachers gained a more sophisticated understanding of the role of these cooperative learning techniques and their potential implications for facilitating inquiry teaching and learning. The teachers acknowledged changing their instructional practices and gaining greater subject knowledge as well as improved teaching skills as the TPD was directly linked to their daily experiences.

Pitjeng-Mosabala and Rollnick (2018) conducted a study titled ‘exploring the development of novice unqualified graduate teachers’ topic-specific PCK in teaching the particulate nature of matter in South Africa’s classrooms’ with 14 teachers who participated in a 10-months PDI programme. The purpose of their study was to investigate how 14 novice unqualified teachers develop Topic-Specific PCK (TSPCK) during the teaching of PNM coupled with Professional Development Intervention (PDI) experiences. The unqualified novice teachers,

are graduates recruited by TeachSA NGO with at least one year of Chemistry in their Science degree, usually have graduated five or fewer years previously and have no teaching qualifications. TeachSA had placed participants in schools in four different provinces in both rural and urban areas, based on the availability of science posts. The 14 teachers were selected for the study due to their allocation to teach Grade 10 classes. Data sources consisted of pre- and post-TSPCK and pre- and post-CK tests, teacher-constructed initial and final CoRes, pre- and post-lesson teacher observation interviews, video-recorded lessons and field notes. The whole group was exposed to part of the PDI because they attended the initial training and the final workshop where they participated in the construction of CoRes. The findings of their study show that of the 14 participants, 10 teachers' overall topic-specific PCK score improved post their PDI. However, 2 of the remaining 4 teachers' topic-specific PCK scores were unchanged, while another 2 teachers showed a regress. Findings reported show the improvement trend in the teachers' pre- and post-CK scores. The average CK score for the group as a whole was 52.79% in the pre-test and 67.57% in the post-test. Taken together these findings show how the initial knowledge of all the teachers was enhanced by the workshop element of the PDI and their related experience. Needless to mention that the current study ran a PDI with its teacher participants and it was meant to establish if similar shifts were produced.

2.10 Chapter Summary

This chapter provided an overview of the research literature related to Problem-Based Learning (PBL), beginner teachers, Teacher Professional Development (TPD), Self-Directed Learning (SDL), 21st-century skills, and social interdependence theory. As this study is topic specific, the literature with reference to the teaching and learning of Particulate Nature of Matter (PNM) was explored. The entire chapter commenced with an intensive discussion on the theoretical framework of Social Interdependence theory leading to the PBL conceptual framework. Elements and core factors relating to PBL were discussed clarify on the instructional method being used in the study. The findings of studies closely related to this study, including implementation of PBL in a Chemistry classroom by beginner teachers, were reviewed detail. Given the implementation of a new strategy in teaching by beginner teachers requires the intervention, PD of teachers was discussed deliberation on the benefits and challenges. The following chapter delves into the research design and methodology, outlining

the sample of teachers and learners, the instruments employed for data generation, and data analysis procedures.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

In this chapter, a description of the research methodology including the research instruments, sampling technique, sample (research participants), and data analysis so as to answer the research questions of this study are discussed. This chapter also includes detailed procedures on how the study was conducted (research methods). The purpose of this study was to explore and enhance beginner Physical Sciences teachers' utilisation of Problem-Based Learning (PBL) in enhancing 21st-century skills *namely*, collaboration, critical thinking, creativity, and communication in order to promote Self-Directed Learning (SDL) in the teaching of the Particulate Nature of Matter (PNM). The research questions guiding the study are as follows:

1. How can Problem-Based Learning (PBL) be enhanced to equip beginner Physical Sciences teachers in promoting 21st-century skills?
2. To which extent do beginner Physical Sciences teachers' use Problem-Based Learning (PBL) in initiating and promoting 21st-century skills before and after a Teacher Professional Development (TPD) programme?
3. What Problem-Based Learning (PBL) principles of practice could be distilled for beginner Physical Sciences Teacher Professional Development (TPD) towards Self-Directed Learning (SDL)?

Towards the end of the chapter, issues of dependability and interpretation are considered in this qualitative design study. A description of the ethics processes is provided, and a short summary concludes the chapter.

3.2 Research Design

Research design is a plan to conduct a study and shows how all other parts of the study are connected to address the research questions (Akhtar, 2016; Li, Liping & Khan, 2018; Rizvi & Bhardwaj, 2019). A research design is an interrelated set of assumptions about the social world which are philosophical, ideological, and epistemological rather than simply data generating techniques (Rist, 1977). In other words, research design provides a clear

procedure on components such as the approach, philosophical foundation, data collection instruments, methods, site selection and sampling, and data analysis.

In order to understand and capture in-depth data, it was ideal to adopt a qualitative case study approach that is exploratory rather than using quantitative research, which sees the world through the lens of numbers and measurements (Thanh & Thanh, 2015). Creswell and Clark (2004), Maree (2007) define qualitative research as a naturalistic approach that aims to understand the central phenomena contextually; and that it is mostly carried out in real-life situations. Qualitative research “is exploratory, and seeks to explain ‘how’ and ‘why’ a particular social phenomenon, or programme, operates as it does in a particular context” (Mohajan, 2018:2). Qualitative research generates multiple sources of data by employing interviews, observations, surveys or open-ended questionnaires, artefacts, content analysis, fieldwork, and archival records in order to strengthen data triangulation, mitigate the potential for bias and strengthen validity (Brown, 2018; Szyjka, 2012).

According to Yin (1994), case studies are the relevant strategies to explain ‘how’ and ‘why’ questions. Few studies (Creswell, 2007; Baškarada, 2014; Bhattacharjee, 2012; Heale & Twycross, 2018; Li *et al.*, 2018; Yin, 2014) define case study as an intensive inquiry that explores and analyse a contemporary situation such as a phenomenon, a person, a community, an institution and event, in depth and within its real-world context aimed to generalise over several units. Additionally, Merriam (1985:204) states that “the case study is one research approach that allows for a level of understanding and explanation not possible through conventional experimental or survey designs.” Several studies (Baxter & Jack, 2008; Bhattacharjee, 2012); Gustafsson, 2017; Johansson, 2003; Meyer, 2001; Rowley, 2002; Yin, 1981; Zainal, 2007) discuss two basic case study designs, namely, single case study and multiple case study.

“A single case design is akin to a single experiment. Single case studies are appropriate when the case is special (in relation to established theory) for some reason. This might arise when the case provides a critical test to a well-established theory, or where the case is extreme, unique, or has something special to reveal.” (Rowley, 2002:21). Furthermore, given the single-case design’s limitation of a single phenomenon making it unable to provide a generalised conclusion (Meyer, 2001; Zainal, 2007), Baxter & Jack (2008) states that the context of the phenomenon being explored must be considered. “The second type of design is

a multiple-case design, in which conclusions are drawn from a group of cases. Multiple-case designs are appropriate when the same phenomenon is thought to exist in a variety of situations. Under these circumstances, each individual case study still must be rigorously conducted, but the collection of several case studies on the same topic is intended to be the basis for replicating or confirming the results” (Yin, 1981:101). The qualitative case study approach demands instruments that allow the study to be comprehensively viewed within their contexts (Gustafsson, 2017). Precisely, an exploratory research based on a single case study was used in this study to generate an in-depth understanding of what knowledge and how beginner Physical Sciences teachers utilised PBL before and after the TPD programme. Case study designs are mainly used for inductive exploration of a phenomenon that is not well understood yet (Gammelgaard, 2017).

Exploratory research design is an investigation that intends to achieve new insights into a case with little to no research knowledge available (Akhtar, 2016; Rizvi & Bhardwaj, 2019). According to Van Wyk (2012), exploratory research design is relevant for studies with high levels of uncertainty about the subject, and the case that is not well understood. Radojevich-Kelley and Hoffman (2012) see the exploratory case study as a method that utilises multiple sources of evidence to examine phenomena within their actual contexts with the strength of examining a series of activities over time on a group of participants. In another opinion, Yin (2003) states that exploratory case study design is employed if the research question asks ‘what’. Qualitative research utilises various data generation instruments such as small-group discussions; semi-structured interviews; in-depth interviews; and analysis of texts and documents (Hammarberg, Kirkman & de Lacey, 2016). In extension, Lopez and Whitehead (2013), Whitehead and Whitehead (2016) point out that qualitative data generation can be *direct data* which is generated through recordable spoken or written words and also observable body language, actions and interactions, or *indirect data* which is generated by someone or something else, such as with documents or photographs reporting an event or an artistic rendition.

Qualitative case study design “aims to examine real-life actual research problems and phenomena in detail” (Turhan, 2019:126). This study focused on the single case of 5 beginner teachers, from 5 different secondary schools in the same district. In the study, the researcher looked at the case of beginner Physical Sciences teachers’ utilisation of the PBL approach while teaching PNM. According to Poni (2014), qualitative research commences the project

with an inductive stance from a particular situation, leading to a theory generated from data. As much as this study was not after theory generation, qualitative data was generated from the participants' responses and practices to infer conclusions. This design allowed gaining an understanding of the extent of beginner Physical Sciences teachers' use of PBL to enhance 21st-century skills before and after a teacher professional development (TPD) programme for affordance of SDL. In corroboration with Dörnyei (2003:47) who states that the researcher "does not know the range of possible answers and therefore cannot provide pre-prepared response categories", this study perceived open-ended questionnaires, semi-structured interviews and "reflective" portfolios to be the best instruments to generate useful qualitative data.

3.3 Philosophical Orientation

Rehman and Alharthi (2016) describe a paradigm as a basic belief system and theoretical framework of understanding the reality of the world and studying it through four components such as ontology, epistemology, methodology and methods. Willis (2007:8) states that "a paradigm is thus a comprehensive belief system, world view, or framework that guides research and practice in a field". Literature outlines few different paradigms to conducting an educational research which include: Interpretivism, Positivism, Critical theory and Post-Positivism (Willis, 2007; Elshafie, 2013; Tracy, 2013; Al Riyami, 2015; Rehman & Alharthi, 2016). However, the aforementioned research paradigms will not all be fully elaborated on except one relevant for this study. Rehman and Alharthi (2016) suggest that a researcher who focuses on one research paradigm and ignores other research paradigms cannot appraise research conducted under a different tradition.

Mack (2010) sees the positivist paradigm as a scientific paradigm with a purpose of research to either prove or disprove a hypothesis. To Lee (1991:343-344) "the positivist approach involves the manipulation of theoretical propositions using the rules of formal logic and the rules of hypothetico-deductive logic, so that the theoretical propositions satisfy the four requirements of falsifiability, logical consistency, relative explanatory power, and survival." Positivist paradigm has limitations that led to the emergence of post-positivism (Rehman & Alharthi, 2016). The positivistic epistemological position is objectivism where the researcher enters the world impartially, discovering absolute knowledge about an objective reality; and the researcher and the participants are independent entities (Scotland, 2012). Positivism and

post-positivism share ontological and epistemological beliefs. Methodology of positivist paradigm is embedded in the scientific method, statistical analysis, and generalisation of findings (Mack, 2016). The ontology of positivism is positioned in realism (Rehman & Alharthi, 2016); thus, positivism addresses causal relationships and basic regularities between different components of the real world (Al Riyami, 2015). This study was not after causal relationships and did not employ positivism and post-positivism paradigms. Limitations that existed within the positivism and post-positivism paradigms led to interpretivism (Mack, 2010).

Interpretivism paradigm contrasts with positivist paradigm such that data generated is objective to test a well-established theory (Lee, 1991; Walsham, 1995). Al Riyami (2015) describes interpretivism as a constructivist paradigm convinced that knowledge is socially constructed. Interpretivism is associated with qualitative studies that are inductive and emergent and it does not intend to generalise its findings (Elshafie, 2013). Interpretive ontology is anti-foundationalist where knowledge is socially constructed by multiple realities; truth and reality are created rather than discovered (Rehman & Alharthi, 2016). The interpretivistic epistemology is inter-subjective knowledge construction (Taylor & Medina, 2011). Interpretivism is generative of qualitative research methods such as case studies, interviews, and observation because they are arguably better ways of getting at how humans interpret the world around them (Willis, 2007). Although interpretive study abandons the scientific procedures of verification and cannot be generalised to other situations, it deliberately intervenes in the research setting to achieve change or improvement; its goal is the creation of focused theory for practice rather than generalisation (Mack, 2010). Failure of interpretivism to acknowledge the political and ideological influences on knowledge and social reality led to establishment of critical theory (Mack, 2010).

Emerging to offer a radical alternative to the established paradigms of positivism and interpretivism, critical paradigm is a philosophy of science that is founded upon necessary truths about the nature of the world (McEvoy & Richards, 2006). The ontological position of critical (paradigm) theory is based on relativism where reality is socially constructed through the media, institutions and society (Al Riyami, 2015). Al Riyami (2015:414) further elaborates that common methodologies found within critical theory (paradigm) are: 1) action research, which is a systematic study that combines action and reflection with the intention of improving practice; 2) critical discourse analysis, which aims to “capture the dynamic nature

of both power relations and text production by uncovering the hegemonic structures within texts”; 3) ideology critique, which illustrates hidden ideologies by revealing participants’ places in systems which empower or disempower them. “The critical paradigm embodies different ideologies such as postmodernism, neo-Marxism and feminism” (Mack, 2010:9). The prime purpose of critical paradigm is to identify, contest and interrogate the power imbalances within the society which fuel ethically questionable profit-making activities that result in broader systemic inequalities and injustices such as social and economic exclusion of some sectors of society, loss of cultural capital and cultural identity amongst ethnic minorities, and anthropocentric climate change and loss of biodiversity (Taylor & Medina, 2011).

This qualitative study was conducted within a philosophical framework of interpretivism paradigm. Interpretivism allows the researcher to view the world through the perceptions and experiences of the participants – for various perspectives and truth versions from participants are accepted (Thanh & Thanh, 2015; Yilmaz, 2013). Applied to educational research, interpretive paradigm enabled the researcher to build a rich local understanding of the life-world experiences of beginner Physical Sciences teachers and of the cultures of their classrooms (Taylor & Medina, 2011; Bertram & Christiansen, 2015). Interpretivism paradigm has some effects on qualitative case study design (Turhan, 2019). Therefore, this paradigm was found to be an interactive-participant approach and was influential in establishing how PBL could be implemented to equip beginner Physical Sciences teachers to promote 21st-century skills for affordance of SDL. Furthermore, interpretivism paradigm investigation, like a single case study design, does not intend to generalise conclusions. Walsham (1995) states that interpretive research, often being an in-depth case study, involves researcher’s frequent visits to the field site for the period of study. In corroboration, Walsham (2006), Harrison, Birks, Franklin and Mills (2017) posits that the researcher’s close involvement is beneficial for in-depth access to participants, issues, and data, moreover, participants can see the researcher is actively making valid contributions to the field site itself, rather than taking the data away and writing it up solely for the study. Interpretivism paradigm allowed the researcher work or/and visit teachers constantly generating data to answer the research questions by approaching the reality from beginner teachers’ own experiences since they started practising (Thanh & Thanh, 2015).

The three main philosophical dimensions that build up this paradigm are: one which relates to the nature of knowledge in the notion of multiple realities (ontology), the development of that knowledge which in this is formed through researcher-participant interaction (epistemology) and a disciplined way to investigate that knowledge (methodology), hence a qualitative case study in this study (Wahyuni, 2012). To understand the social world from the participants' experiences and obtain rich descriptions of their social constructs, interpretivism paradigm favours the researcher to interact with participants (Wahyuni, 2012), which is exactly what I did in this study. Although interpretive paradigm has limitations such as lacking the ability to yield general theories to larger populations and lack of objectivity, it uses a narrative form of analysis to describe specifics and highly detailed accounts of a particular social reality (Wahyuni, 2012; Rehman, 2016). The inability to yield general theories to larger populations is really not a limitation in this study because from the onset, generating a theory to larger populations has not been the purpose but the study sought to enhance Physical Sciences beginner teachers to utilise PBL in enhancing 21st-century skills in order to promote Self-Directed Learning (SDL) in the teaching and learning of Particulate Nature of Matter (PNM). Mindful that reaching a consensus can be problematic, legitimacy and trustworthiness was achieved without claiming uncontested certainty.

3.4 Data Generation Instruments

Data generation instruments are measurement tools aimed to obtain data in order to answer the research questions of the study. Open-ended questionnaire, portfolio (after classroom PBL implementation following the TPD programme), and individual open-ended interviews are the tools that were employed in this study gather the required data from the participants.

3.4.1 Open-Ended Questionnaire

According to Bulmer (cited by Bird, 2009:1307), “the questionnaire is a well-established tool within social science research for acquiring information on participant social characteristics, present and past behaviour, standards of behaviour or attitudes and their beliefs and reasons for action with respect to the topic under investigation.” Although questionnaires have some limitations, they have numerous strengths such as providing insights into social trends, processes, values, attitudes, and interpretations (McGuirk & O'Neill, 2016). This study employed an open-ended questionnaire to gather qualitative information required on background knowledge of participants regarding PBL and 21st-century skills for affordance

of SDL in the teaching of the topic –Particulate Nature of Matter (PNM) in order to address the first research question. An open-ended questionnaire is a tool used to corroborate and illustrate the participants’ responses by providing valuable information (Bird, 2009), which was used to organise an effective TPD programme to their needs. An open-ended questionnaire used in this study was self-developed by the researcher with the help of an expert in the field of PBL to ensure reliability and validity to inform the nature of the TPD programme and ultimately to address the research question(s) of this study. It consists of two sections; firstly, the *background section* and second, the *questions* related to the construct(s) under investigation. Background data has eight questions, and construct-related questions are twenty-two. Examples of such questions include: “*How do you describe your teaching of Particulate Nature of Matter concepts?*”; “*What is your understanding of Problem-Based Learning?*”; “*List five 21st-century skills that you know*”; and “*Explain how you inculcate and develop the 21st-century skills (if any) you mentioned in your learners.*” As anticipated, open-ended responses allowed the researcher to understand and present the world as it is seen and experienced by the participants (Yilmaz, 2013). A copy of a completed open-ended questionnaire is attached (see Appendix A).

3.4.2 Teacher Professional Development (TPD) programme

A Teacher Professional Development (TPD) is defined by Darling-Hammond, Hyler and Gardner (2017) as a structured professional active learning (can involve any relevant learning activity that is formal or informal and self-directed) conducted within a sufficient duration that results in changes and ensure competence to teachers’ knowledge and practices, and improvements in learners learning outcomes. In addition to the preceding definition, this study further sees a TPD a systematic approach that can inform teachers on how to implement the new knowledge in a way that will not increase or negatively impact on their work and allowing for long-lasting relationship with the facilitators. PBL TPD programme is pivotal to achieving the purpose this study.

As mentioned earlier in Chapter 2, a one-day PBL TPD programme was conducted for the participants in this study. The purpose of this PD programme was to enhance the use of PBL by beginner Physical Sciences to promote 21st-century skills while teaching PNM. TPD for in-service teachers is seen as an important factor in improving South African education and improving teachers’ confidence (Christiansen & Bertram, 2019). TPD conducted in this study corroborated Darling-Hammond *et al.* (2017) and Bates and Morgan (2018)’s seven

characteristics of an effective TPD outlined earlier in Chapter 2. It was expected that engaging beginner teachers in long-term in-depth learning opportunities that address the content and pedagogy relevant to the curriculum taught in their classes such as PBL TPD might enhance the use of PBL in their teaching of PNM, thus promote the 21st-century skills and boost Self-Directed Learning (SDL) amongst their learners (DBE, 2011). According to Turiman, Wook and Osman (2019), the acquisition of the 21st-century skills is associated with SDL. The TPD intervention programme for this study was conducted at the NWU Mafikeng Campus. The duration of the TPD programme was 8 hours which ran from 9h00 until 17h00 and there were two 15-minutes tea breaks and a 30-minutes lunch. The researcher was assisted by an expert from PBL sub-area of SDL research entity from the NWU to run TPD programme together with the researcher assistant. The participants worked together one group of 5 members. The group members remained with the same roles (group-leader, scribe, researcher and presenter) for the entire TPD training. The necessity of this approach was to honour the traditional approach of PBL hence participants were in a small group.

The PBL expert first introduced the PBL approach and stated the intervention objectives. The researcher discussed the 21st-century skills as seen by this study. The researcher then introduced PNM problem and explained it to the participants. The participants were given a problem to work on and the researcher with the assistant and the expert facilitated the intervention programme. The participants had one (1) problem to work on for three (3) hours before lunch about the content (PNM) and PBL, and one (1) problem to work on for two (2) hours after lunch about teaching (PBL) of the content to enhance 21st-century skills for affordance of SDL. Example of a PBL problem that was given to the participants is as follows:

Problem 1: Chemistry of Matter and Materials (Particulate Nature of Matter).

The central heating in your home during winter season is the cooking stove. You realised that you could warm your kitchen by turning on the stove and keeping the oven door open. During the evening summer season, it is hot and you cannot open windows due to mosquitos flying inside the house. Some of your classmates are of the opinion that you could cool your kitchen by leaving the refrigerator door open. However, your parents disagree with your classmates' views. When you discuss this with your chemistry teacher, where after she/he then decided that you have to solve this problem in your PBL groups. In your PBL groups you have to do research and inform the rest of the class of your findings of above-mentioned problem.

It is noteworthy to mention that the Physical Sciences (chemistry) content for this problem was aligned with Curriculum and Assessment Policy statements (CAPS). Furthermore, this PBL problem was properly planned and aligned with the Annual Teaching Plan (ATP) 2020 – the content of the problem was for term 1 (January-March) which is when the PBL was implemented. The above problem was given to the participants to work on during the TPD since it was intended to be used during the PBL implementation with their learners. However, all other problems included both the content knowledge and pedagogical knowledge of the topic of the PNM. While on the PNM content, the Chemistry expert discussed CAPS document and the importance of adhering to it. Then the researcher further highlighted the 21st-century skills discussed in this study as outlined by CAPS. The grade 10 PNM content focused on in this study is outlined on Figure 3.1 as extracted from the Physical Sciences CAPS document.

Time	Topics Grade 10	Content, Concepts & Skills	Practical Activities	Resource Material	Guidelines for Teachers
2 HOURS	<u>States of Matter and the Kinetic Molecular Theory</u>	Physical state is only one of the ways of classifying matter. The Kinetic-molecular theory and intermolecular forces are the basis for solid, liquid, gas and solution phenomena.			Revision of matter and states of matter is the bigger picture.
1 hour	Three states of matter	- Verify the particulate nature of matter by investigating diffusion and Brownian motion - List and characterize the three states of matter - Define freezing point, melting point and boiling point - Identify the physical state of a substance at a specific temperature, given the melting point and the boiling point of the substance - Define melting, evaporation, freezing, sublimation and condensation as changes in state - Demonstrate these changes of state	<u>Prescribed experiment for formal assessment</u> Draw the heating and cooling curve for water. Start with ice in a glass beaker and use a thermometer to read the temperature every 1 minute when you determine the heating curve of water. Do the same with the cooling curve of water starting at the boiling point. Give your results on a graph	Materials: Burner, glass beaker, ice water and a thermometer.	An activity that classifies a variety of compounds and combines all these properties, including KMT, would be useful to revise the content. To save teaching time it is recommended that integrates teachings and practical work is used as strategy for this topic and all other topics
1 hour	Kinetic Molecular Theory	Describe a solid, a liquid, and a gas according to the Kinetic Molecular Theory in terms of particles of matter	Use play dough or marbles to represent gases liquids and solids. explain the levels: macroscopic, sub-microscopic and use use symbols effectively		

Figure 3.1: Physical Sciences CAPS document extract of PNM

As mentioned earlier in Chapter 2, under the theoretical framework section, the implementation of PBL is generally without any lectures or tutorial sessions, and learners are typically working together within small groups (Havenga & Van Wyk, 2017). However, the participants were informed of PBL and its benefits, and the objectives of the intervention programme were explicitly stated. Finally, PBL expert facilitated and engaged on the PBL lesson plans and PBL assessments (both teacher- and learner-based assessments). Wei, Darling-Hammond and Adamson (2010) state that a sustained TPD for beginner teachers goes more than eight hours in duration. Therefore, it is important to state that post the one-day intervention programme with the beginner teachers, the researcher continued to engage with the teachers on one-on-one basis to assist with the lesson planning and compilation of the portfolio (advising on how to introduce the lesson, grouping of learners looking at the number of learners a teacher has in a classroom respectively; how to capture the sample of questions learners; and how to observe and capture the 21st-century skills while implementing PBL) until it was ready for submission – especially the reflection section to ensure the use of PBL in affordance of SDL for the learners was well practised. Furthermore, the researcher continued to engage with the teachers in order to try to minimise or assist with the challenges

that the teachers were faced with. Such challenges may include time, implementation (observing the PBL process and capturing 21st-century skills), teaching aids (models), and so forth. Although research does not outline a duration of a productive TPD, it may be important to state that the TPD process was continuous and not only one day. There was a continual interaction of each teacher participant with the researcher and the PBL expert on daily basis till the topic PNM was completely taught. The one-day was for all participants in one room but the researcher continued to meet with each participant individually on daily basis. Due to the number of periods Physical Sciences must have and various periods duration, the PNM topic was anticipated to be taught for a week as outlined on Figure 3.1. However, number of days regarding the teaching of this topic is further elaborated on the later section 3.6 with the 2020 ATP. A description of the one-day TPD intervention programme is shown in Table 3.1.

Working together in one group, each participant was expected to have at least one duty such as being a scribe, researcher, leader and/or presenter. By working together, it was expected that communication and collaboration skills might be promoted. Attempting to solve the *problem* given was expected to promote critical thinking and creativity.

3.4.3 Portfolio compilation

“Portfolios provide rich information regarding the curriculum and its implementation” (Alabdelwahab, 2002:45). Portfolios can serve different purposes, for instance, they can be used to observe progression in teacher professional development to promote teaching and learning (Smith & Tillema, 1998). “The portfolio is used as a document in and alongside professional practice for integrating evolving thoughts and actions and is directed by personal goals and learning needs” (Tillema, 2001:127). In this study, a portfolio compilation by each participant was required to document a long-term development in the sense that the portfolio was presented and given during the TPD programme. The portfolio consisted of compiled various data that is described later in this section post TPD while teaching PNM in their classrooms to capture the experiences and changes that might have come with the implementation of PBL.

Table 3.1: Outline of one-day Problem-Based Learning Teacher Professional Development programme

Time	Activity
09h00	Introductions, objectives and 21 st -century skills
09h30	Breakaway groups (2) Working on problem 1
11h00	Tea break
11h15	PNM content and CAPS document
11h30	Presentation; discussion; reflection (both groups)
12h45	Lunch
13h30	Commencement into groups Working on problem 2
15h15	Tea break
15h30	Consolidation
15h45	Presentation; discussion; reflection
17h00	Closure – end of the programme.

This study conceptualised portfolio use as a relevant strategy and technique to address this study's research questions. This study adopted the definition by Smith and Tillema (2003) which states that a portfolio is a reflective tool that is purposeful and personal with collected array of work providing evidence of growth and accomplishments. A portfolio was intended as a data collection tool regarding participants' progress, perceptions and experiences during their teaching. Additionally, the portfolio was also intended to capture what the researcher would observe if he was there. Darling-Hammond *et al.* (2017) posit two important points: (1) According to literature effective PD influences on teacher pedagogical knowledge and/or practices but does not measure learners' responses. (2) Feedback and reflection are critical factors to help the teacher when PD is involved. A portfolio is described by Edgerton, Hutchings and Quinlian (cited by Khan & Begum, 2012:368) as follows:

- “Portfolios provide documented evidence of teaching that is connected to the specifics and contexts of what is being taught.
- They go beyond exclusive reliance on student [teachers] ratings because they include a range of evidence from a variety of sources.

- In the process of selecting and organizing their portfolio material, faculty [teachers] think hard about their teaching, a practice, which is likely to lead improvement in practice.
- Portfolios are a step toward a more public, professional view of teaching. They reflect teaching as a scholarly activity”.

Therefore, this study found the portfolio to be a relatively good tool for the teacher to report and reflect on the learners and the teaching and learning approach. The whole PBL lesson taught about the PNM was captured in various contents of the portfolio which are:

1. PBL lesson plan;

The contents of the PBL lesson plan(s), aimed at addressing the first research question, are PNM concepts, learners’ grade and number for evidence.

2. PBL problem(s) used during implementation;

The PBL problems chosen by teachers during implementation are aimed at observing the correlation between the PNM content and the learning issues. The PBL problem during implementation is the driver of the teaching-learning situation for evidence.

3. Teacher and learners’ roles during PBL implementation;

The beginner teachers’ knowledge on the PBL process underpinning the teacher’s and learners’ roles were considered satisfactory during data analysis in Chapter 4. However, this study acknowledges minor difference and modifications regarding theoretical and practical perspectives concerning each beginner teacher’s realities.

4. Learners’ worksheets;

Learners’ group reports submitted to the teacher at the end of the lesson was captured inside the portfolio. The learners’ work served as evidence of the topic, the PBL problem used and to see number of learners in PBL groups.

5. 21st-century skills observed, teacher-based and learner-based assessment rubrics.

The portfolio had a template (see Appendix B) regarding the four 21st-century skills discussed in this study for the teacher to indicate and comment on each skill observed if any. Furthermore, the portfolio had a teacher’s rubric to assess learners’ work (see Appendix K). Finally, the portfolio had learners’ rubric to assess themselves on the PBL process as a team and individual reflection during the PBL lesson (see Appendix

L). The teacher's and learners' rubrics are discussed in detail later in this chapter on section 3.7.2.

6. Details of what happened during the PBL lesson;

Data regarding what happened during the PBL lesson is aimed at observing how the teacher as a facilitator introduced the PBL process, description of learners' PBL groups, and some of the questions asked by learners during the PBL teaching-learning situation.

3.4.4 Interviews

Kassu (2019) describes interviews as a loosely structured qualitative in-depth dialogue with people who are considered to be particularly knowledgeable about the topic of interest. For this study, semi-structured interviews were used. Semi-structured interviews are usually conducted in a face-to-face setting which permits the researcher to seek new insights, ask questions, and assess phenomena in different perspectives. During the interviews, open-ended questions ask participants for both facts and opinions; and also allows for follow-up questions and prompts based on the given answers (Dikko, 2016). Although open-ended interviews allow the participants to contribute as much detailed information as they desire, it can be difficult for one to find similar themes and codes from the interview transcripts which on the other hand can minimise the biases in the study (Turner, 2010). In this study, open-ended questions were used for individual face-to-face interviews to explore the views, perceptions, and experiences of participants. Interview questions were self-developed by the researcher, SDL-PBL expert and the study leader.

The interview questions were of a general nature on teacher participant's teaching approaches which were open-ended and some of the questions needed further elaboration and probing. Some questions focused on TPD programmes, some on implementation of PBL while teaching PNM to enhance 21st-century skills, and some on the compilation of the portfolio. In her study, Rollnick's (2017) approach in her study was adopted where the interview was the last tool to be used aimed at capturing further insight to allow for connections to be made about the whole research data. The advantages of an interview were that the interviewer could adapt the questions where necessary and probe during the interview process in order get a clearer response to questions as suggested by Dhurumraj (2013). Examples of interview questions asked include: *How would you describe your experience about the workshop*

programme? Explain the impact (if any) of the workshop on your knowledge/teaching regarding 'problem-based learning'. Explain the impact of the workshop on your teaching regarding 'self-directed learning' and '21st-century skills'? Explain how you benefited from the workshop? Tell me about your teaching before and after the workshop? How would you describe utilising problem-based learning in teaching 'Particulate Nature of Matter'? Appendix C provides a full version of the interview questions.

3.5 Site Selection, Sampling Technique and Sample

This section provides the site selection, sampling technique and the sample pertaining to this study. The participants in this research study were beginner Physical Sciences teachers who were purposively sampled from various secondary schools of the North West Province and in the Ngaka Modiri Molema (NMM) District. These included rural, urban and township secondary schools and participants were teaching in these schools.

3.5.1 Site Selection

The study was conveniently conducted in one (NMM) out of the four districts of the North West province in South Africa due to geographical proximity and accessibility to the researcher. NMM District consists of various Area Offices which include; Ramotshere Moiloa, Mahikeng, Ratlou, Ditsobotla and Tswaing. The map below, Figure 3.2, outlines the North West province divided into four districts and their various Area Offices respectively. The participants in this study were from all the 4 Area Offices of the NMM District, excluding Tswaing.

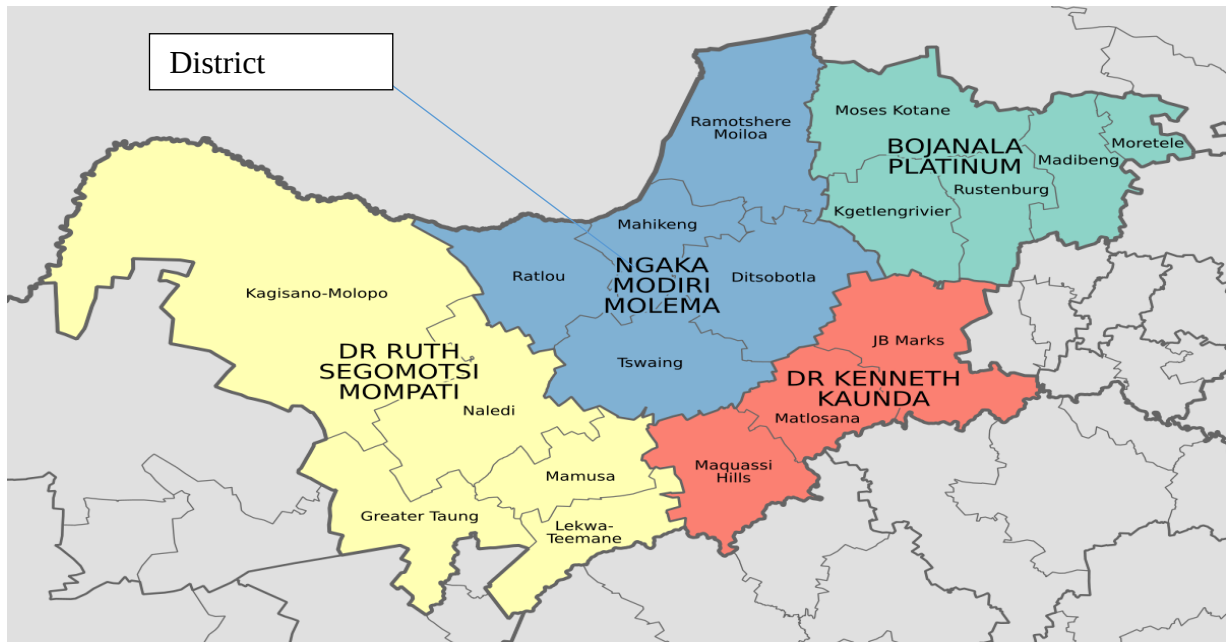


Figure 3.2: Demarcation of Ngaka Modiri Molema District

(https://en.wikipedia.org/wiki/List_of_municipalities_in_the_North_West) 20/10/2019

3.5.2 Sampling technique and Participants

Purposive sampling was employed in this study to identify a small number of participants and obtain rich information that addresses the research questions of this study (Patton, 1990; Yilmaz, 2013). Purposive sampling allows for the specific identification of information-rich cases (Etikan *et al.*, 2016; Whitehead and Whitehead, 2016). This study extended the sampling by further utilising the snowballing technique which is a form of purposive sampling. Snowball sampling is identification of participants by asking the initially identified participants to suggest other possible candidates (Farrugia, 2019). This technique was necessary for sampling of this study due to the difficulty to access Physical Sciences beginner teachers. A sample can refer to a total quantity of the things or cases, usually people which are subject to be studied in a research (Etikan, Musa & Alkassim, 2016). “In qualitative research, there are no overall formal criteria for determining sample size and, therefore, no rules to suggest when a sample size is small or large enough for the study” (Whitehead & Whitehead, 2016). Moreover, Boddy (2016) argues that qualitative research questions are not answered based on the sample size. The in-depth data required due to the methodology chosen for this study to answer the research questions determined that a small sample was

selected to ensure in-depth data collection strategies and prolonged engagement at participants' sites.

3.5.2.1 Teachers

This study utilised purposeful sampling by identifying and studying participants who possess particular knowledge being sought for (Etikan *et al.*, 2016), and in this case, beginner Physical Sciences teachers. The participants should have taught for less than 5 years to be classified as beginner teachers. The snowballing method was employed and allowed the researcher to ask the first few participants to refer him to other potential participants who share same characteristics as them (Li *et al.*, 2018). In this study, the researcher asked the first two beginner Physical Sciences teachers to refer him to other beginner teachers they know, who referred to others until the number of required participants was attained. The participants of this study were 5 beginner Physical Sciences teachers from different schools in the aforementioned district. Pseudonyms were allocated to these participants to protect their identity as further explained under the ethical consideration section in this chapter (section 3.10). In order to protect the confidentiality in this study, pseudonyms were allocated participants (Mukungu, 2017). As alluded by Yimaz (2013), the reason for selecting 5 participants was to exploit in-depth data collection strategies used in this study. This ensured that the research problem under investigation was studied through a range of lenses which allowed multiple angles of the phenomenon to be uncovered and scrutinised. In selecting 5 participants, an in-depth exploration of the use of PBL by the beginner Physical Sciences teachers in the teaching of PNM to promote 21st-century skills was achieved. The beginner Physical Sciences teachers are those with 5 years or fewer of teaching experience as mentioned earlier. For up to 5 years, this study suggests there shall be little mastery of teaching experience. Beginner Physical Sciences teachers were expected to have knowledge about the PNM – a broad topic they teach under “Matter and Materials” in the South African Physical Sciences Curriculum and Assessment Policy Statement (CAPS) (DBE, 2011:8).

Table 3.2: A summary of the participants' biographical data

Item	Soros	Rapula	Koti	Lucas	Kganya
GRADE(S) TAUGHT	10	10; 11; 12	10; 11	10	10
Average number of learners per grade level	5 learners	12 learners	20 learners	22 learners	20 learners
TEACHING EXPERIENCE	2 years	3 years	2 years	1 year	3 years
QUALIFICATIONS	B. Ed	B. Ed	B. Ed	B. Ed	B. Ed
SPECIALISATION	Physical Sciences & Mathematics	Physical Sciences & Mathematics	Physical Sciences & Life Sciences	Physical Sciences & Mathematics	Physical Sciences & Mathematics

Table 3.2 presents biographical information of the 5 beginner Physical Sciences teachers sampled for this study. All the beginner teachers had less than 4 years teaching experience. Soros and Rapula are teaching in farm secondary schools. Teacher Soros was teaching only grade 10 Physical Sciences. Rapula was teaching grade 10-12 Physical Sciences. Koti's school may be classified under the former 'Model C' schools. Koti was teaching grade 10 and 11 Physical Sciences. Lucas and Kganya are teaching in township secondary schools where each taught grade 10 Physical Sciences.

3.5.2.2 Learners

Each teacher selected one Grade 10 class which he or she worked with in the study. Soros and Rapula, each had one class of 5 learners. As a result of a small roll, their learners were the Physical Sciences class where PBL was implemented. Koti, Lucas and Kganya had two Grade 10 classes, each randomly selected one class to implement PBL in the teaching of PNM. Table 3.3 shows the number of learners for each teacher specifically for the grade 10 Physical Sciences class they utilised PBL in.

Table 3.3: Each participant's number of learners in a grade 10 classroom

Teacher	Number of learners
Soros	5
Rapula	5
Koti	27
Lucas	26
Kganya	41

PBL was implemented in the teaching of the PNM in the grade 10 Physical Sciences classroom by each of the teacher participants. During implementation, these learners were divided to work into PBL small groups of 5 or 6 members. Due to a consequence of low roll of learners of Soros and Rapula, each had only one PBL group of 5 members. Koti divided his learners into five groups where three groups had 5 members and two groups had 6 members. Lucas divided his learners into four groups of 6 members in two groups and 7 members in the other two groups. Contrary to the number of members required per PBL group as done by other teachers, Kganya divided her learners into three groups of 10 members and one group of 11 members. After they (Koti, Lucas and Kganya) divided learners into few groups, each teacher focused on one PBL group for a thorough observation of PBL process and the promotion of the 21st-century skills.

3.6 Research Methods

Firstly, the independent person assisting the researcher met participants individually during the weekdays in their free or convenient times to request their participation in the study. The independent person further met with the participants at the places that were convenient and comfortable for the participants to complete the open-ended questionnaire. It is important to note that beginner teachers' knowledge about 21st-century skills was expected to be unsubstantiated. Secondly, the independent expert PBL person assisting the researcher together with the researcher arranged an intervention programme where the participants engaged in the implementation of PBL on the topic of the PNM as discussed above under *Teacher Professional Development (TPD) programme*. The participants were given a problem on the PNM to work on, aimed at promoting the 21st-century skills. After the intervention programme for implementing PBL, the participants were expected to teach a short curriculum-based PNM content section outlined on Table 3.4 through a PBL approach.

Table 3.4 is an extract from the Physical Sciences ATP 2020 formulated from CAPS document (see Table 3.1) that teachers must follow. As discussed in Chapter 2, section 2.5, Table 3.4 shows a part of PNM content section which beginner teachers taught. This extract further shows other aspects such as cumulative percentage for curriculum coverage, a week in which the content must be taught, amount of days and time to be spent on the content, the specific outline of how the content must be covered, practical activities that can be done and finally, the prescribed experiment to be done for formal assessment “the heating curve of water”.

Table 3.4: Extract from the Physical Sciences ATP 2020 formulated from CAPS

% cumulative	Week	Time frame		Topic	Content, Concepts and Skills	Practical activities	Date completed
				States of Matter and the Kinetic Molecular Theory	Physical state is only one of the ways of classifying matter. The Kinetic-molecular theory and intermolecular forces are the basis for solid, liquid, gas and solution phenomena		
1.5 %	3	27-31 Jan 5 days	1 Hrs	Three states of matter	□ Verify Particulate Nature of Matter by: ◆ Diffusion ◆ Brownian motion. □ List and characterize the three states of matter □ Define: ◆ Freezing, boiling & melting point ◆ Melting, evaporation, freezing, sublimation and condensation as changes in state □ Identify the physical state and change of state of a substance at a specific temperature, given the mp and the bp of the substance.	◆ Use play dough/marbles to represent each phase ◆ Explain macroscopic, submicroscopic ◆ Use symbols (g, l, s)	
2.4 %			1 Hrs	Kinetic Molecular Theory	□ Describe a solid, a liquid and a gas according to the Kinetic Molecular Theory in terms of particles of matter.		
					Prescribed experiment for formal assessment: □ Heating curve of water. Give results on a graph.		

Each participant then compiled and submitted a portfolio where they reflected on their experience, progress and evaluation of both the TPD and the implementation of PBL while teaching PNM. As stated on section 3.4.3, the portfolio also outlined the PBL activities that were given to the learners. Finally, after answering open-ended questionnaire, attending the intervention programme and implementation of PBL while teaching PNM and on days preferred by participants, this study employed individual interviews which were audio-recorded and participants were requested to elaborate their responses to allow them to be as candid as possible in providing insight on the open-ended questionnaire, TPD programme, PBL implementation and on the portfolios submitted. Then each audio recording was transcribed and analysed using open coding sought supporting evidence to triangulate with other data. Some open-ended questionnaire questions were rephrased and used for interviews purposes as mentioned before.

3.7 Data Analysis

Gardner (2009) defines data analysis as data inspecting, cleaning, transforming and modelling with the intention of highlighting useful information, suggesting conclusions to answering research questions in order to address the research problem. Data analysis in this study was inductive. “The inductive approach is a systematic procedure for analysing qualitative data in which the analysis is likely to be guided by specific evaluation objectives” (Thomas, 2006:238). In this study, the inductive approach refers to analysing raw data using an analytical tool to draw concepts, themes, or a model through interpretations made from the raw data by the researcher. This section presents how data from various data generation instruments was analysed. First presented is the data analysis for open-ended questionnaires and semi-structured interviews. This is followed by data from the portfolio.

3.7.1 Open-Ended Questionnaire and Semi-Structured Interviews

This study adopted the Saldaña’s (2009) model as the analytic tool. According to Stuckey (2015), coding is preparatory work for high order thinking about the study; moreover, coding is in itself analysis. In this study, coding used categorised data transcribed from *open-ended questionnaires, portfolios and individual interviews*. To Thomas (2006), this is a process of reading, identifying texts relating and answering research questions, categorising those texts to reduce overlaps and incorporating important categories to create a small number

summarising categories. Usually a summarising phrase, name or label for a segment of data is ascribed and accounts for each stretch of data. As in many studies, these labels are placed at the beginning of the data analysis. I read through the whole transcribed qualitative data, specifically the interview transcripts, and then attach labels line by line. Codes were assigned to segments of the text (examples include: Staying on task, collaboration and contributing equitably, produce quality work and distribution of tasks among others) a process known as open coding. I applied manual coding and no computer-assisted software programme was used throughout the whole data analysis process.

After open coding, data was put back together through axial coding. Determining dominant themes and patterns in this research was the primary purpose of axial coding, then reducing and reorganizing the data. The result of axial coding was a list of categories (examples include: quality of the group outcome as a measure of success, improvement of both the process and the outcomes, enhancement of Self-Directed Learning (SDL), and responsibility and evidence of interdependence among others). Themes (examples include: collaboration, critical thinking, communication and creativity) were then generated from these categories. Saldaña (2009), describes the process of going from codes to themes and this was employed in this study as shown in Figure 3.2.

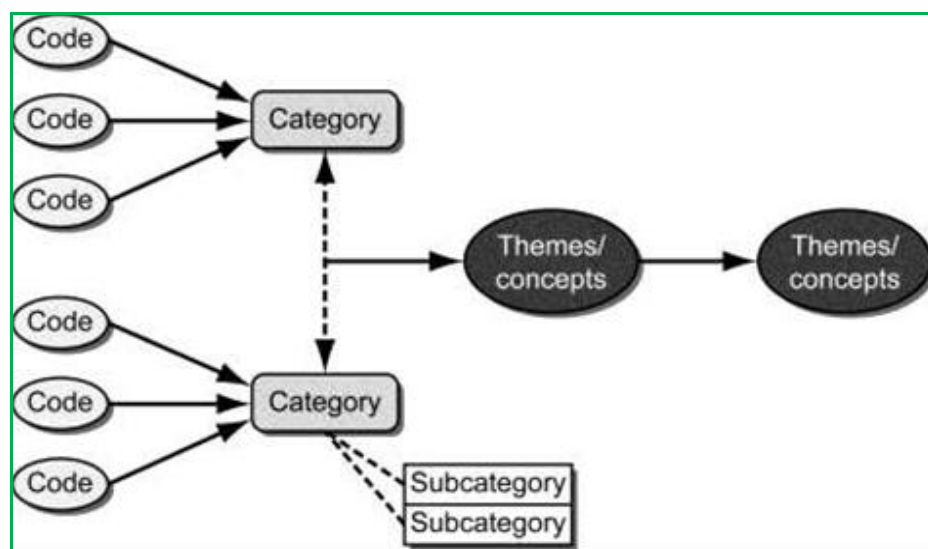


Figure 3.3: Saldaña's codes theory model for qualitative inquiry adopted (2009:12)

Before drawing conclusions, results were fully explicated and discussed during and after corroborating the questionnaire, interview and portfolio data (prior and post intervention).

3.7.2 The Portfolio

“Portfolio assessment can measure teachers' content knowledge, intellectual and problem-solving abilities, pedagogical skills, curriculum knowledge, insight, and knowledge of learners” (Smith, Harris, Sammons, Waters, Jordan, Martin, Smith & Cobb, 2001:29). Firstly, a rubric was used to evaluate each participant's entire portfolio ensuring that all aspects of PBL were covered. Andrade, Wang, Du and Akawi (2009) define a rubric as a document that articulates the expectations for a project by listing the criteria, or what counts, and describing levels of quality in a way that indicates if the project was correctly or incorrectly done. Three researchers (one assistant supervisor and two Master's students working in the field of Science Education), who had been previously trained on the instrument, all specialising in the field of Science Education, independently went through all five portfolios, and produced scores for assessing the implementation of PBL and promotion of 21st-century skills for SDL in the teaching of PNM by beginner physical sciences teachers, for each of the five sections of the adapted Smith *et al.* (2001) instrument. The same colleagues validated the scoring of Golightly's teacher-rubric (2013) instrument adapted as an analytical tool for assessing learners' PBL process and submitted report on different areas.

The Interstate New Teacher Assessment and Support Consortium (INTASC) performance standards scoring rubric from Smith *et al.* (2001) instrument was adapted for this study as an instrument for data analysis to assess the developing competencies of the beginner teachers. In their rubric, Smith *et al.* (2001) had 10 INTASC principles served as the basis to be evaluated, which this study modified and reduced to 6 INTASC principles. Four principles were dropped which had nothing to do with what the study was aimed at for the relevant purpose in the portfolio, and an example of such a principle is ‘partnerships with school and community’ (see scoring rubric attached as appendix M). Second, researchers were required to score according to data sections inside the portfolio by responding to each of the 6 principles on a scoring criteria ranging from 4 = Clear, convincing and consistent evidence; 3 = Clear evidence; 2 = limited evidence; 1 = No evidence. Finally, the indication checklist was adapted based on the modified principles. In scoring, each item response was allocated 1, 2, 3 or 4 from “no evidence” to “clear, convincing and consistent evidence”, respectively. A high score (maximum = 24) is taken to mean that the overall proficiency of PBL implementation was *highly satisfactory* and a low score (minimum = 6) means that there is no evidence of PBL implementation at all and *unsatisfactory*. This rubric is further described on results

presentation in Chapter 5. The unique aspect of this study was twofold: assessing the implementation of PBL and promotion of 21st-century skills for SDL in the teaching of PNM by beginner physical sciences teachers; this is therefore what the portfolio reflected by means of INTASC principles.

Lastly, two rubrics (teacher- and learner-based assessments) were used to assess the learners' work in groups. The teacher-based rubric was adapted from NWU Faculty of Education Geography Department (Golightly, 2013) and it assessed learners' PBL process and submitted report on different areas (see Appendix K). Initially, Golightly's rubric (2013) criteria categories and weightings are as follows: demarcation of the problem (4); formulating of the learning objectives (8); the scope and quality of the provisional research (20); the use of recent literature, resources and data (8); identification and recommendation of possible solutions for the problem (12); writing skills (4); and referencing (4). The total marks in Golightly's rubric is 60. During adaptation, the use of recent literature, resources and data, and referencing were removed since learners' primary sources are prescribed textbooks approved by the provincial Departments of Education. Golightly's (2013) assessment rubric for PBL activity criteria in this study (Chemistry – PNM) after adaptation was as follows: demarcation of the problem (4), formulation of learning objectives (12), the scope and quality of the provisional research (20), identification and recommendation of possible solutions to the problem (20), and writing skills (4) retaining the overall total mark of 60. The weighting of 'formulation of learning objectives' was adjusted from 8 to 12 and 'identification and recommendation of possible solutions to the problem' weighting was adjusted from 12 to 8, while all other categories retained their original weightings. This rubric is further described on results presentation in Chapter 5.

The learner-based rubric was adopted from the University of Rochester Life Sciences Learning Centre (Family Secrets, 2009) and it evaluated PBL problem-solving, teamwork and processing skills for the group. This rubric which became an analytical tool had 19 areas to assess team members' skills such as "identifies relevant facts (*'what do we know?'*)"; "distribute tasks" and "effectively reflect on teamwork". It is worth noting that the learner-based rubric had 5 assessment levels for problem-solving, teamwork and processing skills namely: 1. Limited; 2. Developing; 3. Proficient; 4. Advanced; and 5. Exemplary. The level ticked by the learners signified the extent at which that skill manifested. Furthermore, learner-based rubric included three (3) problem-solving and teamwork reflection questions.

An example of such a question is “Suggest one specific, practical change the team could make that would improve the teams’ leaning, problem solving or teamwork skills” (see Appendix L). This rubric is further described on results presentation in Chapter 5. The relationship between the two rubrics is further shown in Chapter 5. The two rubrics were used for assessing learners’ group work. Golightly’s (2013) assessment rubric for PBL activity and Family Secrets’ (2009) PBL problem-solving, teamwork and processing skills rubric are further deliberated in details in Chapter 5 where results are presented. It is worth noting that some of the responses within the portfolio were also analysed using Saldaña’s (2009) model described on the preceding section.

Inter-rater reliability coefficients were calculated for each of the five sections and six sections on the ‘the teacher-based assessment rubric for the PBL activity’ and ‘overall level of proficiency of PBL implementation’ respectively using STATA (an Integrated Statistical Software package for data analysis, management and graphics). The following Kappa (κ) coefficients were obtained: Demarcation of the problem (0.9812); Formulation of learning objectives (0.9473); and The scope and quality of provisional research (0.9315); Identification and recommendation of possible solutions for the problem (0.9656); Writing skills (0.9782) (see, Appendix D). This was taken to signify consensus among the three researchers.

For the second instrument, the following Kappa (κ) coefficients were obtained: Content knowledge being taught (0.9814); PBL implementation (0.9365); Instructions adapted to meet diverse learners (0.9748); 21st-century skills observed (0.9632); Assessment of learners’ work to improve enhancement of 21st-century skills (0.9871); and Reflections and professional development (0.9881) (see, Appendix E). This was taken to signify consensus among the three researchers.

3.8 Researcher’s Role

The interpretative nature of qualitative research results in the study meant that as researcher, I had to be typically closely involved with participants (Creswell, 2009). Furthermore, the relationship between the researcher and the participants is viewed as inextricably connected (Yilmaz, 2013), hence the researcher developed a close, empathic and working relationship with the participants. As researcher, I became more of a critical friend. Therefore, the researcher was always available for questions regarding the content of PNM and the PBL

approach, assisting with developing lesson plans and lesson preparations for PBL implementation and for compilation of the portfolio. I assisted to adapt the teacher's usual lesson plan into a PBL lesson plan. Given the amount of learners the teacher has in a Physical Sciences classroom I would suggest on the amount of learners per group. A teacher would call me on the phone or send me a text on social media app (such as WhatsApp) and ask questions, sometimes requesting to meet because s/he is not sure about the best way to start a PBL lesson and I would assist by brainstorming and drawing a plan. I would remind the teacher that, the content s/he would ideally teach, become learning issues or lesson objectives that learners must decide on their own in order to solve the given task. I constantly had to remind teachers that teaching and learning situation depends on the learners more than them. I would then show/remind teachers how to use the teacher-based assessment rubric for the PBL activity and how the learners must use the learner-based assessment rubric to evaluate learner participation. Some concerns included the worry of: teaching aids which I assisted the teacher with; time management during the implementation; and time management with regard to series and number of PBL lessons to teach.

3.9 Trustworthiness

To ensure the quality of this study, the degree of credibility, fairness, confirmability, dependability and transferability in data memos was used to enhance audit trail with regards conclusions and answering the research questions (Connely, 2016). The research instrument (open-ended questionnaire) was an assessment to minimise ambiguity and biases, and data was triangulated. Furthermore, the information gathered in the open-ended questionnaire was later verified during the individual interviews.

Credibility refers to the participants' involvement in the study findings to ensure the results of the study are true or credible (Yilmaz, 2013). In this study the researcher undertook a prolonged immersion in the field, checked his interpretations with his participants, and displayed a process of learning with the help of the supervisor. *Dependability* is defined by Paskevicius (2018), Schwandt (2015) as the data process being reliable and stable throughout the course of the research such that it is logical and traceable. The researcher engaged in an open-ended inquiry. This process helped the researcher to minimize potential bias and to consider multiple realities throughout the study. This study reports the TPD process, process of interviews, process of portfolio compilation and data analysis to enable future researchers to repeat the work where necessary for dependability. *Transferability* refers to the

application of the research to other contexts and settings for ensuring that the results can be related and helpful to understand the phenomena in other contexts (Paskevicius, 2018). Extended by Gammelgaard (2017:911), transferability “truth values are established by information about coding procedures, comparisons, iteration and refutation.” This study provided a sufficient rich description making achievable for the reader to compare his/her own social context with the social setting of this research. *Confirmability* attempts to show that the findings reported and the interpretations made from findings, do not derive from the imagination or emotions of the researchers, rather are clearly linked to generated data (Liamputtong, 2013). This was achieved through applying a theoretical framework, reporting data in verbatim and some of the raw results which have been snapshotted and attached on the section of appendices (see Appendix F).

3.10 Ethical Considerations

“A core part of qualitative research is its ethical processes, which embrace its justice, protection of individual’s identity and dignity as well as the truthful presentation of research results” (Petrova, Dewing & Camilleri, 2016:443). Ethical clearance application was submitted to the Ethics Committee of the Faculty of Education for approval (known as EDU-REC) prior commencement of this study. Permission to conduct a research study was granted. A copy of ethical clearance approval is included as Appendix G. In the field of educational research, ethical issues need to be taken seriously to protect participants against any violation of their rights, therefore permission to conduct a research study with beginner Physical Sciences teachers across the North West Province was further requested, then granted from the North West Education Department (NWED) – a copy is included (see Appendix H). Both permission letters from the University and NWED were used to request permission to conduct the research study from the identified participants’ school principals and school governing bodies respectively. The researcher assistant was requested to sign a confidentiality agreement which is attached (see Appendix I).

Participants’ informed consent: The independent person assisting the researcher provided each participant with a letter of consent which ensured that the aim and objectives of the study, as well as the procedures, followed in the research, are clearly stated. Each participant was informed of their rights to refuse or withdraw to participate in the study at any time. Participants’ informed consent is attached (see Appendix J).

Participants' anonymity: The participants in the study were requested to complete an informed consent form and were informed that their privacy and right to remain anonymous shall be respected throughout the study, and information they share shall be treated as confidential. Where names are required, participants were requested to give pseudo-names. Anonymity may be more correctly termed pseudonymity (Mukungu, 2017). In this study, pseudonyms were given to the participants for the confidentiality purposes and to bring the human element aspect to the study.

Participants' Transparency: Transparency was ensured by openly discussing the purpose, the objectives, and the goals of the research with all the participants in the research. At no time did the researcher and his assistant withhold information about the true nature of the research.

Honesty and uprightness: The evaluation of the research was carried out with the honesty and uprightness expected in research. The participants are fairly represented in the study; benefitted by learning and identifying problems about their teaching and were empowered to improve their social situation. These were not compromised in this study. There was no fabrication, falsification or misrepresentation of evidence, data, findings, and conclusions. The researcher communicated the findings in a clear, straightforward and appropriate language to all stakeholders.

Participant's respect, safety, dignity, and self-worth: The researcher respected and safeguarded the dignity and self-worth of all the research participants by being mindful of the cultural, religious, gender and other significant differences present in the research population. It was further stated clearly to all the participants that their participation in the study was voluntary, and that should they for some reason want to withdraw from the study, they have the right to do so at any time without any punishment.

3.10.1 Ethical considerations regarding research data

To ensure that participants' information and data were treated with confidentiality and respect, access to the used research instruments and other data was restricted to the researcher and the supervisor only – and after the study was completed would be disposed of via shredding after 5 years. The responses of the participants were never discussed outside of the researcher and his supervisor.

Criteria for the generation of data: The data generated in this research was analysed according to the criteria for data generation, so as to ensure its authenticity, validity, reliability and ability successful prediction (Lincoln & Guba, 2000).

Authenticity and believability of data: Authenticity of data refers to the genuineness and representation of data, while the reliability of data is the extent to which data are regarded as true and credible, with both aspects being major reflections of quality (Marco & Larkin, 2000:693). An audit trail was further used to accomplish this aspect.

Security and respect of data: To ensure an acceptable level of security, raw data collected from the open-ended questionnaires, portfolios, and audio records and transcripts interviews were stored in a lockable cupboard at the North-West University in the supervisor's office. Other data was stored on my personal computer as well as my supervisor's personal computer, both of which are password protected. Post completion of the research project all the confidential information regarding the schools, participants and data would be disposed of via shredding and formatting of the audio recorder after 5 years.

Encountered problems: Some of the risks the study seemed to pose to the participants was that participating in the study may have inconvenienced the beginner teachers' personal time; especially one the day of the intervention programme. However, regarding data collection, arrangements were made to ensure that the activities of the study can take place at convenient times for beginner teachers not affecting teachers and learners' teaching and learning time.

For any information of the participants' identification, which was only put on the consent forms, was not used during data analysis and discussion of the findings for the research write-up and so that the research would not link individual responses with participants' identities. It was my role as the researcher under the observation of my supervisor to evaluate the results, analyse and write the research report.

3.11 Chapter Summary

The focus of this chapter was to explore the case study qualitative research design methodology applied to explore and enhance utilisation of PBL in promoting 21st-century skills such as collaboration, critical thinking, creativity, and communication in order for affordance of SDL while teaching the PNM by 5 beginner Physical Sciences teachers who

were purposefully sampled. This chapter also focused on presenting data generation, analysis, validation, trustworthiness and ethical considerations. Manual coding, one of the good qualitative data analysis procedures, was followed to gain insight into the beginner teachers experiences regarding PBL knowledge shift before (with an open-ended questionnaire) and after (with portfolio compilation and open-ended interview) the one-day TPD programme. Conclusions were finally drawn from data analysis. The next chapter proffers results presentation, analysis and discussion.

CHAPTER 4: PRE-TEACHER PROFESSIONAL DEVELOPMENT RESULTS PRESENTATION, INTERPRETATION AND DISCUSSION

4.1 Introduction

In this chapter, the pre-professional development data are presented, interpreted and discussed. To generate data, a self-designed open-ended questionnaire validated as explained in Chapter 3 was administered to capture and explore beginner teachers' knowledge of Problem-Based Learning (PBL) in promoting 21st-century skills in the teaching of Particulate Nature of Matter (PNM) before a Teacher Professional Development (TPD) was conducted. The open-ended questionnaire aimed at gathering data in order to answer research questions of this study, specifically research question 1 and 2. Besides, the TPD programme was tailor-made based on beginner teachers' responses to the open-ended questionnaire. A brief overview of open-ended questionnaire results based on four concepts that guided the Teacher Professional Development (TPD) programme is presented, followed by the conclusions regarding the preparation of the TPD programme.

4.2 Open-Ended Question Concepts Overview

This section presents the results interpretations and analysis of the beginner Physical Sciences teachers regarding their knowledge of PBL (definition, process and implementation), teaching of the Particulate Nature of Matter (PNM), promoting of the 21st-century and Self-Directed Learning (SDL) before attending the TPD workshop, from the open-ended questionnaire. The concepts consist of four major themes, *namely*:

1. Beginner teachers' teaching of the PNM;
2. Beginner teachers' knowledge of PBL (definition, process and implementation);
3. Beginner teachers' promotion of the 21st-century skills (collaboration, critical thinking, creativity & communication); and
4. Beginner teachers' enhancing of SDL.

Firstly, presentation of results is on 'Beginner teachers' teaching of the PNM' and the order outlined above is maintained when presenting, interpreting and discussing results. As results for each section are presented, this is immediately followed by interpretation and discussion. Thus, discussion is embedded within the results.

4.3 Beginner teachers' teaching of the PNM

This study is topic-specific regarding Physical Sciences beginner teachers' teaching of Particulate Nature of Matter as indicated in preceding chapters. To achieve this study's purpose of enhancing Physical Sciences beginner teachers to utilise PBL in enhancing 21st-century skills in order to promote SDL in the teaching and learning of PNM, beginner teachers were asked to: 'describe their teaching of Particulate Nature of Matter', 'mention the teaching approaches that were introduced to them during teacher training', 'teaching approaches they utilise while teaching Particulate Nature of Matter', and 'reasons for using those teaching approach(es)'. The teacher participants explained how they teach and listed various teaching approaches they utilise. Table 4.1 outlines the teaching approaches by beginner Physical Sciences teachers and their rationale for using such approaches.

Table 4.1: Teaching approaches used by teachers and their justifications

Teacher	Teaching approach(es) used by teacher	Rationale for teaching approach
Soros	Discussion; Cooperative learning; Experimentation.	They allow learners to actively acquire knowledge.
Rapula	Researching; Cooperative learning; Discussion.	These methods allow the teacher to identify and address misconceptions.
Koti	Demonstration; Direct instruction; Inquiry-Based Learning; Game-Based Learning; Cooperative learning.	To promote learners' critical thinking.
Lucas	None	Invalid
Kganya	Demonstration and Group discussion; Explaining and Question and Answer; Practical experiments.	To arouse learners' interest in learning science.

As can be seen from Table 4.1, each beginner teacher uses various teaching approaches to teach PNM. Cooperative learning and discussion are the most commonly used approaches amongst beginner teachers. Although some of the teaching approaches are similar from one teacher to another, beginner teachers' rationale for using preferred teaching approaches differ. Soros prefers delineated teaching approaches for the learners' active involvement.

Rapula utilises the defined teaching approaches for identifying and addressing learners' misconceptions. Kganya's rationale is based on arousing the learners' interest. It is worth noting that Koti prefers stated teaching approaches to promote one of the 21st-century skills, namely, critical-thinking. Lucas mentioned what could not be identified as teaching approaches, hence none are outlined.

While one of the teachers prefers teaching PNM by demonstration using simulation, other teachers rely on learners' prior-knowledge and real-life experiences. When asked to mention other known teaching approaches which were introduced to them during their teacher-training but do not utilise, none of the teachers mentioned PBL. The reasons for not utilising those other teaching approaches included: they more teacher-centred and do not actively engage learners; lack of resources (equipment and technology); and they lead to summative assessment. Of the 5 beginner teachers, 3 were satisfied with their teaching of PNM while the other 2 were not satisfied. Teachers alluded that cooperative learning and discussion are the teaching approaches they utilise to enhance the 21st-century skills.

As mentioned earlier in Chapter 2, this study anticipated that although beginner teachers might have an understanding of the science content knowledge including PNM, teacher participants might have limited knowledge on the teaching approach(es) including Problem-Based Learning (PBL). As a result, data generation was based on the teaching of PNM on whether beginner teachers knew and understood PNM. The results show that in the many teaching approaches to teach PNM, none of the beginner teachers uses PBL. On the question of teaching approaches that beginner teachers were introduced to, during their tertiary teacher-training, this study found that the teachers were introduced to the very same teaching approaches they use to teach PNM. Although it may not be a reason for any of the beginner teachers, since none of the beginner teachers mentioned PBL, this might explain why none of the teachers utilise PBL while teaching PNM. In other words, the teacher participants were teaching the way they were taught. The most interesting finding was that one of the teachers described their teaching of PNM as *“challenging as it requires deep understanding and visualisation and in most cases there is just never the best approach to teach it.”* This particular beginner teacher 'feels' that PNM is difficult such that there is no teaching approach that can articulate it. This might also explain why beginner teachers simply utilise teaching approaches they have been exposed to.

Furthermore, what is stated by this particular beginner teacher also accords with the earlier observations as mentioned earlier in Chapter 2 that PNM is abstract and presents multiple teaching challenges. The findings in this section corroborate those of prior studies (Cox, 2014; Owens, 2013) who equally found that beginner teachers are most likely to use teaching approaches they have been exposed to in the past. Another important finding was that one of the beginner teachers preferred stated teaching approaches to promote one of the 21st-century skills important in this study, namely, critical-thinking.

4.4 Beginner teachers' knowledge of PBL (definition, process and implementation)

To capture data about teachers' knowledge of PBL, five questions were asked and analysed. The five questions sought to establish information about teachers' definition of PBL; teachers' knowledge about the PBL process focusing on the roles, and prior knowledge of implementing PBL in the teaching of the PNM. The significance of this was to establish how much teachers knew about the PBL informing the aspects that should be focused on by the facilitator during the intervention programme. It is worth noting that after pertinent review of literature no studies in literature were found that investigated beginner teachers' knowledge of PBL. Table 4.2 illustrates teacher participants' understanding of the construct problem-based learning (PBL).

Table 4.2: Teacher participants understanding of Problem-Based Learning

Teacher	PBL definition	Teacher understanding of PBL in verbatim
Soros	Problem-solving.	<u>Soros</u> : Problem-Based Learning is a learner-centred method where learners engage actively on constructing their knowledge through problem-solving.
Koti	Cooperative learning.	<u>Koti</u> : It is a learner-centred approach whereby learners discover things for themselves and solve problems, involving group work and learners share ideas through cooperation.
Rapula, Lucas and Kganya	Open-ended/Real-life problem.	<u>Rapula</u> : I would assume that Problem-Based Learning is the method of using a problem at hand to gather information, analyse and interpret that information to solve the problem and learning along the process. <u>Lucas</u> : Problem-Based Learning is a learner-centred approach in which learners attempt to learn a particular content through experience of solving a particular open-ended problem. <u>Kganya</u> : Problem-Based Learning includes giving learners real life problems and require them to solve the problems using their own methods.

When asked to describe their understanding of PBL, beginner teachers gave responses as outlined on Table 4.2. Soros described PBL as a problem-solving approach. Koti described PBL as cooperative learning. Teacher Rapula, Lucas and Kganya described PBL as open-ended or real-life problem approach. No beginner teacher's description of PBL was correct according the definition of PBL accepted by this study from the literature. However, problem-solving, cooperative learning and open-ended or real-life problem are all part of PBL. The finding regarding Soros's definition (see, Table 4.2) concurs with prior studies (Jonassen, 2011; Stehle & Peters-Burton, 2019), who view PBL as closely related to problem-solving. However, other researchers (Ali, 2019; Ayaz, 2015; Awan, Hussain & Anwar, 2017; Baran, 2016; Ceker & Ozdamli, 2016; Hmelo-Silver, 2004; Koh & Chapman, 2019; Wood, 2003) see problem-solving as a skill that can enhanced through PBL

implementation rather than seeing as an approach. There are similarities between the Koti's understanding of PBL in this study and PBL description by Jayaram (2013) and Saka and Kumaş (2009) who are of a view that PBL is based on cooperative learning. Beginner teachers' (Rapula, Lucas and Kganya) understanding of PBL as an open-ended or real-life problem that learners must solve using their own method and knowledge (see, Table 4.2) is consistent with the views of Overton and Randles (2015), Jonassen (2011), Havenga and Van Wyk (2017), Golightly and Raath (2015), and Havenga (2018b).

As defined by this study, PBL is operationalised as a process where one or a group starts with a real-life or content-based ill-structured problem to achieve learning objectives. Furthermore, for the group to achieve learning outcomes, group members must work cooperatively. This PBL definition involves all the three components (problem-solving, cooperative-learning and real-life problem) as mentioned by beginner teachers as shown on Table 4.2. The current study contends that solving a real-life problem cooperatively, the learners must achieve the learning objectives rather than simply solving the problem. Therefore, from the analysis above, none of the five beginner teachers provided an acceptable complete definition of PBL. However, it is noteworthy to mention that surprisingly, each definition shows partial understanding that teachers have an idea about PBL. It is surprising because the findings presented earlier in this study show that beginner teachers have never used PBL to teach. Therefore, this analysis urged emphasis on PBL definition during the TPD programme since beginner teachers were to implement it in their Physical Sciences classrooms.

This study further set out with the aim of assessing beginner teachers' knowledge of PBL, role of the teacher and roles played by the learners' prior PBL implementation in the teaching of PNM. This study further assesses beginner teachers' knowledge of utilising PBL while teaching PNM. Table 4.3 outlines all this verbatim, that is, the vignettes uttered by the teacher participants.

Table 4.3: Beginner teachers' knowledge of PBL process and roles in PNM teaching (stated in verbatim)

Teacher's role during PBL	Learners' role during PBL	Teachers' prior knowledge of utilising PBL in PNM
<u>Soros:</u> Facilitate learning and help clear learners' errors and misconceptions where necessary.	<u>Soros:</u> Actively participating in constructing their own knowledge by solving problems posed by the teacher.	<u>Soros:</u> None Teacher believes in "teaching in a learner-centred approach."
<u>Rapula:</u> The teacher acts as the facilitator and guided learners through their discoveries.	<u>Rapula:</u> Learners become their own teachers , they look for information and make means to use that information to address the problem.	<u>Rapula:</u> None Teacher has basic knowledge. There has not been much exposure or rather exploration of Problem-Based Learning.
<u>Koti:</u> The teacher is there to coach or guide the learners when solving problems or acquiring knowledge.	<u>Koti:</u> The learner should be an effective self-monitor ; Learners should be cooperative when working in groups and should be responsible for their work; Learners should be able to determine and find material to be used.	<u>Koti:</u> Inconclusive Teacher believes "learners are able to relate different state of matter, more especially when given time and space to compare things that they use in their daily lives."
<u>Lucas:</u> The educator's role is to facilitate and be available for consultation by the learners.	<u>Lucas:</u> Learners are actively involved ; pose questions of inquiry to educators; attempt to solve various problems (scientific) related to the topic and towards realisation of the lesson objectives.	<u>Lucas:</u> None Teacher states, "the knowledge I have is to request learners to state all material they consider to be matter and thereafter classify it in either liquid, solid or gas."
<u>Kganya:</u> The teacher acts as a facilitator , whereby he/she only guides learners towards solving problems.	<u>Kganya:</u> The learners are the investigators and they solve problems by doing investigations and research.	<u>Kganya:</u> None Teacher believes that "Problem-Based Learning should be based on real world problems that learners encounter in their daily lives."

Table 4.3 shows beginner teachers' knowledge of PBL role players and their prior knowledge of using PBL in the teaching of PNM in verbatim. When describing the teacher's role during the PBL process, four beginner teachers described the teacher as the facilitator as shown on Table 4.3. Other words that appeared in the explanations included guide and coach, described by Koti (see Table 4.3). Unrelentingly, Table 4.5 shows that teacher Soros and Lucas described learners' roles as active participants during the PBL process. Submissions made by teacher Rapula and Koti are related, describing that learners' role is to be their own teachers –

self-monitored as outlined in Table 4.3. To Kganya, the role of the learners is to be investigators; and this description was also highlighted by Koti, who further stated that learners must also find their own learning material. It is interesting to note that in all five beginner teachers' knowledge of the PBL process regarding learners' and teachers' roles is suitable. This is interesting because teachers' understanding of PBL is limited. Beginner teachers' knowledge of PBL role players gels with what is mentioned in Chapter 2, where various experts (Ansari, Rahman, Badgujar, Sami & Abdullah, 2015; Dolmans, Wolfhagen & Ginns, 2010; Etherington, 2011; Plucker & Nowak, 1999) describe teachers as facilitator/coach and other experts (Ali, 2019; Cylen & Yigitalp, 2016) describe learners as active participants in groups. However, none of the teachers mentioned learners' roles per group such as a group leader, scribe and a member. As a result, although PBL process was not overly emphasised during TPD intervention programme, learners' roles per group were highlighted.

Finally, another important finding shown on Table 4.3 is that beginner teachers had no prior knowledge of implementing PBL in the teaching of PNM. It is not surprising that beginner teachers might not have used PBL to teach PNM since PBL approach was unknown to them looking at the findings discussed earlier in this chapter. These results were important to ensure that the TPD programme is linked with beginner teachers' experiences as mentioned earlier in Chapter 2. Therefore, during the intervention, utilisation of PBL in the teaching of PNM was a driving force while highlighting on the 21st-century skills as detailed in the CAPS and SDL. Surprisingly, when asked, beginner teachers believed that PBL could play a positive role on the learners by encouraging them to be: problem-solvers, independent of the teacher, and critical-thinkers. These findings showed that beginner teachers were interested to know more about PBL and ready to implement it in their Chemistry classrooms.

4.5 Beginner teachers' promotion of the 21st-century skills (collaboration, critical-thinking, creativity & communication)

As set out in Table 4.4, there are the five 21st-century skills known by beginner teachers. Nonetheless, it is inevitable to point out on the outset that Table 4.4 is presented in a way that primarily shows four of the 21st-century skills considered by this study, followed by other recognised 21st-century skills and finally, wrongly identified 21st-century skills as listed by beginner teachers. The 21st-century skills which this study focused on are: communication, collaboration, critical-thinking and creativity. However, other 21st-century skills as discussed

in Chapter 2 are not ignored. Conversely, other skills listed by teachers as 21st-century skills which are not recognised as such are also shown as wrongly identified skills.

Table 4.4: Five 21st-century skills identified by each beginner teacher

Teacher	Communication	Collaboration	Critical thinking	Creativity	Other 21 st - century skills	Wrongly identified 21 st -century skills
Soros	✓	✓	✓		Innovation.	Integration.
Rapula	✓		✓		Technology, information literacy.	Cooperative learning.
Koti			✓		Problem-solving, self-direction.	Analysis, interpretation, synthesising information, teamwork, self-discipline, listening.
Lucas	✓		✓	✓	Technology literacy, problem solving	
Kganya						Drawing, interpreting, calculating, setting up experiments and recording observable data.

The 21st-century skills discussed in this study are signalled by a tick on each beginner teacher respectively, then other skills listed by the teacher participants are indicated by writing them down. As shown on Table 4.4, Kganya did not know any 21st-century skills, that is, both those discussed in this study and outside of this study. These findings were alarming since these skills are discussed in the Physical Sciences CAPS document. Furthermore, Table 4.4 shows that of many skills, instead of five, mentioned by Koti, only critical-thinking was part of this study, two more skills were categorised as other, and the rest were wrongly identified as 21st-century skills. Table 4.4 further shows that Rapula could only identify only two skills under focus in this study, two other 21st-century skills and one wrongly identified skill. Soros and Lucas equally mentioned three 21st-century considered by this study and other 21st-

century skills, however, there was one skill which was wrongly identified by Soros. Although all the four 21st-century skills this study ought to promote are outlined from four beginner teachers together, none of the beginner teachers listed them all. Furthermore, four beginner teachers wrongly identified some skills as the 21st-century skills except teacher Lucas.

In reviewing the literature, data was found on the association between the 21st-century skills and learners' science achievement and SDL. Unfortunately, the results of this study indicate that beginner teachers' knowledge of the 21st-century skills is limited since none of them mentioned all the 21st-century skills explored in this study. It is difficult to explain this result, but it might be related to the fact that since there are many 21st-century skills, beginner teachers only mentioned the first few that came to their mind. However, the same cannot be said about Kganya since none of the 21st-century skills were mentioned.

Therefore, these findings highly dictated emphasis on the 21st-century skills during the TPD programme. As mentioned in the literature review, the South African Physical Sciences curriculum aims (DBE, 2011) and the importance of the 21st-century skills as argued by many scholars (Al Kandari & Al Qattan, 2020; Cheng, 2020; Grimus, 2020; Rifandi & Rahmi, 2019) were emphasised to beginner teachers during the TPD programme. Beginner teachers also outlined that they inculcate and develop the outlined 21st-century skills shown in Table 4.3 by using teaching approaches shown in Table 4.1 while teaching various PNM concepts. Although, these results differ from Rusmansyah, Yuanita, Ibrahim, Isnawati and Prahani (2019) and Ismail (2019) who argue that PBL is the relevant approach to inculcate the 21st-century skills explored in this study, they are consistent with Alismail and McGuire (2015), that cooperative learning is also one of the teaching approaches that can enhance 21st-century skills.

4.6 Beginner teachers' enhancing of SDL

SDL is mentioned earlier in Chapter 2 as one of main features of PBL, one of the sections on the questionnaire aimed to capture data on how beginner teachers promote SDL, how the learners taught by beginner teachers exhibit SDL and the 21st-century skills which might afford learners SDL if promoted. The results of this study on this theme show that beginner teachers promote SDL on their learners by utilising the teaching approaches outlined in Table 4.1. It was therefore necessary to introduce and enhance PBL utilisation by TPD programme. As mentioned earlier in the literature review section, there are various ways for learners to

exhibit SDL. The current study found that beginner teachers' learners exhibit SDL through the following:

- Working together;
- Exploring ideas;
- Showing readiness and desire to learn;
- Showing confidence and taking ownership;
- Positive attitude.

The findings of the current study corroborate two of the four stages outlined by Grow (1991), who states that in stage 2, SDL can be exhibited through learners when they are interested and motivated to learn; and in stage 3, learners have skills and knowledge and see themselves as owners of their education. These findings show very little regarding learners diagnosing their own learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies and evaluating learning outcomes as stated by Knowles (1975), Ansari *et al.* (2015), Morris (2019a), Robinson and Persky (2020), and Ansarian and Teoh (2018).

Finally, 21st-century skills that beginner teachers suggest might enhance SDL included: critical-thinking; creativity; reasoning; interpretation; problem-solving; communication; technology literacy; Conducting practical investigations; drawing; and initiative skills. None of the teachers mentioned collaboration. Teacher Kganya still did not mention any 21st-century skills – this has made it evident that Kganya did not know any 21st-century skills. Figure 4.1 shows the summary of the 21st-century skills which beginner teachers suggest might enhance SDL among the learners in form of a word-cloud.

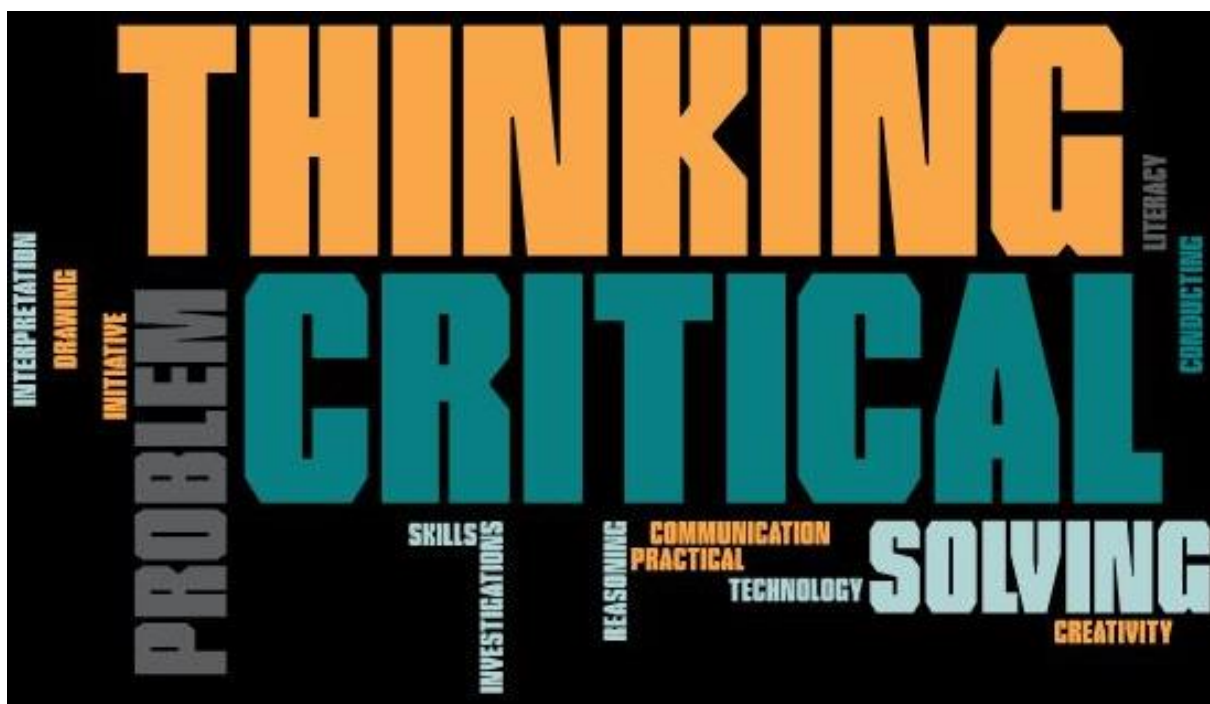


Figure 4.1: Word-cloud of 21st-century skills that might enhance SDL as suggested by beginner Physical Sciences teachers

Figure 4.1 shows a word-cloud of 21st-century skills that might enhance SDL as suggested by beginner Physical Sciences teachers and based on their responses. This word-cloud shows each skill according to the frequency it was mentioned by beginner teachers. The larger the skill, the more it was mentioned by all beginner teachers, the smaller the skill the lesser it was mentioned. Therefore, 21st-century skills such as communication and creativity as part of this study, were only mentioned once. Finally, critical-thinking as a 21st-century skill was mentioned three times. Therefore, it was impressive to see that four of the five beginner teachers agree that 21st-century skills might enhance SDL among the learners. Prior studies (Rana, Ardichvili & Polesello, 2016; Robinson & Persky, 2020) have equally noted the importance of skills such as problem-solving, collaboration, communication, self-awareness, innovation, professionalism, interaction and teamwork, and the use of relevant technologies in order to promote SDL. The aforementioned skills include the four 21st-century skills this study aims to promote through PBL implementation for SDL. Furthermore, these results therefore need to be interpreted with caution because the concepts of PBL, 21st-century skills and SDL have proven to be less known to teachers.

4.7 Chapter Summary

This chapter focused on the pre-teacher professional development data and interpretations from beginner teachers generated through open-ended questionnaire responses. The first question in this research was “How can Problem-Based Learning (PBL) be enhanced to equip beginner Physical Sciences teachers in promoting 21st-century skills?” The results presented, interpreted and discussed in this chapter provided baseline data upon which the teacher professional development intervention programme was developed. The findings in this study illustrate that beginner teachers’ knowledge of PBL is inadequate due to lack of exposure. These results essentially clarify that the beginner Physical Science teachers in the NMM District needed a TPD programme regarding the implementation of PBL in the teaching of PNM to promote the 21st-century skills for SDL. However, with a small sample size, caution must be applied, as the findings might not be applicable to all other beginner Physical Sciences. The following chapter presents post-teacher professional development programme findings and interpretations.

CHAPTER 5: RESULTS PRESENTATION, INTERPRETATION AND DISCUSSION

5.1 Introduction

This chapter presents and discusses results of the study and addresses the research questions. The rationale for this study was to explore utilisation of Problem-Based Learning (PBL) in enhancing 21st-century by beginner Physical Sciences teachers after a Teacher Professional Development (TPD). Beginner Physical Sciences teachers' interview responses were analysed using Saldaña's (2009) analytical tool model for qualitative inquiry as described in Chapter 3, section 3.7. The portfolio data was analysed using Golightly's (2013) and Family Secret's (2009) rubrics for learners' activities as described in detail in Chapter 3, section 3.7. The overall portfolio data was analysed using the adapted Smith *et al.*'s (2001) analytical tool. While coding and categorising beginner teachers' responses, emerging themes were identified. In addition, learners' responsiveness regarding the PBL implementation is emphasized. The results are presented in the order in which the research questions are posed. Finally, this chapter outlines the application of the theoretical lens of social interdependence theory and a PBL conceptual framework in the discussion sections as used to interpret the data. The chapter terminates with a concise summary.

5.2 Research Question 1

How can problem-based learning (PBL) be enhanced to equip beginner Physical Sciences teachers in promoting 21st-century skills?

In order to generate data for research question one (1), data generation instruments, namely, open-ended questionnaire (see Appendix A), portfolio (see section 3.4.3) and interview were employed (see Appendix C). Data from the portfolio and interviews are presented concurrently for corroboration and data triangulation. The responses from the portfolio sections such as the 21st-century skills observation template, teacher- and learner-based rubrics and details of what happened during PBL implementation in the classroom and interviews were further analysed and grouped into few themes that relate to each 21st-century skill. Table 5.1 outlines the identified themes according to the four specific 21st-century skills discussed in this study.

Table 5.1: Each 21st-century skill with the theme(s) associated with it

21 st -century skills	Themes
Collaboration	• Quality of the group process and outcome as a measure of success. • Enhances Self-Directed Learning (SDL): Responsibility, and evidence of interdependence.
Critical thinking	• Analyse and combine acquired information to develop own interpretations. • Ability to connect relevant information, criticise and problem solving.
Communication	• Able to perform interpersonal, written, and oral communication. • Able to be part of the community.
Creativity	• Ability to offer new perspectives, generate novel and meaningful ideas, raise new questions, and come up with solutions.

5.2.1 Collaboration

During the TPD intervention programme, the importance of collaboration was discussed and participants worked in a group where there was a group-leader and a scribe. Collaboration was highlighted from the CAPS document where it is stated that the national curriculum aims to produce learners that are able to: work effectively as individuals and with others as a members of a team to achieve a common goal; organise and manage themselves and their activities responsibly and effectively. It is worth mentioning that of the five (5) beginner teachers, four indicated to have observed the collaboration 21st-century skill according to the 21st-century skills observation template in the portfolio submitted. Generally, the teachers commented that their learners could work cooperatively in the PBL groups. Each theme for collaboration is presented in detail below.

5.2.1.1 Quality of the group process and outcome as a measure of success

As mentioned earlier in Chapter 3, section 3.7.2, the teacher-based assessment rubric for the PBL activity had an overall mark of 60 as adapted from Golightly (2013). The assessment rubric for the PBL activity criteria scores were defined by four quality levels namely, *excellent*, *good*, *efficient* and *inefficient*. For instance, ‘demarcation of the problem’ criterion

and ‘writing skills’ criterion, each has a total score of 4 spread on a continuum where 4 is *excellent*, 3 is *good*, 2 is *efficient* and 1 is *inefficient*. Regarding ‘formulation of learning objectives’, it has a total weighting score of 12 which is spread on a continuum as follows: 10-12 score is *excellent*; 6-9 score is *good*; 3-5 is *efficient*; and 1-2 is *inefficient*. ‘The scope and quality of provisional research’ and ‘identification and recommendation of possible solutions for the problem’ criteria both have the total weight score of 20. The two criteria have their *excellent* score as 12-20 and their *good* score is 11-15. For the ‘scope and quality of provisional research’ criterion, 6-10 weighting defines *efficient* while 1-5 defines *inefficient*. For ‘identification and recommendation of possible solutions for the problem’ criterion, *efficient* is defined by the score range of 5-10 whereas *inefficient* score range is 1-4. Each beginner teacher’s rubric marks were analysed and results are presented in Table 5.2.

Table 5.2: Results from evaluation of the teacher-based assessment rubric for the PBL activity

	Criteria					Total score
	Demarcation of the problem	Formulation of learning objectives	The scope and quality of provisional research	Identification and recommendation of possible solutions for the problem	Writing skills	
Weight (score)	4	12	20	20	4	60
Soros	4	5	12	13	4	38
Rapula	3	5	16	15	3	42
Koti	2	6	15	15	2	40
Lucas	3	5	18	14	3	43
Kganya	1	1	5	4	1	12

Pertaining to ‘demarcation of the problem’, the quality levels are described as follows: *excellent* (4): the demarcation of the problem has been very well done and complete; *good* (3): the demarcation of the problem has been satisfactory; *efficient* (2): the demarcation of the problem shows gaps and needs further attention; *inefficient* (1): the demarcation of the problem is poor and vague and need to be redone. As illustrated in Table 5.2, Soros’s learners were excellent in demarcating the problem. Rapula’s and Lucas’s learners’ demarcation of the problem mark is 3, meaning that they were good. Koti’s indicated that his learners were efficient in demarcating the problem. Kganya’s learners were marked inefficient in this criteria. Relating to ‘formulation of learning objectives’, descriptions are as follows: 10-12

score is excellent: the learning purpose is well defined and formulated completely; *6-9 score is good*: the learning purpose has been defined as satisfactory; *3-5 is efficient*: the learning purpose is incomplete and not well defined; *1-2 is inefficient*: the learning purpose is poorly defined and incomplete. The learning purpose needs to be reformulated. Therefore, in this instance as set in Table 5.2, Soros, Rapula and Lucas considered their learners to be efficient scoring them 5. Koti's learners were scored 6, indicating that his learners were good. Kganya's learners were considered inefficient.

With reference to 'the scope and quality of provisional' criterion, the four quality levels descriptions are: *excellent score as 12-20*: exceptionally well-developed description was given of the chemistry issues that are found in the CAPS document. It shows a good understanding of the problem; *good score as 11-15*: a satisfactory developed description was given of the chemistry issues that are found in the CAPS document. This shows a good understanding of the topic; *efficient as 6-10*: the description of the chemistry problems in the real-life situation in South Africa should be further developed since there are gaps in the understanding of the problem; *inefficient as 1-5*: poorly developed description of the chemistry problems in South Africa which leads to a poor understanding of the problem. It need to be redone. As Table 5.2 indicates, Soros scored his learners 12, Rapula scored her learners 16, Koti scored his learners 15, and Lucas scored his learners 18. Although Soros, Rapula, Koti and Lucas scored their learners differently, their scores suggest that their learners were excellent. Kganya deemed her learner inefficient.

Concerning the 'identification and recommendation of possible solutions for the problem' criterion, quality levels are described as follows: *excellent range of 12-20*: a complete and exceptionally well formulated solutions and recommendations were made for the problem; *good score range of 11-15*: complete and well formulated solutions and recommendations were made for the problem; *efficient score range of 5-10*: only certain solutions and recommendations is applicable to the problem; *inefficient score range of 1-4*: very weak formulated solutions and recommendations were made. As shown on Table 5.2, Soros, Rapula, Koti and Lucas deemed their learners excellent. Kganya's score of 4 being the lowest, denotes that the learners were inefficient.

Shifting focus to 'writing skills' criterion, descriptors are as follows: *excellent*: the report is impartial and highly professionally written; *good*: the report is impartial and professionally

written; *efficient*: parts of the report does not testify to impartiality and professionalism. Spelling mistakes are common; *inefficient*: the report does not testify to impartiality and professionalism. Too many spelling mistakes. Report needs to be rewritten. As indicated in Table 5.2, each beginner teacher scored their learners as follows: Soros scored his learners ‘excellent’; Rapula and Lucas both scored their learners ‘good’; Koti’s learners were scored ‘efficient’; and Kganya deemed her learners ‘inefficient’.

Finally, the total weighting of the PBL activity equates to 60 marks. Therefore, the highest score (maximum = 60) and a lowest score (minimum = 5) indicate overall performance of PBL activity by the teacher. The continuum on which the scores were framed is as follows: Inefficient-unsatisfactory (5-18.75); efficient-fairly acceptable (18.75-32.5); good-moderately satisfactory (32.5-46.25); and excellent-highly satisfactory (46.25-60.0). As shown in Figure 5.1, Soros, Rapula, Koti and Lucas showed that learners were good at completing the task and presenting their solutions in a professionally written manner. Learners were able to successfully complete the task and provide solutions and recommendations for the problem; the learners’ overall performance was *good*. Although each of the four beginner teachers’ (Soros, Rapula, Koti and Lucas) learners’ overall performance varied, their ultimate performances fall under the same continuum which is *good*. Kganya’s PBL activity rubric showed that learners’ performance was *inefficient* in all criteria of completing a PBL task; Kganya’s learners’ overall performance was unsatisfactory. Figure 5.1 shows the summary of each beginner teacher’s learners’ performance.

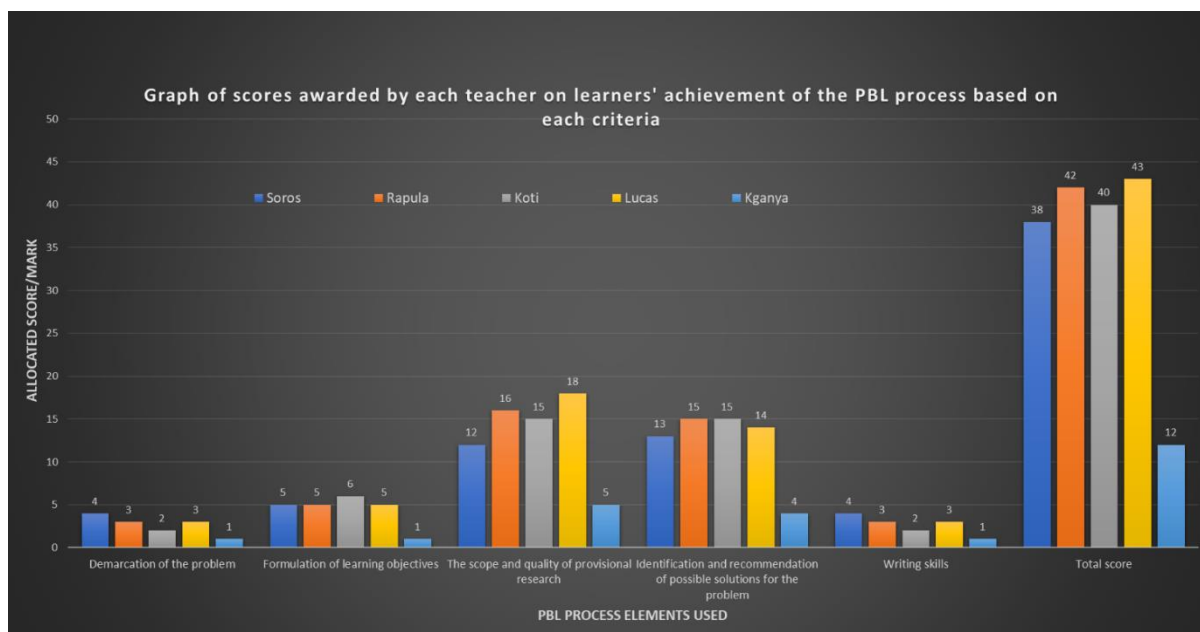


Figure 5.1: Graph of scores awarded by each teacher on learners’ achievement of PBL process

Learners were provided with PBL problem-solving, teamwork and processing skills rubric (as adapted from Family Secrets, 2009) to assess themselves as a group (as explained in Chapter 3 section 3.7). The learner-based rubric assesses various aspects relating to the PBL process and skill in the following levels: 1. Limited; 2. Developing; 3. Proficient; 4. Advanced; and 5. Exemplary. The identified aspects of the learner-based rubric which relate to collaboration skill about the PBL group members are: task distribution; collaborate and contribute equitably; manage conflicts; effectively reflect on teamwork; and building consensus. Table 5.3 outlines description of each level for each aspect relating to collaboration as reflected on the rubric (see Appendix L). As outlined in Table 5.3, the learner-based rubric does not describe ‘developing’ and ‘advanced’ and leaves them blank; however, the learners were instructed to mark them if they positioned themselves as in-between.

Table 5.3: Description of levels on aspects relating to Collaboration

Team members	1 Limited	2 Developing	3 Proficient	4 Advanced	5 Exemplary
Distribute tasks	Do not distribute tasks equally.		Distribute tasks equally.		Distribute tasks based on team members' skills.
Collaborate and contribute equitably	Let one or two team members do most of the work.		Ensure that all team members contribute fully.		Know and encourage each other's strengths to do quality work.
Manage conflicts	Do not recognize or take action to reduce conflict.		Resolve conflicts to continue to stay "on task."		Identify and actively use "win-win" solutions to manage conflict.
Effectively reflect on teamwork	Do not contribute to discussions about their work as a team.		Use the results of this rubric to suggest ways to improve teamwork.		Regularly monitor and assess teamwork of individuals and group as a whole.
Build consensus	Do not attempt consensus process.		Use consensus process to work effectively.		Seek out feedback and process this information to improve teamwork.

For Soros's and Koti's learners' rubrics show that each group leader was able to distribute tasks *proficiently* while learners' collaboration skill was marked *exemplary*; learners knew and encouraged each other's strengths to do quality work. Rapula's learners' collaboration skill was *advanced*. Lucas's learners' rubric shows that the group leader distributed tasks based on team members' skills (*exemplary*), and their collaboration skill was *proficient*. Kganya's learners' tasks distribution and collaboration skills were *limited*. Shifting focus to team members' ability to manage conflicts, Soros's learners rated themselves *exemplary*; Rapula's learners rated themselves as *advanced*, Koti's and Lucas's learners rated themselves as *proficient*, and Kganya's learners rated themselves as *limited*. Regarding their skill to effectively reflect on the teamwork, learners rated themselves as follows: Soros: *Advanced*; Rapula: *Proficient*; Koti and Lucas: *Exemplary*; Kganya: *Limited*. Another aspect relating to

collaboration on the learner-based rubric where learners rated themselves was building consensus. Learners' ratings were as follows: Rapula and Koti: Proficient; Soros and Lucas: Advanced; Kganya: Limited.

Learner-based assessment rubric had reflection questions on problem-solving and teamwork. According to learners' reflection on PBL problem-solving and teamwork, application of prior knowledge from group members to draw conclusions and working together is important. Highlighting major findings on this aspect, Soros's learners stated that they would like to work together frequently since they benefited more knowledge working together in collaboration. Rapula's learners stated that they should encourage one another to all contribute equally to the work because they learn more working together.

During the interview, participants were asked to state PBL benefits on their learners. Soros said that: "Collaboration and generating ideas were skills that learners gained during the PBL implementation while teaching PNM." Rapula said that: "Learners learn more than learning only about the topic during PBL when working together."

5.2.1.2 Self-Directed Learning (SDL): Responsibility and evidence of interdependence

On completion of Koti's learners' reflection on the rubric's PBL problem-solving and teamwork in the portfolio, the teacher wrote, "*PBL enhances self-directedness such that they can research relevant information and apply it to a specific context.*" According to the observations made by Rapula as outlined on observed 21st-century skills, learners relied on themselves as a group rather than depending on the teacher. Learners were responsible for their own work. One of Rapula's learner's reflection on the PBL problem-solving and teamwork reflection stated that, "*Not everyone in our team contributed to this research, next time we should all take part in the research by finding information from the internet. They only took part in the discussion in class.*" Soros stated that learners were self-directed during the PBL lesson:

They (learners) were not depending on me as a teacher rather think critically, use their skills and prior knowledge regarding PNM and I was just guiding them plus were not starting from the scratch. They can work together, think critically, communicate and find answers before I can guide.

From interviews, Soros observed SDL amongst the learners' post PBL lesson, stating that:

“After PBL utilisation, I realised that learners were positive and cooperating because their way of thinking and doing things is not the same as before. PBL has promoted learners working on their own to solve problems regarding PNM, PBL promoted their independency.”

Rapula responded during the interview that it was difficult to observe SDL within the learners. However, it seemed that learners relied on themselves more as a group than on the teacher. Koti believes that PBL promoted SDL amongst his learners mentioning, *“Allowing learners to work on PBL problem as a group, they depended on each other rather than the teacher. Ultimately they will have ended up believing in themselves also as individuals.”* During the interview participants were asked to state PBL benefits on their learners. Lucas stated:

Teamwork is an important skill to develop because as science learners, they must know that as scientists they will not work as individuals; many science careers require teamwork. Therefore, it is important for my learners to develop these skills while in school.

Kganya does not believe that PBL promoted SDL in her learners.

5.2.2 Critical thinking

Generally, critical thinking is a skill associated with problem-solving. As mentioned earlier in Chapter 2 section 2.5, critical thinking is the ability to think clearly and rationally in order to analyse and combine acquired information to develop own interpretations, learning and critiquing facts triggered by working on a problem through collaboration. This corroborates aims of CAPS to produce learners that are able to collect, analyse, organise and critically evaluate information. Therefore, during the TPD intervention, utilisation of PBL was emphasised to be one of the approaches that can promote critical thinking. Critical thinking could be observed on the type of questions learners ask, ability of learners to develop learning objectives, ability of learners to collect, analyse, organise and use information to formulate recommendations and solutions for the problem.

5.2.2.1 Analyse and combine acquired information to develop own interpretations

From the portfolio using the observed 21st-century skills template, Soros, Rapula, Koti and Lucas observed that critical-thinking was promoted during PBL implementation. However,

Kganya's data shows that this skill was not promoted. Soros mentioned that his learners showed an understanding during the PBL process before he could guide them. However, Soros's rubric for PBL activity shows that learners' ability to formulate learning objective was efficient, being the lowest. The learners' scope and quality of the provisional research was rated excellent by Soros on the PBL activity rubric. Rapula stated that her learners' arguments and the ability to criticize their own solutions to the problems showed that critical thinking was promoted with her learners. Furthermore, Rapula's assessment rubric shows that learners' ability of formulating learning objectives was efficient. The assessment rubric shows that learners' scope and quality of research was exceptionally well developed, rated excellent. Koti's comment is difficult to grasp since his comment was that critical thinking was "fair". However, according to the teacher's assessment rubric of the PBL activity, Koti's learners' formulation of learning objectives was good, suggesting that it was satisfactory. Koti marked his learners' scope and quality of provisional research good; learners' skill of acquiring information showed good understanding of the problem. Lucas stated that his learners showed critical thinking during discussions since they could explain the effects of temperature and possible outcomes on the particles. Similar to Soros and Rapula, Lucas's learners' ability to formulate learning objectives was efficient. Lucas's rubric shows that learners' scope and quality of the provisional research was excellent. Kganya did not observe this skill amongst her learners. Kganya's assessment shows that learners' ability to formulate their own learning objectives was inefficient. Some of the questions learners asked during the PBL process in class were as follows: *"What is the size of the room? Is the house built with cement and bricks, or metal sheets or wood like a Wendy-house? Which part of the problem must we focus on? Is the temperature, heat and energy the same? How long must the refrigerator be open? Can we include the electricity consumption? What is Brownian motion? Should we provide definitions of concepts such as boiling and melting points?"*

The learner-based assessment had four areas relating to the critical-thinking skill where learners had to rate themselves in a PBL group. Such areas are presented in Table 5.4 together with how each beginner teacher's learners rated themselves.

Table 5.4: Each beginner teacher's learners' rating

Criteria	Soros	Rapula	Koti	Lucas	Kganya
Identifies Relevant Facts ("What do we know?")	<u>5 Exemplary</u> Helps distinguish facts from opinions/inference s.	<u>3 Proficient</u> Identifies most relevant facts.	<u>3 Proficient</u> Identifies most relevant facts.	<u>3 Proficient</u> Identifies most relevant facts.	<u>3 Proficient</u> Identifies most relevant facts.
Asks Relevant Questions ("What more do we want to know?")	<u>3 Proficient</u> Asks basic kinds of "who, what, where, when" questions.	<u>4 Advanced</u>	<u>4 Advanced</u>	<u>5 Exemplary</u> Asks higher-level questions which reflect depth of thought.	<u>4 Advanced</u>
Selects Useful Information from Appropriate Sources	<u>5 Exemplary</u> Obtains reliable and wide-ranging information from sources beyond those provided.	<u>4 Advanced</u>	<u>2 Developing</u>	<u>5 Exemplary</u> Obtains reliable and wide-ranging information from sources beyond those provided.	<u>4 Advanced</u>
Develops Multiple Solutions to Major Problem(s)	<u>5 Exemplary</u> Distinguishes between major & minor problems; identifies direct & indirect stakeholders.	<u>4 Advanced</u>	<u>3 Proficient</u> Identifies major problem and major stakeholders.	<u>4 Advanced</u>	<u>4 Advanced</u>

During interviews, teachers were asked: How can you describe your exposure on PBL, 21st-century skills and SDL? Soros stated that PBL gives him a chance to guide the learners as they get the chance to explore and acquire knowledge on their own; stated in verbatim as follows:

My experience is that, PBL gave me a chance to give the learners work to do on their own and it made one realise that it gives me advantage to only guide them to make sure they are on the right path; Best experience. It improves their critical-thinking, and communicate to share ideas in the classrooms between myself and the learners.

Lucas stated that with the use of PBL to teach PNM, learners' level of knowledge and research is astonishing, *"It is amazing the things that one will discover that learners know or can come with, when they are given a chance."*

5.2.2.2 Ability to connect relevant information and problem-solving

From the portfolio, the assessment rubric for the PBL activity under the criterion of ‘identification and recommendation of possible solutions for the problem’, was marked ‘good’ for the learners by Soros, Rapula, Koti and Lucas, while it was marked ‘inefficient’ for Kganya’s learners. ‘Good’ rating in the teacher’s rubric means *complete and well formulated solutions and recommendations were made for the problem*. However, it is worth mentioning that the marks for this section weighted 11-15. ‘Inefficient’ for this criterion meant *very weak formulated solutions and recommendations were made*, weighting 1- 4 marks.

During the interview, Koti’s response was as follows to the question: How would you describe utilising PBL in teaching PNM?

It (PBL) was a good experience for the learners because they get to make sense of the content they are learning in the classroom. Especially with the PBL problems that you had given us, the learners got the idea and were able to relate the content with the real-life experiences; things they already knew. I could see that it was fascinating for them (learners), the smiles on their faces as I was observing them coming with the solutions for the problem.

When asked during interviews, what do you think was beneficial on your learners while utilising PBL? Soros mentioned that his learners were not dependent on him, furthermore, stating that the topic of PNM was not new to his learners. His response verbatim is as follows:

They (learners) were not depending on me as a teacher rather, they could think critically, use their skills and prior knowledge regarding PNM to solve the problem, and I was just guiding them plus were not starting from scratch. Learners can work together, think critically, communicate and find answers before I could guide them.

Lucas stated that critical thinking was enhanced on his learners which boosted their performance in the topic. His response was, “*Learners were able to show critical-thinking, which is a good skill which boosted their performance.*” On the interview question of “How could you tell that 21st-century skills were enhanced on your learners while utilising PBL?” Lucas said, “*Because they could communicate ideas, thinking critically to come up with*

solutions. And they were creative coming up with solutions. They also managed to work together cooperatively.”

5.2.3 Communication

Communication skill being one of the 21st-century skills this study aims to promote, was emphasised during the TPD programme and highlighted from the CAPS document. The national curriculum of the Republic of South Africa aims to produce learners that are able to: communicate effectively using visual, symbolic and/or language skills in various modes; and demonstrate an understanding of the world as a set of related systems by recognising that the problem solving context do not exist in isolation. It worth noting that the topic of PNM may require visual, symbolic representations and language skills to communicate and demonstrate ideas. Similar to the aforementioned skills (collaboration and critical thinking), communication is a skill that was observed by all participants during PBL implementation. The following themes were developed from data generated from participants.

5.2.3.1 Able to perform interpersonal, written, and oral communication

As mentioned earlier, the observed 21st-century skills template in the portfolio submitted by all beginner teachers showed communication skills while teaching PNM using PBL. In the observed 21st-century skills template, Soros commented that communication was the skill observed the most amongst the learners. Soros further stated that he focused on this skill since it is a key to other skills. In the assessment rubric for the PBL activity, Soros scored his learners' writing skills 'excellent', which means that their submitted report was impartial and highly professionally written. Equally, Soros's learners scored themselves 'exemplary' on their ability to organise and present information effectively. 'Exemplary' means that learners were able to summarise information from many sources and present it in a concise accurate and insightful manner. Furthermore, learners rated their ability to produce quality work to be advanced. In completing the PBL problem-solving and teamwork reflection section, learners stated they have learned to listen to their peers attentively and that sharing of information helps to make the problem easier to solve.

In observing communication skill amongst her learners, Rapula commented that *“Communication was the most reflected skill in the group. Learners were communicating with one another, and with the teacher, listening and writing.”* Rapula's learners writing

skills on the submitted report was scored ‘Good’, meaning that report was impartial and professionally written. Rapula’s learners’ rubric scored their ability to organise and present information effectively as ‘Exemplary’. Similar to Soros’s learners, Rapula’s learners rated their ability to produce quality to be ‘advanced’. Koti, like other participants, also observed communication skill among his learners while learning through PBL. Koti’s learners’ writing skill was rated ‘efficient’ in the teacher-based assessment rubric. This means that parts of the report did not testify to impartiality and professionalism such that spellings and mistakes were common. Koti’s learner-based rubric shows that learners’ ability to organise and present information effectively is ‘Advanced’. Lucas observed communication skill during the PBL implementation in the teaching of PNM. In the assessment rubric, similar to Rapula, Lucas rated his learners’ writing skills ‘Good’. Lucas’s learners scored their ability to organise and present information effectively ‘advanced’. Communication skill was observed also by Kganya on her learners. However, being the only one, Kganya’s learners were scored ‘Inefficient’ on the teacher-based assessment rubric on the submitted report. Kganya’s learners did not testify of impartiality and professionalism with many spelling errors. Kganya’s learners equally score themselves ‘Limited’ regarding organising and presenting of information effectively on their rubric. Limited rating means that the learners could not organise information to clearly present solutions to the problem.

Kganya said: *“The only skill that was there was communication because learners were talking and interacting with one another even though they were making noise. I do not think any other skill was promoted other than communication”* in response to the interview question: How could you tell that 21st-century skills were enhanced on your learners while utilising PBL?

5.2.3.2 Able to be part of the community

There are few indicators on learner-based rubric which informed this theme. It can be argued that there are certain qualities and attributes regarding being part of the community which draws to communication skill. Such indicators are presented in Table 5.5 for each beginner teacher’s learners and their scores.

Table 5.5: Indicators signifying learners' participation in the learning community

Indicators	Soros	Rapula	Koti	Lucas	Kganya
Manage time	<u>4 Advanced</u>	<u>3 Proficient</u> Use time efficiently and complete all tasks on time.	<u>4 Advanced</u>	<u>2 Developing</u>	<u>1 Limited</u> Do not monitor their progress or recognise time constraints.
Stay on task	<u>4 Advanced</u>	<u>3 Proficient</u> Use time in focused and productive ways.	<u>3 Proficient</u> Use time in focused and productive ways.	<u>4 Advanced</u>	<u>1 Limited</u> Are easily distracted or frequently go "off task".
Come prepared	<u>4 Advanced</u>	<u>3 Proficient</u> Consistently prepared with needed materials.	<u>4 Advanced</u>	<u>4 Advanced</u>	<u>1 Limited</u> Not consistently prepared with needed materials.
Maintain positive attitude	<u>4 Advanced</u>	<u>3 Proficient</u> Exhibits positive attitudes or behaviours towards work and others.	<u>3 Proficient</u> Exhibits positive attitudes or behaviours towards work and others.	<u>3 Proficient</u> Exhibits positive attitudes or behaviours towards work and others.	<u>1 Limited</u> Exhibits negative behaviours; use "put down" expressions.

During the interview, when asked: How would you describe utilising PBL in teaching PNM? Rapula responded, *"PBL implementation was difficult for both myself and the learners at first, but at last, it seems the learners had adjusted and were communicating loudly discussing ideas."* When asked the question, how could you tell that 21st-century skills were enhanced on your learners while utilising PBL? Koti said, *"The questions learners were asking; the notes they wrote; learners' interaction; and the smiles on their faces it was clear that they were fascinated. PBL brought life in a Physical Sciences classroom."*

5.2.4 Creativity

This considered that creativity is a skill that is difficult to observe and/or promote, and that it is inseparable from critical-thinking, anticipates that implementation of PBL in the teaching of PNM can promote creativity. CAPS document states one of its aims as producing learners that are able to identify and solve problems and make decisions using critical and creative thinking. As mentioned in Chapter 2 section 2.5, creativity involves offering new perspectives, generating novel and meaningful ideas, raise new questions, and come up with

novel solutions to ill-defined problems in specified contexts of value. As in the PBL process, creativity allows learners the freedom to make mistakes while thinking divergently rather than accuracy and the solution. Some of the various ways of observing creativity is presented by the generated theme below.

5.2.4.1 Ability to offer new perspectives, generate novel and meaningful ideas, raise new questions, and come up with solutions

It is important to note that from portfolio data, not all beginner teachers observed this skill during the PBL implementation in their classrooms. Rapula and Koti are the only participants who observed creativity skill while Soros, Lucas and Kganya did not observe it. However, although Rapula shows to have observed creativity amongst her learners according to the 21st-century skills observed template during the PBL lesson, her comment highlights that it was difficult to observe: *“It seemed there was creativity listening to learners’ arguments, but is it was difficult to observe it.”* In observing creativity amongst his learners, Koti only commented that it was ‘Good’. Some of the indicators regarding creativity can be observed on the learner-based rubric, such as choosing a course of action and supporting choice; and brainstorming. Learners’ responses gathered from their self-assessment rubrics are presented in Table 5.6 from each participant.

Table 5.6: Indicators eliciting how learner creativity was observed on the learner-based rubric

Indicator	Soros	Rapula	Koti	Lucas	Kganya
Choose a course of action and supports choice.	<u>5 Exemplary</u> Selects a solution based both on ethics and risks/benefits to multiple stakeholders.	<u>2 Developing</u>	<u>3 Proficient</u> Selects and supports a course of action based on ethics or risks/benefits to one stakeholder.	<u>Advanced</u>	<u>1 Limited</u> Cannot select or support course of action.
Use Brainstorming “rules”.	<u>4 Advanced</u>	<u>4 Advanced</u>	<u>5 Exemplary</u> Develop new “rules” as needed to facilitate the brainstorming process.	<u>1 Limited</u> Do not use brainstorm “rules”, allow others to block the process.	<u>1 Limited</u> Do not use brainstorm “rules”, allow others to block the process.

During interviews, when asked the question, How would you describe utilising PBL in teaching PNM?, Soros said, *“PNM is a topic learners experience in their daily basis, therefore they (learners) have tried to see how things (content) in class relates with real-life problems; learners realise that they see things differently using real-life situations.”* When teacher participants were asked the question, “How could you tell that 21st-century skills were enhanced on your learners while utilising PBL? Only two of the participants who observed creativity during implementation could respond. Their responses are as follows:

Rapula said:

Creativity was there in solving the problem. I could say that my learners were very creative because their process of arriving to the solutions was unique since it included some “Physics” aspects which were somewhat distant from the content of I intended to teach.

Koti responded by saying, *“As much as I was facilitating and guiding the learners, they were always ahead and they were not afraid to make mistakes. And like I mentioned, their interest and energy for the task were high.”*

5.3 Discussion of Results for data presented for Research Question One

How can problem-based learning (PBL) be enhanced to equip beginner Physical sciences teachers in promoting 21st-century skills?

Chapter 2 outlined some of the PBL formats which organise teaching and learning elements differently for various purposes on different situations. The embedded PBL model was adopted by this study since it can be implemented in a course for a short while for a particular intention. The previous section in this chapter presented data generated from various instruments employed by this study. The interpretations and discussions that follow are aimed at answering research question one in this section in terms of 21st-century skills.

5.3.1 Collaboration

Interdependent collaboration being one of the basic aspects PBL, may be assessed through the quality of the group process and successful outcomes. A strong relationship between collaboration and successful achievement has been reported in the literature (Krenik, 2014; Thakur *et al.*, 2018). This study adapted Golightly’s (2013) rubric to assess the learners’ PBL

process and outcomes within small groups. The researcher can ascertain that this is the first time this instrument has been used in this way in the South African context. As mentioned in Chapter 2, the principles of the theoretical framework underpinning this study were infused during the PBL classroom implementation. Beginner teachers looked at: knowledge construction and extension as learners' task; the learners as active participants in constructing their own knowledge; roles as developers and enhancers of learners' skills; education as a personal transaction among the learners, between the learners and the teacher and work task; creating a conducive and cooperative atmosphere. The results emanating from employing this rubric in a Physical Sciences classroom are encouraging. Therefore, further research to develop the Golightly's (2013) rubric for the purposes of assessing learners' PBL tasks in Physical Sciences is recommended. Prior studies (Aidoo *et al.*, 2016; Krenik, 2014; Thakur *et al.*, 2018) have noted the importance of exposing learners to PBL and traditional teaching approach of teaching chemistry. Beginner teachers were able to implement PBL in the teaching of PNM and successfully use Golightly's rubric to assess PBL process and learners' tasks. It is worth mentioning that PBL process directs successful outcomes in the learners' tasks. The results of this study show that four of the five promoted collaboration skill such that learners were able to successfully complete the task and provide solutions and recommendations for the problem. As anticipated, collaboration was promoted as a result of positive interdependence within PBL groups. The present findings seem to be consistent with that of Penn and Arshad (2017), and Golightly (2020) which reported comparatively high occurrence of collaboration on the learners since they managed to complete their task.

As mentioned earlier in Chapter 2, the literature review section, PBL assessments discussed enhance social team interactions and productivity, thus, preparing the learners for the future. One teacher's overall performance is unsatisfactory, therefore, it can be deduced that PBL did not promote *collaboration* skill amongst that particular teacher's learners; the quality of group process and outcome was unsuccessful. A possible explanation for this might be the result of negative interdependence as anticipated by social interdependence theory. In the literature review, Haartman, (2017) acknowledges that learners working in a small group do not always approach a given work collaboratively and may instead view it as a competition. This might have happened with learners for this one teacher in question.

Yet again, as mentioned earlier in Chapter 2, PBL requires learner-based assessment and facilitator's assessment ensure that learners and teacher are looking at and for same things.

With regard to learner-based rubric, the results of this study regarding task distribution; collaborate and contribute equitably; manage conflicts; effectively reflect on teamwork; and building consensus show that learners' collaboration skill was promoted. The results further show that learners knew and encouraged each other's strengths to do quality work. This finding of the study proves promotive interaction as expressed by the theoretical framework. According to Li (2017) and Torre *et al.* (2016), promotive interaction occurs in a face-to-face manner and encourages direct interaction with each other and contributes to achieving group goals and personal development. As shown by the results presented, the extent and level at which this skill manifested varied. The assessment made by learners of the four teachers was consistent with that of their teachers. Therefore, in this regard, teacher- and learner-based assessments are aligned. Surprisingly, the same cannot be said about participants who scored the learners low and the learners equally scored themselves low. As mentioned by Lee and Fu (2019), this study was able to minimise assessment challenges by providing beginner teachers with proper guidance throughout the study on how assessment rubrics should be used.

Interestingly, two outstanding reflections comments were from one participant's learners who stated that they would like to work together frequently since they gained more knowledge working together in collaboration; and another participant's learners who stated that they should encourage one another to all contribute equally to the work because they learn more through working together. Remarkably, both teacher participants reiterated the same as their learners in their interview responses. These results corroborate that collaboration was promoted and also, learners acquired more knowledge than intended. The results of this study show evidence that the theoretical framework tenet of *group processing skills* was observed since learners were allowed to discuss, to share, and to reflect as mentioned by Li (2017), and Rovers, Clarebout, Savelberg and van Merriënboer (2018).

In the current study, implementation of PBL to promote collaboration for SDL found that interdependent collaboration in PBL enhances self-directedness such that learners are: responsible of their own learning; and rely on one another within as a PBL group rather than relying on the teacher. This finding echoes the argument by Stehle and Peters-Burton (2019) who state that collaboration enhances SDL. This finding validates Nursa'ban *et al.* (2019) finding that PBL implementation promotes SDL. As evidenced by one participant's learner's reflection on the PBL problem-solving and teamwork reflection comment, the results of this study show that although learners do not contribute equally during the PBL task, there is

interdependence. The results of this study show that during PBL implementation, the following are logical inferences and conclusions:

- Learners can work together, think critically, communicate and find answers before they can be guided; and PBL promotes learners' independency;
- Learners rely on themselves more as a group than on the teacher;
- Learners' self-esteem is boosted since they ultimately believe in themselves both as a team and as individuals;
- Learners acquire interdependency which is how most science careers function in the real-world.

The above logical inferences and conclusions made, are based on the teachers' perceptions about learners during the PBL implementation. These findings further support those evident in Grow (1991), which suggest that learners exhibit SDL when: (1) they are not dependent on the teacher; (2) they are interested and motivated; (3) they have skills and knowledge and see themselves as owners of their education; (4) they can set their own goals and standards without the help of the teacher. The findings of this study further show that the process of maturation entailing the development from dependency toward increasing self-directedness was observed. This process was identified by Knowles (1980) as Andragogy. By extension, the results of this study further show that absence of PBL collaboration results in a failure to promote responsibility and interdependence (SDL) on the learners.

5.3.2 Critical-thinking

A strong relationship was established between PBL problems and critical-thinking and this was discussed in the literature review section of this study. On assessing the promotion of critical-thinking through PBL approach, the results presented in this study demonstrate that learners argue and criticize their own solutions to the problems, and this is a manifestation of critical-thinking. Formulation of learning objectives is one of the basic elements of PBL process. This study associates this element with critical-thinking. Although critical-thinking quality level is low amongst most learners, it is clear that it was promoted. This study acknowledges that there is a room for improvement in equipping beginner teachers with PBL such that this skill is promoted to the realm of good or excellent. The fact that one participant rated the learners good, suggests that PBL can promote critical-thinking amongst the learners.

One unanticipated finding was that critical-thinking was not promoted in one participant's learners given the already reported results.

One other element in PBL associated with critical-thinking in this study is 'the scope and quality of provisional research found good'. This study's results indicate that four of the five beginner teachers promoted this skill to the highest level, while one beginner teacher did not promote it. With regard to the two PBL elements which are related to critical-thinking skill, it is evident that critical-thinking was promoted. However, the observed difference between four participants who scored their learners excellent and one participants who scored the learners inefficient is unsettling in this study. Essentially, this deviates from the patterns anticipated, and even though this was not significant, the fact remains that this particular participant was not consistent with those of the learners attesting that critical-thinking was not promoted.

Review of pertinent literature indicates that documentation of the type of questions learners ask during PBL has received little attention unless this study missed it. This study documented some of the questions that the learners asked during the PBL implementation in the Chemistry classroom. It can be argued that these questions reflected the learners' thinking. Some of these questions focused on the context of the PBL problem (*What is the size of the room?; Is the house built with cement and bricks, or metal sheets or wood like a Wendy-house?; How long must the refrigerator be open?; Can we include the electricity consumption?*), some focused on content of PNM (*Is the temperature, heat and energy the same?; What is Brownian motion?; Should we provide definitions of concepts such as boiling and melting points?*), and others focused on the PBL process (*Which part of the problem must we focus on?*). These questions show characteristics of critical thinkers outlined by Malmir and Shoorcheh (2012), suggesting that learners were asking relevant questions, admitted lack of understanding; showed a sense of curiosity; analysed the problems; and were eager to establish solutions. The learner-based rubric had an area where learners rated the type of questions they asked which this study associated with critical-thinking. All the five participants' learners rated themselves between proficient, advanced and exemplary; the researcher shares the same view. Therefore, this study considers this particular finding significant and unique.

With regards the learner-based assessment, there were four areas relating to the critical-thinking skill where learners had to rate themselves in a PBL group. The two areas are closely related to the PBL elements on which they were assessed by their teachers: Identifies Relevant Facts (“What do we know?”) and Selects Useful Information from Appropriate Sources. The learner-based assessment area ‘Identifies Relevant Facts (“What do we know?”)’, relates with the teacher-based assessment on ‘Formulation of learning objectives’. With regards this relationship between assessment, Soros, Rapula and Lucas (see Figure 5.1) marked their learners efficient, whereas their learners marked themselves as follows: Soros - exemplary; Rapula and Lucas - proficient. Furthermore, Koti marked his learners good, whereas they rated themselves proficient. Finally, Kganya considered her learners inefficient, but they considered themselves proficient. It is somewhat surprising that similar to Soros and his learners’, Kganya and her learners’ assessments contradicts one another. Teacher Soros’s mark defining efficient, contradicts his learners rating of exemplary. Comparably, Kganya’s inefficient quality level contradicts his learners’ rating of proficient. This finding of this study is consistent with that of Prasetyo and Hima (2019) found that the learner-based assessment scores were higher than the scores from the facilitator’s assessment. The most interesting finding was that assessment made by Rapula, Koti and Lucas concur with their learners’ assessment. This finding is interesting as the context at which these teachers are teaching is different such that one (Rapula) teaches in the farm school, another (Koti) teaches in the ‘Model C’ school, and the other (Lucas) teaches in a township school as outlined in Chapter 3, section 3.5.2.1. Despite various contexts, this finding shows that PBL can be successfully implemented while teaching PNM to promote one of the 21st-century skills, *namely*, critical-thinking.

Shifting focus to assessments made by the learners on ‘Selects Useful Information from Appropriate Sources’ area relating to ‘the scope and quality of provisional research good’ on teachers’ assessment. As mentioned earlier in this section, Soros, Rapula, Koti and Lucas, marked their learners excellent, and Kganya marked her learners inefficient. The assessment made by Soros, Rapula and Lucas corroborates their learners’ assessments. Their learners rated themselves the highest (exemplary and advanced) too. Contrary to expectation, this study finds that there is assessment misalignment, on Koti and his learners, and Kganya and her learners. Teacher Kganya’s learners considered themselves developing rather than advanced or exemplary. This is a new finding were learners scored themselves lower than the teacher. Kganya’s learners rated themselves advanced rather than developing or limited. As

mentioned earlier in Chapter 2, Li, Xiong, Zang, Kornhaber, Lyu, Chung and Suen, (2016) posit that more than one type of assessment could result in some inconsistencies such that learners' and teachers' ratings differ significantly. It can be argued that inconsistencies of assessments were relatively low in this study. The results of this study indicate that, after PBL implementation, the participants believe that PBL improve critical-thinking skill when learners are given a chance. Literature (Dillon, McDonnell, Murphy & White, 2018; Johansson & Svensson, 2019; Lee, 2013) is replete with the difficulty in adopting and implementing an assessment on a PBL approach in the classroom. However, this was not the case for this study because of the clear rubrics which were employed.

Pertaining to 'identification and recommendation of possible solutions for the problem' on facilitator's rubrics, is another PBL element associated with critical-thinking in this study. Four of the five teachers promoted critical-thinking in their learners to a moderate satisfaction, while one participant promotion of this skill was unsatisfactory. The findings of the current study are consistent with those of Narmaditya, Wulandari and Sakarji (2018) who found that learners' critical thinking skills were enhanced dramatically after the implementation of PBL in a lesson. It is evident that critical-thinking was inculcated by 4 out of 5 of the teachers on their learners through PBL. The 'identification and recommendation of possible solutions for the problem' is related to area of 'Develops Multiple Solutions to Major Problem(s)' on learner-based assessment. This is in agreement with arguments made by Bailey and Mentz (2015), Havenga (2015b), and Oyibe, *et al.* (2015) that in critical-thinking learners are engaged to evaluate and criticise information and make informed judgments to direct their knowledge in a constructive manner. The learner- and teacher-based assessments are aligned for four teachers, both the teachers' scores and the learners' ratings are relatively high and approximately the same. However, one participant's assessments contradict one another. In Chapter 2, it is argued that learner-based assessment within PBL is important for developing 21st-century skills, promoting SDL and fostering personal development within the learners (Roberts, Jorm, Gentilcore & Crossley, 2017).

During interviews, this study found that during PBL in Chemistry classroom, the learners get the opportunity to make sense of the content they are learning; learners can relate the curriculum content to their real-life experiences. Furthermore, this study found that the learners find PBL interesting. This finding corroborates Gonzalez (2019), who states that the PBL approach increases learners' motivation. One of the significant findings of this study

was that PBL enhances learners critical-thinking which boosted their performance in the topic of PNM. There are similarities between this particular finding in this study and arguments made by Ayaz (2015), Awan, Hussain and Anwar (2017), and Merritt, Lee, Rillero and Kinach (2017) that the learners taught through PBL approach shows better understanding of chemistry concepts, better attitude towards learning Chemistry, and prove to have acquired critical-thinking and problem-solving skill. A South African study investigating the effects of PBL on students' achievement in Chemistry by Aidoo *et al.* (2016) reported a significant difference in the achievement between the students' performance after being exposed to PBL and traditional teaching approach of teaching chemistry. Aidoo *et al.*'s (2016) findings further showed that the learners' problem-solving and critical-thinking were promoted during PBL implementation.

The aforementioned findings of this study support submissions made by other scholars, Wood (2003), Nariman and Chrispeels (2016), Dmitrenko (2017), and Ali (2019) that teaching learners through PBL enhances their skills to search relevant information, involving the real-world in a learning situation, encourages and motivates learners to learn, encourages learners to be responsible for the development of other skills and attribute, learning and retaining information better and longer, higher academic achievement, and improved 21st-century skills.

5.3.3 Communication

Another 21st-century skill which this study aimed to promote as a result of PBL implementation is communication. The results indicate that communication was promoted on the learners of all participants of this study. The results further show that participants and their learners agree that communication skill was promoted. Communication can be difficult to promote when the learners are exposed to PBL for the first time. Tipton (2019) administered deductive-dominant content analysis in a study. The findings by Tipton (2019) showed that home-school teachers emphasized that the communication skill was reflected in PBL implementation. Following the argument by Landon (2019) that acquiring communication skill does not mean learners can communicate effectively across all forms of communication, however, learners must at least be able to perform interpersonal, written, and oral communication in order to participate globally, this study promoted interpersonal communication within learners' groups, between the learners and the teacher, written communication between learners, content and the teacher.

5.3.4 Creativity

Although Hamid (2018) argues that critical-thinking and creative skills are inseparable because they sharpen one another, this study considered them separately. The results of this study show that creativity is not easy to observe and promote on the learners through PBL. This study found that most participants did not observe this skill or this skill was not promoted. The participants who observed this skill do so with some degree of uncertainty. Nonetheless, those participants' learners' results indicate that creativity was promoted. It is difficult to explain this result, but it might be related to teachers' beliefs regarding what they *really* consider creative. However, during TPD, beginner teachers were advised to view creativity as the ability to refine existing concepts or generate new ideas; to be open-minded and courageous to explore; work creatively with others; and creative and innovative production. One significant finding in the interview responses is that learners were always ahead and not afraid to make mistakes. The literature does not present much regarding these findings with respect to creativity.

5.3.5 Supposition remarks answering researcher question one

As suggested by Rusdin and Ali (2019) in Chapter 2, teachers must employ teaching approaches that fulfil the 21st century education thus effectively fostering the 21st-century-skills such as the 4Cs in their classrooms. This study equipped beginner Physical Sciences teachers with the PBL approach to promote the 21st-century 4Cs. This study amplifies how PBL can be enhanced through TPD programme and support, to equip beginner Physical Sciences teachers in promoting the 21st-century skills. The findings of this study corroborates submissions made by Johnson and Johnson (2009) about positive interdependence which are: increased achievement and greater productivity; motivates and individuals and develops of new insights and more use of higher level reasoning strategies; more willingness to work; and better collaborative and cooperative skills. This study produced results which corroborate the findings of a great deal of the previous work in this field.

The results of this study provide evidence of *psychological processes* as mentioned in Chapter 2. As a result of positive interdependence, substitutability, inducibility and positive cathexis were reflected by learners during PBL implementation. It is therefore extrapolated that post enhancement, beginner Physical Sciences teachers were able to implement PBL and

promote collaboration skill amongst their learners. This study confirms that PBL is associated with promoting 21st-century skills.

5.4 Research Question Two

To what extent do beginner physical sciences teachers' use problem-based learning (PBL) in initiating and promoting 21st-century skills before and after a teacher professional development (TPD) programme?

5.4.1 Summary of Pre-Teacher Professional Development Results

As mentioned earlier in Chapter 4, this study found that before the TPD programme beginner teachers' showed an understanding of the science content knowledge including PNM regarding teaching of the PNM, however, had limited knowledge on the teaching using Problem-Based Learning (PBL). Pertaining to knowledge and utilisation of PBL, none of the beginner teachers used PBL. Furthermore, none of the five beginner teachers provided an acceptable definition of PBL; teachers' understanding of PBL was established limited. Shifting focus to beginner teachers' promotion of the 21st-century skills (collaboration, critical thinking, creativity & communication), none of the participants mentioned how they promote all the four 21st-century skills in their teaching and learning process. The last theme as identified in Chapter 4 relates to the enhancement of SDL and this study found that there is room to improve the way in which beginner teachers enhance SDL through their teaching.

5.4.2 Post-Teacher Professional Development Results

This section presents results addressing the second research question in terms of the extent to which beginner Physical Sciences teachers utilise PBL in initiating and promotion of 21st-century skills post the TPD programme. Results were generated from each beginner teacher's whole portfolio. The analytical tool used to evaluate teachers' portfolios was adapted from Smith *et al.*'s (2001) Interstate New Teacher Assessment and Support Consortium (INTASC) performance standards scoring rubric. These findings are also corroborated with teacher interviews. As mentioned in Chapter 3 section 3.4.2, participants were professionally developed on various areas such as PBL approach to teach PNM and 21st-century skills in conjunction with the CAPS document during the TPD programme. The TPD programme was informed by the participants' open-ended questionnaire responses. Although beginner

teachers' PNM content knowledge was not the focus of this study, it was considered satisfactory during the TPD programme. However, two out of the five teacher participants indicated that their content knowledge was challenged and enhanced. Another point worth mentioning is that during the TPD programme, beginner teachers' showed clear, convincing and consistent evidence that they can construct a meaningful lesson plan with all expected elements. Participants were instructed not to include a lesson plan in the portfolio by the researcher.

As mentioned in Chapter 3 section 3.7.2, an adapted Smith *et al.*'s (2001) scoring rubric was used to assess beginner teachers' portfolios on 6 INTASC principles, namely: content knowledge being taught; PBL implementation; instructions adapted to meet diverse learners; 21st-century skills observed template; assessment of learners' work to improve enhancement of 21st-century skills; as well as reflections and TPD. In assessing the aforementioned INTASC principles, data was sourced from various parts of the portfolio using the scoring criteria of 1- 4 where 4 = Clear, convincing and consistent evidence; 3 = Clear evidence; 2 = limited evidence; 1 = No evidence. The results are presented in the order of the INTASC principles as outlined in the rubric (see Appendix M). It is important to note that portfolio sections which inform this principle are not scrutinised in isolation; participants' data of the portfolio was expected to be interwoven and corroborated by other data generated from other instruments used in this study.

5.4.2.1 Content knowledge taught

This principle, like all others, is indicated by a checklist as outlined in the rubric (see Appendix M). According to the rubric, this principle is shown by the following: clear illustration of PNM central concepts being taught; understanding of the content knowledge and CAPS curriculum goal; and understanding of the teaching-learning situation. The indication checklist is drawn from the portfolio parts such as the lesson plan, PBL problem used and learners work. However, as mentioned earlier in this section, participants' knowledge regarding the lesson plan was considered satisfactory. Another part which informs this principle is the PBL problem used during implementation which was provided to the participants and therefore did not have to be submitted with the portfolio. As a result, all the participants were scored 4 which was considered a default score.

5.4.2.2 PBL implementation

This principle is concerned with the practice in the classroom. The portfolio parts that informed this principle were as follows: the teacher's role as the facilitator; learners' roles within the group and as active participants; and learners' work during the PBL implementation process. The learners' work is intended to corroborate each teacher's report. The indication checklist regarding this theme clarifies if the teacher: understands how learners should learn and develop; and provides a learning opportunity and environment that adheres to PBL approach to support learners' cognitive, social and personal development. Each beginner teacher was scored as follows regarding this principle:

Teacher Soros: Teacher Soros's role as a facilitator was clearly stated and in agreement with the description as articulated in Chapter 2 and discussed during the TPD programme. The teacher showed understanding of how learners should learn and develop during the PBL implementation. The teacher facilitated learning of the PBL groups putting responsibility on the learners, observing learners' interactions and asking probing questions. However, there is no evidence of the teacher adhering to the PBL approach in the manner expected regarding learners' roles within the PBL group. Although learners were grouped into a required number, their roles such as a group leader and scribe were not clearly stated in the portfolio. This shortcoming is further reflected on learners' report since their role are not indicated resulting in the criterion score of 3.

Teacher Rapula: Teacher Rapula's implementation of PBL showed clear, convincing and consistent evidence (criterion score 4). The description of the teacher's role was detailed showing that the teacher understood the how the learners should learn and develop. The teacher provided a learning opportunity and environment that adhered to the PBL approach promoting 21st-century skills. The teacher working with a group of five learners, ensured that learners understood their roles as active participants within the PBL group. The descriptions provided by the teacher in the portfolio were further supported by learners' report showing their roles within the group.

Teacher Koti: Teacher Koti's portfolio provided clear, convincing and consistent evidence of PBL implementation (criterion score of 4). Koti presented the PBL problem to the learners and allowed them to work in groups which adheres to the requirements of PBL approach.

Regarding facilitation, Koti constantly checked his learners' progress, guiding learners thinking and assisting learners with some of the questions asked. Koti was in charge of his classroom and kept good discipline on his learners. The learners understood their role during implementation; this is also supported by learners' work. Koti understood how learners must learn and develop during PBL implementation. It is evident that learners were provided with the learning opportunity and an environment adhering to the PBL approach supporting learners' cognitive development regarding the content, and social and personal development regarding the 21st-century skills.

Teacher Lucas: Teacher Lucas also scored the highest in this criterion (score of 4) in implementing PBL in his classroom. Lucas described his role as a facilitator as follows:

I ensured that the classroom environment promotes discussion method by allowing learners to sit in groups. All the 26 learners were split into four groups (two groups with 6 learners and the other two groups with 7 learners). The teacher then moved from group to group ensuring that learners understood the topic and that effective discussion is taking place amongst group members.

Under learners' roles, Lucas explains learners as active participants within the groups, with each group having a group leader and the scribe. This part of the portfolio provides a clear, convincing and consistent evidence that Lucas understood how learner should learn and develop during implementation of PBL. Lucas performed his role providing learners with an environment that adheres to PBL approach to support learners' development.

When asked during interviews, how would you describe utilising PBL in teaching PNM? Lucas responded:

I gave learners the PBL problem, and allowed learners to explore different areas in the problem of the Kinetic Molecular theory and they came up with their own knowledge and drew solutions. In our discussion I also used simulations for some of PNM concepts such as diffusion, Kinetic Molecular Theory e.t.c. observing what happens to molecules or particles when the temperature changes. Then went through some concepts such as diffusion, KMT, e.t.c. Finally, learners could focus researching more information to come up with the solutions.

Teacher Kganya: Teacher Kganya's portfolio provided limited to no evidence about her understanding of how learners learn and develop during the PBL implementation. The score

of 1 is justified by the Kganya's partial understanding that learners should learn and develop through groups. However, Kganya did not provide a learning opportunity and environment that adheres to PBL approach in terms of number of learners within PBL groups. Kganya divided her learners into 4 groups (three groups of 10 members and one group of 11 members). Teacher's role description, learners' roles description and learners' report corroborates that Kganya failed to adhere to PBL approach. The numbers that learners were divided into, violated the aspects of PBL approach. Furthermore, the learners did not have roles. It is evident that Kganya did not facilitate the PBL implementation.

5.4.2.3 Instructions adapted to meet diverse learners

This principle was aimed at observing if the participants understood their learners' diversity, facilitated and guided their learners, and brought multiple perspectives to learners' discussions. The portfolio part which provided data of this principle was 'details of what happened during the lesson' of teaching PNM through PBL. Therefore, main highlights from what transpired during the PBL implementation are reported. The results are presented for each participant in verbatim as written in the portfolio sections and the score each obtained.

Soros stated:

At first, learners were not sure of what to do. Once learners were in a group, one learner volunteered to be a group-leader and then elected a scribe. The learners' progress was slow because some learners were not contributing. The learners were being guided and asked questions to boost their thinking skills. The learners did not finish the work in the 1-hour period therefore learners took the work home to go and research more. During the subsequent period the learners were actively participating, managed to discuss and complete their work by the end of the period.

Soros provided clear, convincing and consistent data, thus scoring 4 for this principle.

Rapula reported that:

Once learners were given the problem, they started by using their textbooks to define learning issues. Learners were discussing and asking question and decided on the approach to solve the problem by sharing responsibilities such that every group member contributes. However, 50-minutes period was not enough for the learners to complete the work, therefore they took the work home and continued working the

following day in the classroom. The learners managed to complete the task during the third period and submitted a written report.

Rapula was scored 2 due to the limited evidence with regard to bringing multiple perspectives to learners' discussions.

Koti's report is as follows:

The teacher firstly grouped the learner and went through the problem with the learners outlining what is expected of them. The teacher asked the learners to choose a group-leader and scribe within their groups. The learners started with discussions attempting to answer the problem. There were disruptions in some groups. Learners managed to formulate lesson objectives, drawing solutions and making evaluation to make recommendations. Since the topic had already been taught before, the learners knew the topic and managed to complete the work in the 1-hour period.

Koti's data is clear and consistent, convincing that he understands learners' diversity, guided learners and brought different perspectives to learners' discussions, therefore scored 4.

Lucas's occurrences are:

The teacher refreshed learners' prior-knowledge regarding some PNM concepts. He then gave the problem to the learners and explained the scenario to the learners within their groups. Allowed learners to discuss the problem and write down their findings.

Lucas was scored 4 because there is clear, convincing and consistent evidence of understanding learners' diversity, guided learners and brought multiple perspectives to learners' discussions hence he refreshed learners' prior-knowledge on PNM concepts and discussed the problem within their groups.

Kganya stated:

I divided learners into four groups. After giving learners the problem I explained it, then I discussed what they are expected to do. There learners were identifying the lesson objectives from their textbooks and previous work. When I was igniting discussion with one group, other groups were making noise. I decided to let them work on their own but the learners were not disciplined. The learners did not finish the work during the 1-hour period. I told learners to take the task home so that each one of them can contribute. During the following, I demanded learners complete their task since I will take the work anyway.

Therefore, Kganya was scored 1 due to lack of facilitation and guidance provided to the learners, and bringing multiple perspectives to learners' discussions.

5.4.2.4 21st-century skills observed

The participants were provided with the 21st-century skills template (see Appendix B) which was part of the portfolio they had to complete. This template was designed to allow participants to indicate the 21st-century skill observed during PBL implementation while learners worked in small PBL groups. The template also had a comment section if the teacher had any. The indication checklist looked if the teacher observed at least one 21st-century skill among the learners. Although this study is aimed at suggesting that the utilisation of PBL may promote the 21st-century skills, it is cognisant that PBL might not promote the anticipated skills. This study also found it impractical for no skill to be promoted while the learners work with a PBL problem in small groups. Data for this theme was also generated from learner-based assessment rubric. Therefore, the reporting of this portfolio part is exactly the same as discussed earlier in this Chapter, section 5.2.

To put it briefly, all participants observed at least one of the four 21st-century skills discussed in this study as indicated by the templates and corroborated by learner-based rubrics. Teacher Soros and teacher Lucas observed three 21st-century skills which are collaboration, critical-thinking, and communication. Teacher Rapula and teacher Koti observed all the four skills. Teacher Kganya indicated to have observed only one skill, communication. The learner-based assessment rubric various aspects relating to each 21st-century skill discussed in this study were also presented earlier. The learner-based rubric results were aligned with teachers' observations. Therefore, Soros, Rapula, Koti, and Lucas obtained a score of 4 since each presented a clear, convincing and consistent evidence. On the contrary, Kganya obtained a score of 1 due to other parts of the portfolio that were presented earlier showing that PBL was not properly implemented. Furthermore, there was limited evidence concerning constructive and meaningful communication apart from the learners' report.

5.4.2.5 Assessment of learners' work to improve enhancement of 21st-century skills

As discussed in Chapter 2, assessment in PBL is a prerequisite to learning and development of professional competencies. The PBL implementation requires assessment from both the

teacher and learners. Therefore, in assessing the participants' portfolio, evidence of teacher-based and learner-based assessment was important. The assessments section in the portfolio report to this INTASC principle. The indication checklist scrutinised the following: use of teacher-based rubric to evaluate learners' work; and use of learner-based assessment rubric self-evaluation by learners within a PBL group. However, assessment details were presented and discussed on various occasions earlier in this chapter. In summation of this principle, each participant was scored 4; all the participants' data was clear, convincing and consistent.

5.4.2.6 Reflections and professional development

This principle checks the teacher's continued observation of the PBL process for both self and the learners during the PBL implementation. This principle further checks the challenges (if any) experienced during the PBL implementation. The section of the portfolio which this principle draws from is 'Reflection and challenges experienced with the implementation of PBL activities in Chemistry'. This part was equally evaluated using the scoring criteria outlined earlier in this section. Participants were scored based on at least one reflection made for self- and for the learners. Participants were further evaluated based on mentioning at least one challenge for the teacher and for the learners. This study finds it almost impossible to employ an unfamiliar teaching approach and not experience any challenges. Teachers' reflections and challenges are tied to TPD. Each participant's reflections are presented verbatim together with challenges experienced and the score obtained.

Soros's reflection was:

PBL is a good and positive approach. Science is learned best when learners are given problems to solve on their own; with PBL, learners are given a chance to solve problems on their own. PBL can work effectively if the content being taught is what the learners experience on their daily basis.

The challenges experienced by Soros were that some learners relied on others; and learners were struggling to formulate learning objectives. Soros obtained a score of 3. He showed clear evidence of reflections and challenges experienced by learners; there is no data relating to teacher's reflections about self to observe professional development. Responding to the question: What negative impacts did you experience while utilising PBL? Soros said:

Those learners were not used to work together or in groups. Therefore, top learners who are doing well were leading, whereas others were reluctant and reliant of them

most of the time. They did not want to think and therefore disadvantaging them. Top learners were the ones coming up with ideas.

The reflections made by Rapula were as follows:

Using of PBL decreased my work, and it seemed too effective for learners and promotes their teamwork skill, content-knowledge and problem-solving skill. Challenges mentioned are: PBL is time-consuming; initially it was difficult for learners to use; I was not confident about using PBL to teach; and PBL requires more documents/material for references rather than general knowledge and textbooks only.

Rapula's data is clear, convincing and consistent, thus scoring 4. In the question: What negative impacts did you experience while utilising PBL? Rapula reiterated the same challenges during the interview.

Koti noted the following in terms of reflection:

The learners were actively participating, showing interest and excitement. PBL brought life and fun in the Physical Sciences classroom. The group-leaders were helpful in maintaining discipline in the classroom. But the learners took more time than it would normally take to complete this topic using teacher-centred method because this topic requires a practical experiment. I also got to know the learners more, engaging with the learners on more like a personal level fulfilled me; I started reflecting on the effectiveness of my teaching.

Koti's challenge was that he found PBL time-consuming. Koti was scored 3, since the challenge experienced during implementation was teacher-related, nonetheless, evidence was clear. During the interview, Koti still complained about time.

Reflections made by Lucas, are as follows:

PBL is very effective in teaching Physical Sciences because, instead of learners passively receiving information, they actively participate and construct their own knowledge. Monitoring four groups was not a problem. It was easy to ensure that no learner was left behind, especially since no individual work is submitted.

The challenges experienced by Lucas were that he was struggling to find positive ways to correct and clear misconceptions he identified without embarrassing the learner in front of other group members. Lucas was scored 3, due to the clear evidence provided. The same challenge was reiterated by Lucas during the interviews.

Regarding reflections, Kganya mentioned the following:

The classroom experience I had was not the same as the experience I had during the intervention. I do not know what I did wrong because I can tell that PBL is a good approach. I think I need workshops regarding PBL in order to boost my confidence. The learners were making noise within their group, PBL was not effective. I do not think they grasp anything. I also think that maybe if I had less number of learners it could have been better.

The challenges stated by Kganya included lack of discipline and time. PBL was not properly implemented by teacher Kganya, resulting in the score of 1; there is a limited evidence showing proper implementation of PBL. Kganya expressed the same challenges during the interview.

5.4.2.7 Portfolio scores for each theme for the five teachers determining overall level of proficiency of PBL implementation

The average totals for each theme were calculated for each teacher. Scores were awarded according to how often a given activity occurred during PBL implementation lessons as captured in the portfolio by scoring the section or part of the portfolio. The scoring was based on an indication checklist which is placed on a continuum ranging from (1) no evidence, (2) limited evidence, (3) clear evidence, and (4) clear, convincing and consistent evidence.

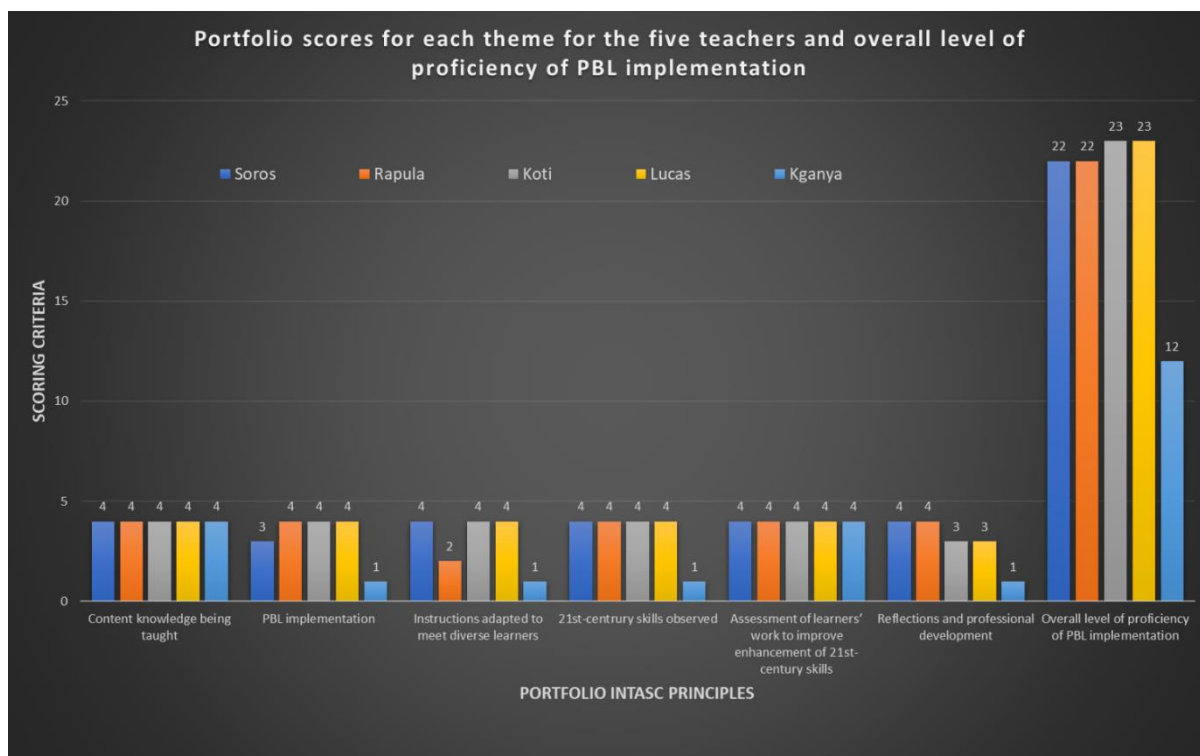


Figure 5.2: Graph showing score for each theme and overall level of proficiency for each of the five teachers

In scoring, each item response was allocated 1, 2, 3 or 4 from “no evidence” to “clear, convincing and consistent evidence”, respectively. A high score (maximum = 24) is taken to mean that to a large extent, an overall level of proficiency of PBL implementation by the teacher is clear, convincing and there is consistent evidence and a low score (minimum = 6) means there is no evidence of an overall level of proficiency of PBL implementation by the teacher. As shown in Figure 5.2, two teachers had a grand total of 22, two other teachers had a grand total of 23 and one teacher had a grand total of 12 out of a possible score of 24. Scores were used to place proficiency of PBL implementation along a continuum ranging from 6 ‘no evidence in PBL utilization’ to 24 ‘clear, convincing and consistent PBL utilisation.’ The continuum on which the scores were mapped is as follows: 6.0 - 10.5 (*no evidence - unsatisfactory*); 10.5 – 15.0 (*limited evidence - fairly acceptable*); 15.0 – 19.5 (*clear evidence –moderately satisfactory*); and 19.5 - 24.0 (*clear, convincing and consistent evidence - highly satisfactory*). Scores of 22 and 23 fall within the fourth band which is that of highly satisfactory PBL implementation though quite at the top end of the band. A score of 12 falls within the second band which is that of fairly acceptable based on limited evidence though at the lower end of the band. In responding to the second research sub-question, it can be concluded that the extent to which beginner physical sciences teachers’ use problem-based

learning (PBL) in initiating and promoting 21st-century skills is highly satisfactory after the TPD programme. One teacher who scored in the fairly acceptable band indicates that improvement is needed in some themes of PBL implementation.

In support of the conclusions made in the preceding section, some corroborating data is presented verbatim from a couple of interview questions posed. When asked, what can you say about your teaching before and after the workshop? Soros said: *“There is a difference because before workshop, learners were dependent on me but now after implementation they can work on their own and as a group.”*

Rapula said:

Firstly, my knowledge of chemistry was challenged and enhanced before and during the workshop. I didn't know this topic is called Particulate Nature of Matter. Before the workshop I just knew PBL but I didn't know it is exactly and had never used it.

Koti said: *“Truly speaking, mostly I stick to my old teaching approach. But sometimes in some topics I will use PBL.”*

Lucas said:

Before, I was teacher-centred because of the CAPS curriculum pacesetter. It was difficult to try to explore different approaches. Therefore, I was more teacher-centred in order to cover the ATP in a given time. But after being exposed to PBL in the workshop, I allowed learners to develop their own knowledge. I could allow learners to work ahead such that I can give them problems before the lesson because they are self-directed. That way I could discover the learners' prior knowledge, where they struggle and the misconceptions that they might have.

Kganya said: *“Before the workshop I only focused on completing the curriculum is outlined by the ATP. After the workshop, I can reflect on my teaching. But I think my teaching will still be the same for a while.”*

On the question, what would you change AND improve in utilising PBL while teaching PNM? Rapula said: *“I will not change anything. I just wish you could give us problems for every topic.”*

Koti said:

I would try to deal with the issue of time. For PBL to be applicable I would modify it in such a way that learners work individually rather than the group in order to reduce amount of time spent by learners trying to solve the problem; that's if it is possible because I think I will be limiting the approach.

Lucas said: *"There is nothing that I would change since this was my first time using PBL."*

Kganya said: *"My knowledge of implementing PBL is poor. So, I do not know what to improve or change."*

5.5 Discussion of results for data presented for research question 2

To which extent do beginner physical sciences teachers' use problem-based learning (PBL) in initiating and promoting 21st-century skills before and after a teacher professional development (TPD) programme?

This study's results indicate that beginner Physical Sciences teachers did not utilise PBL in initiating and promoting 21st-century skills before the TPD programme. As mentioned earlier, the results of this study relating to beginner teachers who participated in this study *prior* the TPD programme were outlined and discussed in Chapter 4. The discussion presented in this section focuses on addressing the extent to which beginner Physical Sciences teachers utilise PBL in initiating and promoting 21st-century skills *after* the TPD programme. The summary of results, interpretations and discussions are outlined in the same order of the themes as the results were outlined.

5.5.1 Content knowledge taught

The participants' knowledge regarding the lesson plan was considered satisfactory. Furthermore, as mentioned earlier, this study found that the participants possess a clear understanding of PNM central concepts taught; understanding of the content knowledge and CAPS curriculum goal; and understanding of the teaching-learning situation. This is in corroboration with the argument by Kaptan and Timurlenk (2012) that most science teachers start their practice with some relatively good content knowledge. As mentioned in Chapter 2, it was anticipated that beginner teachers might have an acceptable content knowledge of PNM.

5.5.2 PBL implementation

This study produced results which corroborate the findings of a great deal of the previous work in this field advocating implementation of PBL in sciences education (Aidoo *et al.*, 2016; Nursa'ban *et al.*, 2019; Thakur *et al.*, 2018; Valdez & Bungihan, 2019; Wahyu & Syaadah, 2018; Boakye & Ampiah, 2017). This study also validates that although there may be challenges, teachers who have never been exposed to PBL before can implement it to satisfaction (Li & Tsai, 2017; Zhukova, 2017). These beginner teachers showed understanding of how learners should learn and develop during the PBL implementation. These teacher participants facilitated learning through PBL groups, putting responsibility on the learners, observing learners' interactions and asking probing questions. However, of the four teachers discussed in the preceding statements, only one participant did not honour the learners' roles within the PBL group. Only one participant showed no evidence of successful PBL implementation while teaching PNM. This participant did not provide a learning opportunity and environment that is conducive to PBL implementation in terms of number of learners within PBL groups. It is evident that this participant's PCK, knowledge about learners and their characteristics; educational contexts; and educational, was not enhanced. A possible explanation for this might be due to what Robson and Mtika (2017) posited that beginner teachers often face complex and dynamic challenges such as personnel, organisations and environments. The most interesting finding was one participants infused simulations to enhance learners' content knowledge on some of the PNM concepts. This finding corroborates the ideas of Alamina and Etokeren (2018), Kawedhar, Mulyani and Indriyanti (2019), and Summerton, Hurst and Clark (2018) who suggested utilisation of visual materials (such as models and simulations) and imagination stretch teaching strategy into the secondary school chemistry teaching-learning situation has a potential to make learning and teaching easier.

5.5.3 Instructions adapted to meet diverse learners

To get insights into how each teacher adapted PBL process to meet his/her diverse learners, beginner teacher noted what transpired during the PBL implementation. The current study found the learners used textbooks as their main sources of information. This finding corroborates Baran (2016) and Suastra *et al.* (2019) who found that each member in the group had an opportunity to present the solution to the rest of the group with the supporting material. Conversely, textbook use as a primary source is standard practice apparently

because learners rely on the teacher and the textbook in their routine learning. This study also found that learners spent more time than what the teacher would usually take complete the topic. This finding supports previous research that first time implementation of PBL may require more time (Havenga, 2018b; Zhukova, 2017). However, this finding may also be corroborating Boakye and Ampiah (2017) who found that beginner teachers generally struggle with time management.

Another finding was that learners shared responsibilities such that every member contributes. However, there can be disruptions during PBL implementation. This finding further support the idea of positive interdependence where learners work together in a small group with shared responsibilities (Johnson & Johnson, 2009). One unanticipated finding was that implementing PBL on a familiar topic, the learners might adapt easily. This particular teacher had already started with the PNM content. Another finding was that when learners are divided into larger groups, they are destructive and unproductive. This is consistent with other research which found classrooms might experience challenges implementing PBL approach and achieving desired outcomes (Valdez & Bungihan, 2019; Wood, 2008).

5.5.4 21st-centrury skills observed

The results of this study pertaining to this aspect were discussed earlier under the first research question (see section 5.4).

5.5.5 Assessment of learners' work to improve enhancement of 21st-century skills

The results of this study pertaining to this study were discussed earlier under the first research question (see section 5.4).

5.5.6 Reflections and professional development

Major reflections and challenges of each participant relating to teachers' professional development are summarised and discussed here. The results show that beginner teachers find PBL to be a good and positive approach for science since learners are given a chance to solve problems on their own; and it decreases their workload. These findings are in agreement with Chua and Karpudewan (2020) who argue that emphasise on a teaching approach that results on the learners doing more work will lead to learners' understanding of chemistry concepts. This study found that PBL allows the teachers to know their learners on a

personal level. This finding supports the idea of good relationships outlined by this study's theoretical framework, *social interdependence theory*, and its components. As mentioned in Chapter 2, social interdependence theory also provides the context for motivation which inherently occurs within a network of interpersonal relationships (Albarracin, 2019; Deutsch, 1949a; Johnson & Johnson, 2003; Sukrajh, 2018). This study further found that PBL helps teachers to reflect on their teaching, and an approach that ensures that no learner is left behind since it requires group work. The findings are in agreement with Jonassen (2011), Havenga and Van Wyk (2017), who argue that PBL is an instructional methodology that is problem focused, student-centred, self-directed, and self-reflective with teachers as facilitators.

One other interesting finding is that the group-leaders were helpful in maintaining discipline in the classroom. This finding corroborates Ansari *et al.*'s (2015) argument that PBL implementation promotes leadership qualities and managerial skills among the learners. Another unanticipated finding was that due to unsuccessful PBL implementation, one participant felt that she needs more training to implement PBL to boost her confidence in order to successfully implement PBL. This finding is in agreement with Zhukova (2017) who found beginner teachers report being afraid of losing control in the classroom and struggling with discipline and behaviour issues due to lack of confidence in implementing PBL.

The challenges experienced by beginner teachers during PBL implementation include: learners struggle to formulate learning objectives; PBL is time-consuming; lack of confidence in using PBL to teach; PBL requires more documents/material for references rather than general knowledge and textbooks only. The challenges found by this study are not new in the field, but well known to both beginner and experienced teachers across disciplines in education, and are heavily reported on many scholars (Aker & Pentón-Herrera, 2020; Ansarian & Teoh, 2018; Ceker & Ozmali, 2016; Hung, 2011; Johansson & Svensson, 2019; Li & Tsai, 2017; Tandogan & Orhan, 2007; Vogeltanz-Holm, Olson, Borg and Hill, 2014; Wood, 2008; Zhukova, 2017). One interesting finding of this study was that one teacher had a struggle to positive ways to correct and clear learners identified misconceptions without embarrassing the learner in front of other group members. It is difficult to explain this finding, but in the researcher's opinion, it might be related the kind of person the teacher is, or the kind of learners the teacher has.

5.5.7 Overall judgment regarding PBL implementation

The findings of this study show that four of the five teachers successfully implemented PBL in the teaching of PNM. It can be concluded that the extent to which beginner Physical Sciences teachers' use problem-based learning (PBL) in initiating and promoting 21st-century skills is highly satisfactory after the TPD programme. However, one teacher's overall assessment of the portfolio indicates that improvement is needed in some themes of PBL implementation. Although some beginner teachers expressed that they shall continue to use their usual approaches than PBL in most of the topics, and apply PBL in some of the topics, they indicated that there is a difference in their teaching after the workshop. This finding corroborates Dudu (2014, 2017) who found that South African Physical Sciences teachers acknowledged that TPD improved their teaching approaches and content knowledge since it was directly linked to their daily experiences. Another interesting finding is that one participant's knowledge of chemistry was challenged and enhanced before and during the workshop. This is found in the pertinent literature that beginner teachers struggle with some of the content, including PNM, they teach (Bekdemir, 2019; Boakye & Ampiah, 2017; Chaves, 2018; Davis, Petish & Smithey, 2006). Similar to Pitjeng-Mosabala and Rollnick (2018), these findings show how the initial knowledge of all the teachers was enhanced by the workshop element of the TPD and their related experience.

Another interesting finding is that some beginner teachers requested for more PBL problems for other Physical Sciences topics. This finding confirms the submissions made by Ansarian and Teoh (2018), Hung (2011) that designing or/and selecting the learning problem to engage the learners for a teaching-learning purpose is not easy. This study recognises that this might be the reason why teachers may not continue implementing PBL in the Physical Sciences classroom. Moreover, unless this study might have missed it, the pertinent literature does not reflect PBL resources bank where problems can be found and used for teaching purposes. Another interesting finding is that one participant expressed that he would like to modify PBL in such a way that learners work individually rather than the group in order to reduce amount of time spent by learners trying to solve the problem. It is difficult to relate this finding since the PBL learning demands teamwork and the teacher might not have appreciated the approach as she did not do well in most components she was evaluated on.

5.6 Research Question 3

What problem-based learning (PBL) principles of practice could be distilled for beginner Physical Sciences teacher professional development (TPD) towards Self-Directed Learning (SDL)?

This section presents results for addressing the third research question of this study in terms of principles of practice from PBL that could be distilled for beginner Physical Sciences TPD towards SDL. The results for this section were generated mainly from interview data with beginner teachers. The results are presented in the order of the PBL principles that could be distilled from the generated data towards SDL. While basis and emphasis of this study was on theory and its implications, it was important to extract principles of practice (Krashen, 1982). Supported by a theory, PBL principles of practice describe how teachers' implementation can generate improved learning over time; principles explain specific changes that can be expected and creates a brief evidence-based synopsis (State of Victoria (Department of Education and Training), 2018).

5.6.1 Culture of learning and personal development

During interviews, teachers were asked: How can you describe your exposure on PBL, 21st-century skills and SDL? Lucas said:

I experienced that using PBL helped me very much when it comes to teaching because many teachers when they start teaching, including myself, we tend to teach the same way that we were taught, and 21st-century skills are not the skills that our teachers were equipped with. Therefore, being exposed to PBL and 21st-century skills helped me as I discovered things I did not know before, especially another approach that I can use to teach PNM and other topics. I believe that this will lead to learners being self-directed. And I think it is good to have self-directed learners because the classroom becomes a learning community.

In the interview question: How did you benefit from this exposure? Soros's response was: *"I have benefited because before, I was using teacher-centred approach. Since implementing it (PBL) in my classroom, it (PBL) shifted learners' thinking to want to do things on their own."*

5.6.2 Expansion of teaching methodologies

During interviews, teachers were asked: How can you describe your exposure on PBL, 21st-century skills and SDL? Kganya said: *“PBL is one a teaching technique that I did not know anything about. It was a great exposure since I learned other ways of delivering the content in the manner that encourage the learners.”*

5.6.3 Enhancement of individual-worth and realisation

Rapula’s responded as follows to the interview question: How did you benefit from this exposure? *“I was not aware of 21st-century skills and I did not give attention to aims of the CAPS document, I just taught. I knew nothing about Self-Directed learning.”* In response to the same interview question, Koti said: *“As a teacher, I am supposed to be a life-long learner. Therefore, I have developed in terms of PCK, 21st-century skills and the concept instilling self-directedness on my learners.”*

5.6.4 Confidence and Knowledge integration

During the interview, Kganya responded as follows to the question: How did you benefit from this exposure?

I benefited from this exposure. I was able to get out of my comfort zone and do new things like teaching PNM using PBL. I got to learn about 21st-century skills from a different perspective. The PBL problems boosted my skill of linking science to everyday life situations.

5.7 Discussion of Results for data presented for research question 3

What PBL principles of practice could be distilled for beginner Physical Sciences TPD towards SDL?

Literature review section in Chapter 2 of this study outlined some of the theoretical principles from PBL in various contexts in the teaching and learning process. Moreover, the literature presented the relationship of PBL and 21st-century skills infused with SDL frameworks guiding this study. The previous sections in this chapter presented results, interpretations and discussions which accorded equipping beginner teachers with PBL to promote 21st-century skills and the extent of PBL implementation before and after the TPD. As mentioned in

Chapter 2, Pretorius (2012) posits that TPD workshops are perceived negatively by most teachers since they do not address their needs. However, this was not the case in this study. The results, interpretations and discussions aimed at answering the research question 3, channelling TPD and practice are made in this section in the order of distilled principles.

Pertaining to *culture of learning and personal development*, it was found that PBL assist teachers in their teaching since before TPD, teachers tend to teach the same way that they were taught in which 21st-century skills were not instilled. This finding corroborates argument by Rusmansyah *et al.* (2020) that PBL is one of the models of learning that can improve 21st-century skills including social and personal development. The conceptual framework of this study reiterate the same (Talat & Chaudhry, 2014). This study further found that with self-directed learners, the classroom ‘easily’ become a learning community. Another finding was that PBL approach shifts learners’ thinking such that they to want to do work on their own. These findings are in agreement with Zhukova’s (2017) findings in which novice teachers pointed to the importance and necessity to create such learning environment where their students feel secure, supported, valued, and respected; according to the teachers, their role is not to force students to learn, but to help them discover their true interests and strengths, boost their curiosity and willingness to learn.

With regards to *expansion of teaching methodologies*, the results of this study show that participants learned PBL as another way of delivering the content in a manner that encourage learners. This finding is agreement with Thakur *et al.*’s (2018) finding that PBL is indeed one of the best strategies that motivates, interests and encourages learners. This finding also accords with our earlier findings, which showed that prior to TPD, none of the teachers utilised PBL due to various reasons which include limited knowledge regarding the approach, lack of exposure to the approach and etcetera. As mentioned in Chapter 2, Bosch, Mentz and Goede (2019) also posit that SDL can encourage learners of varying readiness and willingness to take ownership of their learning and be motivated.

Shifting focus to *enhancement of individual-worth and realisation*, the current study found that some beginner teachers initially were not aware of the 21st-century skills and aims of the CAPS document, did not know about self-directed learning (SDL). Another inference from results of this study is an acknowledgement that teachers must be life-long learners. Furthermore, arguably the participants realised they have developed in terms of their PCK,

knowledge regarding 21st-century skills and the concept instilling self-directedness on the learners. The present findings seem to be consistent with other research which found that the concept of SDL is not known to teachers, as a result, are often not self-directed and do not enhance self-directed learning in their classrooms (Sebotsa, De Beer & Kriek, 2019).

Pertaining to *confidence and knowledge integration*, the current study found that due to PBL TPD programme, teachers were able to get out of their comfort zones and implement PBL in the teaching of PNM. This finding corroborates Christiansen and Bertram's (2019) assertions that TPD for in-service teachers is an important factor in improving South African education and improving teachers' confidence in teaching-learning situation. Concerning integration, this study found that PBL problems boosted the ability of linking science content to everyday life situations. There are similarities between attitudes expressed by beginner teachers in this study and those described by Capon and Kuhn (2004), and Evensen and Hmelo-Silver (2000) who submits that ability to integrate new knowledge into prior-knowledge as a results of PBL, is a reflection of successful SDL. A possible explanation for this might be due to contextualised PBL problems (Beghetto, 2006; Hung, 2019; Morris, 2020). Another possible explanation for this might be due to submissions made by Curran *et al.* (2019) that SDL is effective when the socio-political context and the teaching-learning situation favour the learner.

5.8 Chapter Summary

This chapter focused on results presentation, interpretations and discussions in order to answer the three research questions of this study. The results were generated from the portfolio compiled by beginner teachers during PBL implementation while teaching PNM, and interviews post TPD programme. The interview responses were analysed using Saldaña's (2009) analytical tool model for qualitative inquiry, and the portfolio data was analysed using Golightly's (2013) and Family Secret's (2009) rubrics for learners' activities. The overall portfolio was analysed using a tool adapted from Smith *et al.*'s (2001). This proceeded into coding and categorising beginner teachers' responses, emerging themes relating to pertinent literature were identified. In addition, learners' responsiveness regarding the PBL implementation were emphasized. First, the results of this study showed how PBL can be enhanced to equip beginner Physical sciences teachers in promoting 21st-century skills. Secondly, this study adopted an embedded PBL approach into which participants were

inducted. The results showed that beginner teachers promoted 21st-century skills during a successful PBL implementation. Secondly, this study clearly elaborated on the extent which beginner Physical Sciences teachers' use PBL in initiating and promoting 21st-century skills post the TPD programme. The discussion showed that the extent to which beginner teachers implemented PBL post the TPD programme was highly satisfactory. Lastly, this study's results outlined PBL principles of practice which could be distilled for beginner Physical Sciences TPD towards SDL. This study presented four PBL principles of practice which could be distilled for beginner Physical Sciences interconnecting TPD towards 21st-century skills and SDL. The results discussed provide clear evidence answering the three research questions of this studies showing that beginner Physical Sciences teachers' utilisation of PBL in the teaching of PNM was enhanced. The following chapter presents the summary, conclusions and recommendations, and terminate in an overview of the whole study.

CHAPTER 6: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This final chapter brings the study to a close by first highlighting the significance of this research on teaching practice and self-directed learning (SDL), followed by a summary of the main study findings buttressed and consolidated by pertinent literature in an effort to answer the research questions. This chapter then delineates the implications of this study findings to the existing literature. Subsequently, this chapter proffers recommendations followed by general overview of the study in the conclusion. Finally, this chapter presents a short reflection of the researcher's journey as encouraged by interpretivist related studies.

6.2 Significance of this research on teaching practice and self-directed learning (SDL)

It is the considered view of this study that without PBL, there will be little to no SDL. With regards the conceptual framework of this study adopted from Talat and Chaudhry (2014) as outlined in Chapter 2 (see Figure 2.1), PBL is an effective teaching approach that promotes 21st-century skills and simultaneously culminates in social and personal development. Together, 21st-century skills as well as social and personal developments lead to both student creativity and student competitiveness. Drawing from the theoretical framework underpinning this study, *social interdependence theory*, learning is considered to occur through collaboration in a small group where each member has a role (Li, 2017; Johnson & Johnson, 1999; 2005; 2009; 2019). Pertinent literature reiterates the same about PBL with a minor exception that PBL begins with an ill-structured contextualised problem. As mentioned in Chapter 2, the tenets of PBL are aligned to the broader philosophy of the social interdependence theory. With regards PBL implementation, 21st-century skills such as communication, collaboration, critical thinking and creativity investigated in this study ought to be enhanced (Golightly & Raath, 2015; Hidayati *et al.*, 2019; Rusmansyah *et al.*, 2020). The enhanced 21st-century skills might in turn result in learner creativity, learner competitiveness (Talat & Chaudhry, 2014), and SDL (Aidoo *et al.*, 2016; Rana *et al.*, 2016; Thakur *et al.*, 2018). It can be concluded that 21st-century skills and SDL are reciprocal and complementary. Furthermore, a situation where learners work as a group independent of the teacher leading to individual learners being independent of one another was recognised

differently by two scholars, Vygotsky (1978) as ZPD, and Knowles (1980) as Andragogy whose constructs were distilled from this study's findings.

6.3 Summary of Findings

This section summarises main findings of this study in the order of the research questions. The research questions follow a similar order of earlier presentation. The main findings of this study are as follows:

6.3.1 Research Question One

How can problem-based learning (PBL) be enhanced to equip beginner physical sciences teachers in promoting 21st-century skills?

The current study found that teacher professional development enhanced beginner Physical Sciences teachers' knowledge and implementation of PBL to promote 21st-century skills for SDL. Interdependent collaboration in PBL enhances self-directedness such that learners are: responsible of their own learning; and rely on one another within as a PBL group rather than relying on the teacher as argued by other scholars (Nursa'ban *et al.*, 2019; Stehle & Peters-Burton, 2019). This study presented findings showing that PBL enhances learners critical-thinking which boosted their performance in the topic of PNM as mentioned in the literature (Ayaz, 2015; Awan, Hussain & Anwar, 2017; Merritt, Lee, Rillero & Kinach, 2017). The results further suggested that although it is evident that PBL promotes communication skill (Ali, 2019; Baran, 2016; Koh & Chapman, 2019; Hidayati *et al.*, 2019; Rusmansyah *et al.*, 2020), it can be difficult to achieve when the learners are exposed to PBL for the first time. With regards this research question, the findings provided evidence relating to one of the core tenets of social interdependence theory outlined by Deutsch (1949a), psychological processes as such as substitutability, inducibility and positive cathexis being reflected by learners during PBL implementation. This study confirms a possibility of promoting 21st-century skills through PBL.

6.3.2 Research Question Two

To what extent do beginner physical sciences teachers' use problem-based learning (PBL) in initiating and promoting 21st-century skills before and after a teacher professional development (TPD) programme?

This study found that before the teacher PD programme, beginner teacher participants had limited knowledge on using Problem-Based Learning (PBL). Moreover, pertaining to knowledge and utilisation of PBL in the teaching of PNM, none of the beginner teachers used PBL prior to the TPD. There was a zero extent of beginner Physical Sciences teachers' utilisation of PBL in initiating and promoting 21st-century skills prior to the TPD programme. Therefore, it was these findings that informed the administering of the one-day TPD. Post the TPD programme, the findings of this study led to a conclusion that the extent to which beginner Physical Sciences teachers' utilise PBL in initiating and promoting the 21st-century skills was highly satisfactory. This conclusion was arrived at after beginner teachers, generally, showed understanding of how learners should learn and develop during the PBL implementation. These teacher participants facilitated learning through PBL groups putting responsibility on the learners, observing learners' interactions and asking probing questions. However, only one participant showed no evidence of successful PBL implementation while teaching PNM; the extent to which this one particular teacher utilised PBL post TPD was unsatisfactory. This study found that beginner teachers experienced challenges which are not new in the field, but well-known to both beginner and experienced teachers across disciplines in education, and heavily reported in many scholars (Aker & Pentón-Herrera, 2020; Ansarian & Teoh, 2018; Ceker & Ozmali, 2016; Hung, 2011; Johansson & Svensson, 2019; Li & Tsai, 2017; Tandogan & Orhan, 2007; Vogeltanz-Holm, Olson, Borg and Hill, 2014; Wood, 2008; Zhukova, 2017). Beginner teachers expressed that there was a noticeable difference in their teaching after the workshop. However, some teachers expressed that they shall continue to use their usual approaches than PBL in most of the topics, and apply PBL in some of the topics.

6.3.3 Research Question Three

What problem-based learning (PBL) principles of practice could be distilled for beginner physical sciences teacher professional development (TPD) towards self-directed learning (SDL)?

The findings of this study reflected PBL principles of practice which could be distilled for beginner Physical Sciences TPD towards 21st-century skills and SDL. The findings of this study showed that successfully utilising PBL in the teaching of PNM may result in the following principles: culture of learning and personal development (this study further found that with self-directed learners, the classroom ‘easily’ become a learning community); expansion of teaching methodologies (the findings indicate that participants learned PBL as another way of delivering the content in a manner that encourage learners); enhancement of individual-worth and realisation (participants realised to have developed in terms of PCK, 21st-century skills and ability to instilling self-directedness on their learners); and confidence and knowledge integration (this study found that: teachers were confident to get out of their usual teaching approach and implement PBL, and PBL problems boost the ability to link science content to everyday life situations). As mentioned earlier, these are PBL principles indicating specific and evidence-based changes that can be expected during PBL implementation.

6.4 Implications of findings to existing literature

The implications of this study’s findings to the existing literature in the field of education research, Physical Sciences education and Problem-Based Learning are as follows: Lack of research regarding the type of questions asked by participants, learners with respect to this study, during PBL implementation. This study argues that the type of questions asked during PBL implementation can reflect participants’ thinking and efforts to solve the PBL problem. This study further avers that lack or/and access of science PBL problems might be an obstruction to PBL implementation. Physical Sciences is a contextual subject or discipline which can be infused with PBL. However, as Ansarian and Teoh (2018) and Hung (2011) have posited, (beginner) teachers lack a skill to design PBL problem to implement PBL. It is evident that both teachers and learners appreciates PBL, therefore, TPD that enhance PBL problems formulation is required so that teachers can be self-directed.

6.5 Limitations of the study

This study evinces some limitations as seen by the researcher. These limitations are outlined in the following:

- The sample was a small one for various reasons, which include: there are fewer beginner Physical Sciences teachers in the district; reluctance to participate; long distances between places (schools and town/NWU). This study was initially intended to engage more participants, unfortunately one was involved in a car accident, one pulled out due to pregnancy, another pulled out due to transferring from the Ngaka Modiri Molema (NMM) District to another one, and the last one was removed from teaching Physical Sciences by the principal.
- The one-day teacher professional development (TPD) intervention and the follow-up engagements were clearly not enough for one teacher participant (teacher Kganya). Ideally, intervention programmes should last for more than a day (Wei *et al.*, 2010). However, due to the time constraints of this study's nature (Master's degree), long distances from schools to the NWU campus and teachers' work pressures, this was not possible. In this study, the TPD intervention was coupled with continued engagement with each individual beginner teacher as a follow-up and support to participants.
- Regarding data generation instruments, initially the researcher intended to use classroom observations, but ended up employing a portfolio due to NWU's stringent ethics guidelines relative to approval regarding classroom observations, and the disruptions that were caused by Covid-19 pandemic. Although such a portfolio provided satisfactory data, the researcher contends that classroom observations might have provided a richer and more authentic data by obtaining both emic and etic perspectives.

Nonetheless, it is the view of the researcher that the findings provided by this study did however manage to give insights of the topic.

6.6 Recommendations

The following recommendations are proposed for application of the study and for further study on utilisation of PBL in Physical Sciences to promote 21st-century skills for SDL.

6.6.1 Recommendations for application of this study

In light of this study's findings, the following recommendations are proffered regarding implementation of PBL in Physical Sciences. Firstly, the findings highlight the need for more beginner TPD on PBL that could boost their confidence. Secondly, this study recommends that beginner teachers who participated in this study ought to continue implementing PBL every year in the teaching of Grade 10 PNM and related topics since they are fully equipped within this area and have PBL problem they can use. Beginner teacher participants are further encouraged to adapt the PBL problems provided to them to during TPD for their specific contexts. Lastly, the researcher recommends a TPD for Physical Sciences teachers that targets the following: formulation of PBL problems, SDL, 21st-century skills and CAPS and implementation of PBL on other topics.

6.6.2 Recommendations for future study

This study recommends that a similar study be conducted in South African again, to establish if this is the case about beginner Physical Sciences teachers elsewhere in terms of their exposure regarding PBL, 21st-century skills, SDL and PNM. If possible, such a replication of this study should be conducted using a mixed method to generate more quantitative data regarding exposure, and generate rich data qualitatively through observations rather than portfolios. Finally, it is recommended that the study should be adapted and expanded to other science subject areas.

6.7 Conclusions of the study

This study began with the introduction and background, mainly concerns regarding beginner teachers' teaching methodologies. Before the purpose of the study and the research questions guiding the study were formulated, the significance, and theoretical and conceptual frameworks were outlined. Furthermore, delimitations of this study were clarified. Finally, this study was undertaken and the outcomes developed as systematically as possible.

An extensive description of PBL including its links to the 21st-century skills and SDL was presented in the literature review in Chapter 2. Concepts such as beginner Physical Sciences teachers, TPD programmes and PNM chemistry content were also amplified and contextualised to this study. Underpinned by social interdependence theory, this study then adopted a qualitative case study approach that is exploratory. This study was conducted within a philosophical framework of interpretivism paradigm, allowing the researcher to view the world through the perceptions and experiences of the beginner teacher participants. Data for this study was generated using instruments such as open-ended questionnaire, portfolio (after classroom PBL implementation following the TPD programme), and interviews. Five beginner Physical Sciences teachers were selected for this study which employed purposive sampling coupled with the snowballing technique. Data was analysed using Saldaña's (2009), and Golightly's (2013) and Family Secret's (2009) rubrics for learners' activities. The overall portfolio data was analysed using adapted Smith *et al.*'s (2001).

The findings of this study showed that of the five participants, four successfully implemented PBL in the teaching of PNM. Arguably, this finding indicates that PBL can be implemented in sciences education, and by teachers who have never been exposed to it. Furthermore, these findings corroborated previous studies' (Aidoo *et al.*, 2016; Valdez & Bungihan, 2019; Wahyu & Eli, 2016; Wahyu & Syaadah, 2018; Zejnilagić-Hajrić *et al.*, 2015), submissions that Problem-Based Learning can be effectively implemented in Chemistry education.

6.8 Reflections on my research journey

I embarked on this study after my personal experiences regarding challenges with finding effective teaching approaches for Physical Sciences. Then I read more around this concern and finally my journey began. This journey was more challenging than I had anticipated. I realised that what I know is less than a drop in the ocean. Nonetheless, I have developed as a researcher and as a person on various aspects and view many aspects differently. This study gave me an opportunity to become exposed to Problem-Based Learning, Self-Directed Learning and 21st-century skills concepts and communities of practice. Most of the time, I did not know what I was doing, how to do anything and why I was doing it. I realised that I do not have interpersonal skills as I thought. Or rather, working with people is difficult. However, I became close to the participants during this journey and even got to know some of their personal problems. The research encouraged me to get embedded in the study. The

qualitative research truly showed me that nothing in the world is not logical. Nonetheless, I have learned. I appreciate this opportunity. I got to apply and understand all the undergraduate knowledge from teaching approaches and methods, learning and teaching theories, and research types. Finally, I got more insight into the Chemistry content. Another aspect that almost stymied this journey was the Covid-19 pandemic; PBL implementation took place during the first term of teaching (January-March) and there was already the scary news of the pandemic – the North-West University ethics took measures to suspend school visits. Interviews were conducted before lockdown was implemented, and that saved my day.

REFERENCES

- Abbey, L., Dowsett, E. & Sullivan, J. 2017. Use of problem-based learning in the teaching and learning of horticultural production. *The Journal of Agricultural Education and Extension*, 23(1): 61-78.
- Afandi, Sajidan, Akhyar, M. & Suryani, N. 2019. Development frameworks of the Indonesian partnership 21st-century skills standards for prospective science teachers: A Delphi study. *Journal Pendidikan IPA Indonesia*, 8(1):89-100.
- Aidoo, B., Boateng, S.K., Kissi, P.S. & Ofori, I. 2016. Effect of Problem-Based Learning on Students' Achievement in Chemistry. *Journal of Education and Practice*, 7(33):103-108.
- Aker, M. & Pentón Herrera, L. J. 2020. 'Smart Literacy Learning in the Twenty-First Century: Facilitating PBSL Pedagogic Collaborative Clouds.' In S. Yu, M. Ally & A. Tsinakos (eds.), *Emerging Technologies and Pedagogies in the Curriculum, Bridging Human and Machine: Future Education with Intelligence*, pp. 429-445, Springer, Singapore. https://doi.org/10.1007/978-981-15-0618-5_25
- Akhtar, D.M.I. 2016. Research design. Available at SSRN 2862445. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2862445 Date of access: 29 Oct. 2019.
- Al Kandari, A.M. & Al Qattan, M.M. 2020. E-Task-Based Learning Approach to Enhancing 21st-Century Learning Outcomes. *International Journal of Instruction*, 13(1):551-566.
- Al Riyami, T. 2015. Main approaches to educational research. *International Journal of Innovation and Research in Educational Sciences*, 2(5):412-416.
- Alabdelwahab, S.Q. 2002. Portfolio assessment: A qualitative investigation of portfolio self-assessment practices in an intermediate EFL classroom, Saudi Arabia. Columbus: OSU. (Dissertation-PhD).
- Alamina, J.I. & Etokeren, I.S. 2018. Effectiveness of Imagination Stretch Teaching Strategy in Correcting Misconceptions of Students about Particulate Nature of Matter. *Journal of Education, Society and Behavioural Science*, 27(1):1-11.
- Albarracin, E. 2019. Positive Interdependence Theory in Effective Manager-Coach and Employee Coaching Relationships. *International Management Review*, 15(2):41-90.
- Ali, S.S. 2019. Problem Based Learning: A Student-Centred Approach. *English Language Teaching*, 12(5):73-78.
- Alias, M., Masek, A. & Salleh, H.H.M. 2015. Self, peer and teacher assessments in problem based learning: Are they in agreement? *Procedia-Social and Behavioural Sciences*, 204:309-317.
- Alismail, H.A. & McGuire, P. 2015. 21st century standards and curriculum: Current research and practice. *Journal of Education and Practice*, 6(6):150-154.
- Alshammari, A. 2019. The 4 Cs. In *Kansas State University Khbrat SUMMIT*. Manhattan, KS: Kansas State University, Centre for Intercultural and Multilingual Advocacy in the College of Education and the English Language Program.

Andrade, H.L. & Brown, G.T. 2016. Student self-assessment in the classroom. *Handbook of human and social conditions in assessment*, 319-334.

Andrade, H.L., Wang, X., Du, Y. & Akawi, R.L. 2009. Rubric Referenced Self-Assessment and Self-Efficacy for Writing. *The Journal of Educational Research*, 102(4):287-302.
<https://doi.org/10.3200/JOER.102.4.287-302>

Ansari, M.T., Rahman, S.A., Badgujar, V.B., Sami, F. & Abdullah, M.S. 2015. Problem-based Learning (PBL): A Novel and Effective Tool of Teaching and Learning. *Indian Journal of Pharmaceutical Education and Research*, 49(4):258-265.

Ansarian, L. & Teoh, M.L. 2018. *Problem-based language learning and teaching: An innovative approach to learn a new language*. Singapore: Springer. https://doi.org/10.1007/978-981-13-0941-0_2

Aoki, K. 2020. 'Technologies for Lifelong and Lifewide Learning and Recognition: A Vision for the Future.' In S. Yu, M. Ally & A. Tsinakos (eds.), *Emerging Technologies and Pedagogies in the Curriculum, Bridging Human and Machine: Future Education with Intelligence*, pp. 41-52, Springer, Singapore.

Astuti, A.P., Aziz, A., Sumarti, S.S. and Bharati, D.A.L., 2019. Preparing 21st Century Teachers: Implementation of 4C Characters Pre-Service Teacher through Teaching Practice. In *Journal of Physics: Conference Series* (Vol. 1233, No. 1, p. 012109). IOP Publishing.

Awan, N.R., Hussain, H. & Anwar, N. 2017. Effects of Problem-based Learning on Students' Critical Thinking Skills, Attitudes towards Learning and Achievement. *Journal of Educational Research*, 20(2):28-41.

Ayaz, M. F. 2015. The effect of the problem-based learning approach on the academic achievements of the students in science lesson: a study of meta-analysis. *International Periodical for the Languages, Literature and History of Turkish or Turkic*, 10(3):139-160.

Ayyildiz, Y. & Tarhan, L. 2018. Problem-based learning in teaching chemistry: Enthalpy changes in systems. *Research in Science & Technological Education*, 36(1):35-54.

Bailey, R. & Mentz, E. 2015. 'IT teachers' experience of teaching-learning strategies to promote critical thinking.' *Issues in Informing Science and Information Technology* 12, 141-152.
<https://doi.org/10.28945/2257>

Baran, M. 2016. Teaching Gases through Problem-Based Learning. *Journal of Education and Training Studies*, 4(4):281-294.

Barell, J. 2010. 'Problem-based learning: The foundation for 21st century skills.' In J. Bellanca & R. Brandt (eds.), *21st century skills: Rethinking how students learn*, pp. 174-199, Solution Tree Press, Bloomington, IN.

Baresh, E.F., Ali, S.M. & Darmi, R. 2019. Using Hybrid Problem-based Learning (HPBL) Approach to Enhance Libyan EFL Students' Engagement with English Language. *International Journal of Education & Literacy Studies*, 7(2):9-20.

Barneveld, A. V. & Strobel, J. 2020. 'Problem-based Learning: Effectiveness, Drivers, and Implementation Challenges.' In X. Du, E. D. Graaff & A. Kolmos (eds.), *Research on PBL Practice in Engineering Education*, pp. 35-44, Sense Publishers, Rotterdam.

Başkarada, S. 2014. Qualitative case studies guidelines. *The Qualitative Report*, 19(40):1-25.

Bates, C.C. & Morgan, D.N. 2018. Seven elements of effective professional development. *The Reading Teacher*, 71(5):623-626.

Baxter, P. & Jack, S. 2008. Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report*, 13(4):544-559. <http://www.nova.edu/ssss/QR/QR13-4/baxter.pdf>

Beghetto, R.A. (2006). Does creativity have a place in classroom discussions? *Prospective teachers' response preferences*. *Thinking skills and Creativity*, 2(1):1-9.

Bekdemir, N. 2019. Adaptation Problems and Solutions of Novice Teachers of English. Ankara: Hacettepe University. (Dissertation-MEd).
<http://www.openaccess.hacettepe.edu.tr:8080/xmlui/bitstream/handle/11655/8077/ADAPTATION%20PROBLEMS%20AND%20SOLUTIONS%20OF%20NOVICE%20TEACHERS%20OF%20ENGLISH.pdf?sequence=1> Date of access: 06 March 2020.

Bertram, C. & Christiansen, I. 2015. *Understanding research: An introductory to reading research*. Pretoria: Van Schaik publisher.

Bhattacharjee, A. 2012. Social science research: Principles, methods, and practices. http://scholarcommons.usf.edu/oa_textbooks/3

Bilbao, J., Varela, C., Rebollar, C., Bravo, E. and García, O. 2018. Selecting Assessments for Problem- Based Learning. *International Journal of Education and Learning Systems*, 3:129-133.

Bird, D.K. 2009. The use of questionnaires for acquiring information on public perception of natural hazards and risk mitigation - A review of current knowledge and practice. *Natural Hazards and Earth System Sciences*, 9(4):1307-1325. www.nat-hazards-earth-syst-sci.net/9/1307/2009/

Björk, L., Stengård, J., Söderberg, M., Andersson, E & Wastensson, G. 2019. Beginning teachers' work satisfaction, self-efficacy and willingness to stay in the profession: A question of job demands-resources balance? *Teachers and Teaching*, 25(8):955-971.
<https://doi.org/10.1080/13540602.2019.1688288>

Boakye, C. & Ampiah, J.G. 2017. Challenges and solutions: The experiences of newly qualified science teachers. *Sage Open*, 7(2). <https://doi.org/10.1177/2158244017706710>

Boddy, C.R. 2016. Sample size for qualitative research. *Qualitative Market Research: An International Journal*, 19(4):426-432. DOI 10.1108/QMR-06-2016-0053

Boholano, H. B. 2017. Smart social networking: 21st century teaching and learning skills. *Research in Pedagogy*, 7(1):21-29.

Bosch, C., Mentz, E. & Goede, R. 2019. 'Self-directed learning: A conceptual overview.' In E. Mentz, J. De Beer & R. Bailey (eds.), *Self-Directed Learning for the 21st Century: Implications for Higher Education*. (NWU Self-Directed Learning Series Volume 1), pp. 1–36, AOSIS, Cape Town.
<https://doi.org/10.4102/aosis.2019.BK134.01>

Botelho, M.G. 1999. Embedded problem-based learning of a clinical subject. *British Dental Journal*, 186(4):192-195.

Brantmeier, C., Vanderplank, R., & Strube, M. 2012. What about me? Individual self-assessment by skill and level of language instruction. *System*, 40(1):144-160.
<https://doi.org/10.1016/j.system.2012.01.003>

Brown, S. 2018. Best Practices in 21st Century Learning Environments: A Study of Two P21 Exemplar Schools. California: Brandman University. (Thesis-PhD).
https://digitalcommons.brandman.edu/edd_dissertations/184

Budiastara, A.K., Erlina, N. & Wicaksono, I. 2019. The Factors Affecting Teachers' Readiness in Developing Science Concept Assessment through Inquiry-Based Learning Process in Elementary Schools. *Advances in Social Sciences Research Journal*, 6(9):355-366.

Bustamante, A.S., White, L.J. & Greenfield, D.B. 2018. Approaches to learning and science education in Head Start: Examining bidirectionality. *Early Childhood Research Quarterly*, 44:34-42.

Capon, N. & Kuhn, D. 2004. What's so good about problem-based learning? *Cognition and Instruction*, 22(1):61-79.

Care, E., Kim, H., Vista, A. & Anderson, K. 2018. Education system alignment for 21st century skills: Focus on assessment. Optimizing Assessment for All (OAA): Brookings Institution.
<https://files.eric.ed.gov/fulltext/ED592779.pdf>

Ceker, E. & Ozdamli, F. 2016. Features and Characteristics of Problem-Based Learning. *Cypriot Journal of Educational Sciences*, 11(4):195-202.

Ceylan, R. & Yiğital, N. 2016. Problem-Based Learning. (In Atasoy, E., Efe, R., Jazdzewska, I. & Yaldir, H., eds. *Current Advances in Education*. Sofia: St. Kliment Ohridski University Press. p. 52-59).

Chaaban, Y. & Du, X. 2017. Novice teachers' job satisfaction and coping strategies: Overcoming contextual challenges at Qatari government schools. *Teaching and Teacher Education*, 67:340-350.

Chaves, A.R. 2018. Novice Elementary Teachers' Experiences with Preparedness to Teach Mathematics: A Phenomenological Study. Lynchburg: Liberty University. (Thesis-PhD).

Cheng, X. 2020. Challenges of 'School's Out, But Class's On' to School Education: Practical Exploration of Chinese Schools during the COVID-19 Pandemic. *Sci Insigt Edu Front*, 5(2):501-516.
https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Challenges+of+%E2%80%9CSchool%E2%80%99s+Out%2C+But+Class%E2%80%99s+On%E2%80%9D+to+School+Education%3A+Practical+Exploration+of+Chinese+Schools+during+the+COVID-19+Pandemic&btnG= Date of access: 12 May 2019.

Chian, M.M., Bridges, S.M. & Lo, E.C. 2019. The Triple Jump in Problem-Based Learning: Unpacking Principles and Practices in Designing Assessment for Curriculum Alignment. *Interdisciplinary Journal of Problem-Based Learning*, 13(2).

Christiansen, I. & Bertram, C. 2019. Early schooling teachers' learning from a formal teacher development programme in South Africa. *International Journal of Educational Development*, 66:78-87.

Chua, K.H. & Karpudewan, M. 2020. Integrating Nanoscience Activities in Enhancing Malaysian Secondary School Students' Understanding of Chemistry Concepts. *EURASIA Journal of Mathematics, Science and Technology Education*, 16:1.

Ciampa, K. 2015. An investigation of teacher candidates' questions and concerns about occasional teaching. *Journal of Applied Research in Higher Education*, 7(2):146-163.

Cise, J.S., Wilson, C.S. & Thie, M.J. 2004. A qualitative tool for critical thinking skill development. *Nurse Educator*, 29(4):147-151.

Cockerill, M., Craig, N. & Thurston, A. 2018. Teacher Perceptions of the Impact of Peer Learning in Their Classrooms: Using Social Interdependence Theory as a Model for Data Analysis and Presentation. *International Journal of Education and Practice*, 6(1):14-27.

Coenders, F. & Verhoef, N. 2019. Lesson study: Professional Development (PD) for beginning and experienced teachers. *Professional Development in Education*, 45(2):217-230.
<https://doi.org/10.1080/19415257.2018.1430050>

Collazos, C. A., Guerrero, L. A., Pino, J. A., Renzi, S., Klobas, J., Ortega, M., Redondo, M. A., & Bravo, C. 2007. Evaluating Collaborative Learning Processes using System-based Measurement. *Educational Technology & Society*, 10 (3):257-274.

Connelly, L.M. 2016. Trustworthiness in qualitative research. *Medsurg Nursing*, 25(6):435-437.

Cox, S.E. 2014. Perceptions and Influences behind Teaching Practices: Do Teachers Teach as They Were Taught? Provo: BYU. (Dissertation-MSc). <https://scholarsarchive.byu.edu/etd/5301>

Creswell, J.W. 2007. *Qualitative inquiry & research design: Choosing among Five Approaches*. 2nd ed. Thousand Oaks, CA: Sage.

Creswell, J. W. 2009. *Research design: Qualitative, quantitative, and mixed methods approaches*. 3rd ed. Thousand Oaks, CA: Sage.

Creswell, J.W. & Clark, V.L.P. 2004. Principles of qualitative research: Designing a qualitative study. *Office of Qualitative & Mixed Methods Research, University of Nebraska, Lincoln*.

Curran, V., Gustafson, D.L., Simmons, K., Lannon, H., Wang, C., Garmsiri, M., Fleet, L. & Wetsch, L. 2019. Adult learners' perceptions of self-directed learning and digital technology usage in continuing professional education: An update for the digital age. *Journal of Adult and Continuing Education*, 25(1):74-93.

Cylen, R. & Yiğitalp, N. 2016. 'Problem-Based Learning', in E. Atasoy, R. Efe, I. Jażdżewska & H. Yaldir (eds.). *Current Advances in Education*, pp. 52-59, St. Kliment Ohridski, University Press, Sofia.

Da Silva, A.B., de Araújo Bispo, A.C.K., Rodriguez, D.G. & Vasquez, F.I.F. 2018. Problem-based learning. *Revista de Gestão*, 25(2):160-177.

Darling-Hammond, L., Hyler, M. E. & Gardner, M. 2017. Effective Teacher Professional Development. Palo Alto, CA: Learning Policy Institute.
<https://learningpolicyinstitute.org/product/teacher-prof-dev>

Davis, E.A., Petish, D. & Smithy, J. 2006. Challenges new science teachers' face. *Review of Educational Research*, 76(4):607-651.

Dawilai, S., Kamyod, C. & Prasad, R. 2019. Effectiveness Comparison of the Traditional Problem-Based Learning and the Proposed Problem-Based Blended Learning in Creative Writing: A Case Study in Thailand. *Wireless Personal Communications*, 1-15. <https://doi.org/10.1007/s11277-019-06638-x>

Department of Basic Education (South Africa). 2011. Integrated Strategic Planning Framework for Teacher Education and Development in South Africa, 2011-2025: Technical Report. Pretoria, South Africa.

De Beer, J. & Gravett, S. 2016. 'The affordances of case-based teaching for self-directed learning: A case study with first year student-teachers.' (In Mentz, E & Oosthuizen, I., eds. *Self-directed learning research: An imperative for transforming the educational landscape*. Cape Town: AOSIS. p. 35-71). <http://dx.doi.org/10.4102/aosis.2016.sdlr14.02> Date of access: 31 March 2019.

De Beer, J. & Petersen, N. 2016. Decolonisation of the science curriculum: a different perspective (#cookbook-labs-must-fall). Proceedings of the ISTE Conference on Mathematics, Science and Technology Education, Kruger National Park, October 2016 /2017. <http://uir.unisa.ac.za/bitstream/handle/10500/22869/Josef%20de%20Beer,%20Neal%20Petersen.pdf?sequence=1> Date of access: 17 February 2020.

De Beer, J. 2017. The elephant in the room: The work-integrated learning of student teachers, and the influence of teacher educator scholarship on their professional development. Proceedings of the ISTE Conference on Mathematics, Science and Technology Education. Kruger National Park, October 2016 /2017. <https://doi.org/10.4102/satnt.v33i1.1179>.

De Villiers, L., de Beer, J. & Golightly, A. 2016. Problem-based and self-directed learning outcomes during an indigenous knowledge intervention for life sciences teachers.

Delisle, R., 1997. *How to use problem-based learning in the classroom*. Available from Ascd e-books: https://books.google.co.za/books?hl=en&lr=&id=9nZPZ6N27EEC&oi=fnd&pg=PR4&dq=Delisle,+R.,+1997.+How+to+use+problem-based+learning+in+the+classroom&ots=OUC40EpU-M&sig=tVdtEfD8w_z63T3J82F4kiy6cws&redir_esc=y#v=onepage&q=Delisle%2C%20R.%2C%201997.%20How%20to%20use%20problem-based%20learning%20in%20the%20classroom&f=false Date of access: 21 Feb. 2020.

Department of Basic Education (South Africa). 2011. Curriculum and Assessment Policy Statement, grades 10-12, Physical Sciences. Government printing works: Pretoria. <http://www.education.gov.za>

Department of Basic Education (South Africa). 2012. National Protocol for Assessment Grades R – 12, Government Notices No. 722 and No. 723, *Government Gazette*, 36042:3, 28 December.

Department of Basic Education (South Africa). 2020. National Senior Certificate Examination Report 2019, January 2020. Government printing works: Pretoria. <https://www.education.gov.za/Resources/Reports.aspx> Date of access: 01 March 2020.

Department of Education and Training (State of Victoria). 2018. Practice principles for excellence in teaching and learning. Melbourne. <https://www.education.vic.gov.au/Documents/school/teachers/support/practiceprinciples.pdf> Date of access 31 May 2020.

Deutsch, M. 1949a. An experimental study of the effects of co-operation and competition upon group process. *Human Relations*, 2(3):199-231.

Deutsch, M. 1949b. A theory of co-operation and competition. *Human Relations*, 2(2):129-152.

Deutsch, M. 1962. Cooperation and trust: Some theoretical notes. In M. R. Jones (Ed.), *Nebraska Symposium on Motivation*, pp. 275–320, Univer. Nebraska Press.

Dhurumraj, T. 2013. Contributory factors to poor learner performance in Physical Sciences in KwaZulu-Natal Province with special reference to schools in the Pinetown District. Pretoria: UNISA. (Dissertation-MEd).

http://uir.unisa.ac.za/bitstream/handle/10500/13343/dissertation_Dhrurumraj_T.pdf?isAllowed=y&sequence=1 Date of access: 06 May 2020.

Dikko, M. 2016. Establishing Construct Validity and Reliability: Pilot Testing of a Qualitative Interview for Research in Takaful (Islamic Insurance). *The Qualitative Report*, 21(3), 521-528. <https://nsuworks.nova.edu/tqr/vol21/iss3/6>

Dillon, S., McDonnell, A., Murphy, D. & White, L. 2018. Alternative Methods to Traditional Written Exam-Based Assessment. PG Diploma in Practitioner Research Projects, DIT. <https://arrow.tudublin.ie/ltpgdprp>

Dmitrenko, N. 2017. Problem-based learning as a learner-centred approach: general review. Available from e-Library.RU: <https://www.elibrary.ru/item.asp?id=26092575> Date of access: 21 Feb. 2020.

Dogan, N. 2017. Blending problem-based learning and history of science approaches to enhance views about scientific inquiry: New wine in an old bottle. *Journal of Education and Training Studies*, 5(10):99-112.

Dolmans, D.H., Wolfhagen, I.H. & Ginns, P. 2010. Measuring approaches to learning in a problem based learning context. *International Journal of Medical Education*, 1:55-60.

Dörnyei, Z. 2003. *Questionnaires in second language research: Constructing, administering, and processing*. Lawrence Erlbaum Associates, Publishers. Mahwah, New Jersey.

Duda, H.J., Susilo, H. & Newcombe, P., 2019. Enhancing different ethnicity science process skills: Problem-based learning through practicum and authentic assessment. *International Journal of Instruction*, 12(1):1207-1222.

Dudu, W.T. 2016. Promoting conceptual change in Physical Sciences teachers: Impact of a professional development intervention, in M.A. Mokoena & I.J. Oosthuizen (eds.), *A scholarly contribution to educational praxis*, pp. 120-156, AOSIS, Cape Town. <http://dx.doi.org/10.4102/aosis.2016.saep12.05>

Dudu, W.T. 2016. Addressing Content Knowledge Gaps, Didactics and Pedagogy to Improve Teacher Effectiveness in Life Sciences in Dinaledi Schools: A Case Study. Proceedings of the 7th Annual Meeting of the Institute of Science and Technology Education (ISTE) Conference hosted by University of South Africa (UNISA) in Kruger National Park, Republic of South (p.315-325).

Dudu, W.T. 2017. Facilitating Small-Scale Implementation of Inquiry-Based Teaching: Encounters and Experiences of Experimento Multipliers in One South African Province. *International Journal of Science and Mathematics Education*, 15(4):625-642.

El Mawas, N. & Muntean, C. 2018, July. Supporting lifelong learning through development of 21st century skills. <https://hal.archives-ouvertes.fr/hal-02250150>

Elsafi, A. 2020. 'Augmented Strategies for Mobile and Ubiquitous Learning Technologies.' In S. Yu, M. Ally & A. Tsinakos (eds.), *Emerging Technologies and Pedagogies in the Curriculum, Bridging Human and Machine: Future Education with Intelligence*, pp. 245-260, Springer, Singapore. https://doi.org/10.1007/978-981-15-0618-5_15

Elshafie, M. 2013. Research Paradigms: The Novice Researcher's Nightmare. *Arab World English Journal*, 4(2):4-13.

- Erkens, M. & Bodemer, D. 2019. Improving collaborative learning: Guiding knowledge exchange through the provision of information about learning partners and learning contents. *Computers & Education*, 128:452-472.
- Etherington, M.B. 2011. Investigative Primary Science: A Problem-based Learning Approach. *Australian Journal of Teacher Education*, 36(9):36-57. <http://ro.ecu.edu.au/ajte/vol36/iss9/4>
- Etikan, I., Musa, S.A. & Alkassim, R.S. 2016. Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(1):1-4.
- Evensen, D.H. & Hmelo-Silver, C.E. 2000. *Problem-based learning: A research perspective on learning interactions*. Routledge.
- Family Secret. 2009. A Problem-Based Learning Case. Life Sciences Learning Centre. New York: University of Rochester. (Coach guide, Introduction to the lessons). https://www.urmc.rochester.edu/MediaLibraries/URMCMedia/life-sciences-learning-center/documents/INTRODUCTION_Coach_Guide.pdf Date of access: 17 Jun. 2019.
- Farrugia, B. 2019. WASP (Write a Scientific Paper): Sampling in qualitative research. *Early Human Development*, 133:69-71. <https://doi.org/10.1016/j.earlhumdev.2019.03.016>
- Gammelgaard, B. 2017. Editorial: The qualitative case study. *International Journal of Logistics Management*, 28(4):910-913. <https://doi.org/10.1108/IJLM-09-2017-0231>
- Gardner, S. K. 2009. *Qualitative research design: An interactive approach*. Thousand Oaks CA: Sage.
- Ghahari, S. & Farokhnia, F. 2017. Peer versus teacher assessment: Implications for CAF triad language ability and critical reflections. *International Journal of School & Educational Psychology*, 6(2):124-137.
- Gilbert, J.K. & Afonso, A.S. 2015. Lifelong learning: Approaches to increasing the understanding of chemistry by everybody. *Chemistry Education*, pp.123-148.
- Golightly, A. & Raath, S. 2015. Problem-based learning to foster deep learning in preservice Geography teacher education. *Journal of Geography*, 114(2):58-68.
- Golightly, A. 2013. *Assessment Rubric for GEOE 311 PBL Activity*. Faculty of Education and Training. Potchefstroom: North-West University. (Study guide, GEOE 311 PEC).
- Golightly, A. 2016, 'Geography student tutors' facilitative skills in a problem-based learning environment', in E. Mentz & I. Oosthuizen (eds.), *Self-directed learning research*, pp. 158-183, AOSIS, Cape Town. <http://dx.doi.org/10.4102/aosis.2016.sdlr14.06>
- Golightly, A. 2020. Self-and peer assessment of preservice Geography teachers' contributions in problem-based learning activities in Geography education. *International Research in Geographical and Environmental Education*, pp.1-16.
- Gonzalez, L. 2019. The Problem-Based Learning Model. *Eighth International Conference on Educational Innovation through Technology (EITT)*, Biloxi, MS, USA, pp. 180-183.
- Grant, M.M. & Tamim, S.R. 2019. 'PBL in K–12 Education'. In M. Moallem, W. Hung & N. Dabbagh (eds.), *The Wiley Handbook of Problem-Based Learning*, pp. 221-244, 2019 John Wiley & Sons, Inc., USA. https://doi.org/10.1007/978-981-15-0618-5_3

Greenhill, V. 2010. 21st Century Knowledge and Skills in Educator Preparation. Partnership for 21st century skills. <https://files.eric.ed.gov/fulltext/ED519336.pdf>

Grimus, M. 2020. 'Emerging Technologies: Impacting Learning, Pedagogy and Curriculum Development.' In S. Yu, M. Ally & A. Tsinakos (eds.), *Emerging Technologies and Pedagogies in the Curriculum, Bridging Human and Machine: Future Education with Intelligence*, pp. 127-151, Springer, Singapore. https://doi.org/10.1007/978-981-15-0618-5_8

Grow, G.O. 1991. Teaching learners to be self-directed. *Adult Education Quarterly*, 41(3):125-149. <http://aeq.sagepub.com/cgi/content/abstract/41/3/125>

Gustafsson, J. 2017. Single case studies vs. multiple case studies: A comparative study. https://scholar.google.com/scholar?hl=en&as_sdt=2005&sciodt=0%2C5&cites=10811895002346806747&scipsc=&q=Single+case+studies+vs.+multiple+case+studies%3A+A+comparative+study&btnG=Date+of+access%3A+04+Apr.+2020
= Date of access: 04 Apr. 2020.

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P. & Valtonen, T. 2017. Preparing teacher-students for twenty-first-century learning practices (PREP 21): A framework for enhancing collaborative problem-solving and strategic learning skills. *Teachers and Teaching*, 23(1):25-41.

Hammarberg, K., Kirkman, M. & de Lacey, S. 2016. Qualitative research methods: When to use them and how to judge them. *Human Reproduction*, 31(3):498-501.

Harrison, A. G. & Treagust, D. F. 2002. 'The particulate nature of matter: Challenges in understanding the sub-microscopic world.' In J. K. Gilbert, O. D. Jong, R. Justi, D. F. Treagust, & J. H. Van Driel (Eds.), *Chemical education: towards research-based practice*, pp. 189-212, Netherlands: Kluwer.

Harrison, H., Birks, M., Franklin, R. & Mills, J. 2017. Case study research: Foundations and methodological orientations. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* (Vol. 18, No. 1). <http://dx.doi.org/10.17169/fqs-18.1.2655>.

Hartmann, C., Olsen, J.K., Brand, C., Aleven, V. & Rummel, N. 2017. *Examining Positive and Negative Interdependence in an Elementary School CSCL Setting*. Proceedings of the CSCL 2017, Philadelphia, PA: International Society of the Learning Sciences (p.633-636).

Havenga, M. & Van Wyk, M.M. 2017. A conceptualised design-based research framework for a problem-based learning approach in a first-year engineering course. *Global Journal of Engineering Education*, 19(3):200-206.

Havenga, M. 2015a. Project-based learning in higher education: Exploring programming students' development towards self-directedness. *South African Journal of Higher Education*, 29(4):135-157.

Havenga, M. 2015b. The role of metacognitive skills in solving object-oriented programming problems: A case study. *TD The Journal for Transdisciplinary Research in Southern Africa*, 11(1):133-147.

Havenga, M. 2018a. Problem-based Projects in Computer Programming: Students' Cooperation, Responsibilities and Dependencies. *African Journal of Research in Mathematics, Science and Technology Education*, 22(2):254-264.

Havenga, M. 2018b, April. Reflective team meetings: A learning experience for first-year engineering students in joint projects. In *2018 IEEE Global Engineering Education Conference (EDUCON)*:314-319.

Heale, R. & Twycross, A. 2018. What is a case study?

<https://ebn.bmj.com/content/ebnurs/21/1/7.full.pdf>

Hidayati, N., Zubaidah, S., Suarsini, E. & Praherdhiono, H. 2019. The integrated PBL-DMM: A learning model to enhance student creativity. *Pedagogika*, 135(3):163-184.

Hlabane, A. 2016. An exploration into learning difficulties experienced by Physical Sciences learners in South African schools. Unpublished paper.

https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=An+exploration+into+learning+difficulties+experienced+by+Physical+Sciences+learners+in+South+African+schools&btnG= Date of access: 25 May 2019

Hmelo-Silver, C.E. & Barrows, H.S. 2015. *Problem-based learning: Goals for learning and strategies for facilitating*. Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows, pp.69-84. https://books.google.co.za/books?hl=en&lr=&id=KhF-BgAAQBAJ&oi=fnd&pg=PA69&dq=Problem-based+learning:+Goals+for+learning+and+strategies+for+facilitating&ots=axh5m_kzYq&sig=OYXu9stWvcvYpM-ZcnMrY3qliFU&redir_esc=y#v=onepage&q=Problem-based%20learning%3A%20Goals%20for%20learning%20and%20strategies%20for%20facilitating&f=false Date of access: 06 March 2020.

Hmelo-Silver, C.E. 2004. Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3):235-266.

Hmelo-Silver, C.E., Bridges, S.M. & McKeown, J.M. 2019. 'Facilitating Problem-Based Learning.' In M. Moallem, W. Hung & N. Dabbagh (eds.), *The Wiley Handbook of Problem-Based Learning*, pp. 297-320, 2019 John Wiley & Sons, Inc., USA.

Howlett, G. & Waemusa, G. 2019. 21st century learning skills and autonomy: Students' perceptions of mobile devices in the Thai EFL context. *Teaching English with Technology*, 19(1):72-85. https://doi.org/10.1007/978-981-15-0618-5_3

Hung, W. 2006. The 3C3R model: A conceptual framework for designing problems in PBL. *Interdisciplinary Journal of Problem-based Learning*, 1(1):55-77. <https://www.researchgate.net/publication/27240123>

Hung, W. 2011. Theory to reality: A few issues in implementing problem-based learning. *Educational Technology Research and Development*, 59(4):529-552.

Hung, W. 2019. 'Problem Design in PBL', in M. Moallem, W. Hung & N. Dabbagh (eds.), *The Wiley Handbook of Problem-Based Learning*, pp. 249-274, John Wiley & Sons, Inc., New Jersey.

Hung, W., Jonassen, D.H. & Liu, R. 2008. Problem-based learning. *Handbook of research on educational communications and technology*, 3(1):485-506.

Hunter, C. & Molapo, T. 2014. Current challenges and future trends for teacher training in Southern Africa: A focused look at Botswana and Lesotho. *Annual Review of Comparative and International Education*, 25:295-328.

Ibrahim, M. & Jamaludin, K.A. 2019. The roles of teacher and students via blended problem-based learning: Improving students' mastery of three representation levels of Chemistry. *EDUCATUM Journal of Science, Mathematics and Technology (EJSMT)*, 6(2):9-21. <https://ejournal.upsi.edu.my/index.php/EJSMT/index>

- Ibrahim, M., Arshad, M., Rosli, M. & Shukor, N. 2017. The Roles of Teacher and Students in Self-directed Learning Process through Blended Problem-Based Learning. *Sains Humanika*, 9(1-4):27-32. www.sainshumanika.utm.my
- Ibrahim, M.M., Arshad, M.Y. & Rosli, M.S. 2015. The need of an integrated framework for the implementation of blended problem-based learning. *International Education Studies*, 8(13):33-40.
- Ismail, S. 2019. Using a Virtual Learning Environment for Problem Based Learning (PBL). *International Journal of Computer Sciences and Engineering*, 7(3):769-773. <https://doi.org/10.26438/ijcse/v7i3.769773>
- Jaleel, S. & Anuroofa, OM. 2017. A Study on the Relationship between Self-Directed Learning and Achievement in Information Technology of Students at Secondary Level. *Universal Journal of Educational Research*, 5(10):1849-1852. <http://www.hrpub.org>
- Jayaram, S. 2014. Implementation of Active Cooperative Learning and Problem-based Learning in an Undergraduate Astrodynamics Course. In 52nd Aerospace Sciences Meeting (p. 0065). <https://arc.aiaa.org/doi/abs/10.2514/6.2014-0065>
- Jing, R.Z. & Tong, L.U.O. 2018. On Exploring the Problem-Based Learning Method of General Education Course. *DEStech Transactions on Social Science, Education and Human Science*, 2nd International Conference on Advanced Education and Management Science (AEMS 2018). https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=On+Exploring+the+Problem-Based+Learning+Method+of+General+Education+Course&btnG= Date of access: 29 Nov. 2019
- Johansson, M. & Svensson, T. 2019. Individual Reflection Paper: Supporting Student's Learning in the Critical Phase of Self-directed Learning in PBL. *Journal of Problem-Based Learning in Higher Education*.
- Johansson, R. 2003. On case study methodology. *Open House International*, 32(3):1-14.
- Johnson, D.W. & Johnson, R.T. 1999. Making cooperative learning work. *Theory into Practice*, 38(2):67-73.
- Johnson, D.W. & Johnson, R.T. 2003. 'Student motivation in co-operative groups: Social interdependence theory', in R.M. Gillies & A.F. Ashman (eds.), *Structuring co-operative learning experiences in primary school*, pp. 136-176, Routledge Falmer, London.
- Johnson, D.W. & Johnson, R.T. 2005. New Developments in Social Interdependence Theory. *Genetic, Social, and General Psychology Monographs*, 131(4):285-358.
- Johnson, D.W. & Johnson, R.T. 2009. An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, 38(5):365-379.
- Johnson, D.W. & Johnson, R.T. 2019. 'The impact of cooperative learning on self-directed learning', in E. Mentz, J. De Beer & R. Bailey (eds.), *Self-Directed Learning for the 21st Century: Implications for Higher Education* (NWU Self-Directed Learning Series Volume 1), pp. 37-66, AOSIS, Cape Town. <https://doi.org/10.4102/aosis.2019.BK134.02>
- Johnson, D.W. & Johnson, R.T. 1974. Instructional goal structure: Cooperative, competitive, or individualistic. *Review of Educational Research*, 44(2):213-240.
- Johnson, D.W., Johnson, R. T. & Roseth, C. 2010. Cooperative learning in middle schools: Interrelationship of relationships and achievement. *Middle Grades Research Journal*, 5(1):1-18.

Johnson, D.W., Johnson, R.T. & Smith, K.A. 1995. *Cooperative learning and individual student achievement in secondary schools*. Secondary schools and cooperative learning: Theories, models, and strategies, pp.3-54.

https://books.google.co.za/books?hl=en&lr=&id=shciAwAAQBAJ&oi=fnd&pg=PA3&dq=Cooperative+learning+and+individual+student+achievement+in+secondary+schools&ots=KzMWVxzZ18&sig=7keYTY7ybT-IQDcLUsmX7IMVjYk&redir_esc=y#v=onepage&q=Cooperative%20learning%20and%20individual%20student%20achievement%20in%20secondary%20schools&f=false Date of access: 23 March 2019.

Jonassen, D. 2011. Supporting Problem Solving in PBL. *Interdisciplinary Journal of Problem-Based Learning*, 5(2):95-119. <https://doi.org/10.7771/1541-5015.1256>

Jongman, M. 2017. The Impact of Social Interdependence Theory in Supply Chain Management. http://essay.utwente.nl/72736/1/Jongman_BA_BMS%5B1%5D.pdf Date of access: 12 Feb. 2020.

Kamin, C.S., O'Sullivan, P.S., Younger, M. & Deterding, R. 2001. Measuring critical thinking in problem-based learning discourse. *Teaching and Learning in Medicine*, 13(1):27-35. https://doi.org/10.1207/S15328015TLM1301_6

Kaptan, K. & Timurlenk, O. 2012. Challenges for science education. *Procedia - Social and Behavioural Sciences*, 51:763-771.

Kaufman, D. & Ireland, A. 2016. Enhancing teacher education with simulations. *TechTrends*, 60(3):260-267.

Kawedhar, M.C., Mulyani, S. & Indriyanti, N.Y. 2019. Analogies and visual aids provided by Chemistry teachers' in Chemistry learning: A case study of pre-service Chemistry teachers. In AIP Conference Proceedings (Vol. 2194, No. 1, p. 020048). AIP Publishing LLC. <https://aip.scitation.org/doi/pdf/10.1063/1.5139780>

Kek, M.Y.C.A. and Huijser, H. 2016. *Problem-based learning into the future: Imagining an agile PBL ecology for learning*. Springer.

Khan, B. & Begum, S. 2012. Portfolio: A professional development and learning tool for teachers. *International Journal of Social Science and Education*, 2(2):363-377. http://ecommons.aku.edu/pakistan_ied_pdcn/6

Khoiriyah, U., Roberts, C., Jorm, C. & Van der Vleuten, C.P.M. 2015. Enhancing students' learning in problem based learning: Validation of a self-assessment scale for active learning and critical thinking. *BMC Medical Education*, 15(1):140.

Kirbulut, Z. D. & Beeth, M. E. 2013. Representations of fundamental Chemistry concepts in relation to the particulate nature of matter. *International Journal of Education in Mathematics, Science and Technology*, 1(2):96-106.

Kitchen, H., Bethell, G., Fordham, E., Henderson, K. & Li, R.R. 2019. Using the evaluation system to promote better assessment and learning.

Knowles, M.S. 1975. *Self-directed learning. A guide for learners and teachers*. Englewood Cliffs: Prentice Hall Regents.

Knowles, M.S. 1980. *The Modern Practice of Adult Education: From Pedagogy to Andragogy*. Englewood Cliffs: Prentice Hall Regents.

- Knowles, M.S. 2014. The adult learner: The definitive classic in adult education and human resource development. Routledge. <https://files.eric.ed.gov/fulltext/ED084368.pdf>
- Koh, K. & Chapman, O. 2019. Problem-based learning, assessment literacy, mathematics knowledge, and competencies in teacher education. *Papers on Postsecondary Learning and Teaching*, 3:74-80.
- Krashen, S. 1982. Principles and practice in second language acquisition. 1st ed. CA: Pergamon Press Inc.
- Krenik, J. 2014. The Influence of Problem-Based Learning on Drawing Ability. Minneapolis: Walden University. (Thesis-PhD). https://www.johnkrenik.com/krenik_dissertation_5_22_2014.pdf
- Landon, K.N. 2019. Student perceptions of learning in the 21st century: An evaluation of the 4Cs. Maryland: Maryland University. (Thesis-PhD). <https://search.proquest.com/openview/01ce16d243a11cc70eae046186585af8/1?pq-origsite=gscholar&cbl=18750&diss=y> Date of access: 06 February 2020.
- Lee, A.S. 1991. Integrating positivist and interpretive approaches to organizational research. *Organization Science*, 2(4):342-365. <https://www.jstor.org/stable/2635169>
- Lee, H. & Blanchard, M. R. 2019. Why Teach With PBL? Motivational Factors Underlying Middle and High School Teachers' Use of Problem-Based Learning. *Interdisciplinary Journal of Problem-Based Learning*, 13(1). <https://doi.org/10.7771/1541-5015.1719>
- Lee, K.Y. & Kwan, C.Y. 2014. McMaster University. *PBL: What is it? "The use of problem-based learning in medical education"*. Retrieved from http://fhs.mcmaster.ca/mdprog/pbl_what_is.html.
- Lee, N. 2013. A conceptual framework for technology-enhanced problem-based learning in construction engineering and management education. *Journal of American Society for Engineering Education*.
- Lee, Y.C. & Fu, W.T. 2019. Supporting peer assessment in education with conversational agents. In *Proceedings of the 24th International Conference on Intelligent User Interfaces: Companion* (pp. 7-8).
- Li, H. 2017. Networking for English Literature Class: Cooperative Learning in Chinese Context. *English Language Teaching*, 10(12):219-229.
- Li, H., Xiong, Y., Hunter, C.V., Guo, X. & Tywoniw, R. 2020. Does peer assessment promote student learning? A meta-analysis. *Assessment & Evaluation in Higher Education*, 45(2):193-211.
- Li, H., Xiong, Y., Zang, X., L. Kornhaber, M., Lyu, Y., Chung, K.S. & K. Suen, H. 2016. Peer assessment in the digital age: A meta-analysis comparing peer and teacher ratings. *Assessment & Evaluation in Higher Education*, 41(2):245-264.
- Li, H.C. & Tsai, T.L. 2017. The implementation of problem-based learning in a Taiwanese primary mathematics classroom: Lessons learned from the students' side of the story. *Educational Studies*, 43(3):354-369. <https://doi.org/10.1080/03055698.2016.1277138>
- Li, S., Yamaguchi, S., Sukhbaatar, J. & Takada, J.I., 2019. The influence of teachers' professional development activities on the factors promoting ICT integration in primary schools in Mongolia. *Education Sciences*, 9(2), p.78. <http://doi:10.3390/educsci9020078>
- Li, W., Liping, P. & Khan, Q. 2018. *Research methods in education*. SAGE Publications.

- Liamputtong, P. 2013. The science of words and the science of numbers. Research method in health: foundations for evidence-based practice. South Melbourne: Oxford.
- Lim, W. K. 2012. Dysfunctional problem-based learning curricula: Resolving the problem. *BMC Medical Education*, 12(1), 1-89.
- Lincoln, Y.S. & Guba, E.G. 2000. 'The only generalization is: There is no generalization', in R. Gomm, M. Hammersley & P. Foster, P., *Case study method*. London: Sage. pp.27-44.
- Lopez, V. & Whitehead, D. 2013. Sampling data and data collection in qualitative research. *Nursing and Midwifery Research: Methods and critical appraisal for evidence-based practice*, pp.124-140.
- Loyens, S.M., Jones, S.H., Mikkers, J. & van Gog, T. 2015. Problem-based learning as a facilitator of conceptual change. *Learning and Instruction*, 38:34-42.
- Loyens, S.M., Magda, J. & Rikers, R.M. 2008. Self-directed learning in problem-based learning and its relationships with self-regulated learning. *Educational Psychology Review*, 20(4):411-427.
- Mack, L. 2010. The philosophical underpinnings of educational research. *Polyglossia*, (19):5-11.
- Mahmoudi, F. & Özkan, Y. 2015. Exploring experienced and novice teachers' perceptions about professional development activities. *Procedia-Social and Behavioural Sciences*, 199:57-64.
- Malmir, A. & Shoorcheh, S. 2012. An investigation of the impact of teaching critical thinking on the Iranian EFL learners' speaking skill. *Journal of Language Teaching and Research*, 3(4):608-617.
- Marco, C.A. & Larkin, G.L. 2000. Research ethics: Ethical issues of data reporting and the quest for authenticity. *Academic Emergency Medicine*, 7(6): 691-694.
- Maree, K. 2007. *First Steps in Research*. Pretoria, South Africa: Van Schaik
http://www.theiia.org/chapters/pubdocs/242/Internal_Controls_Basics_IIA_0,40709
- Mashau, T.S., Mutshaeni, H.N. & Kone, L.R. 2016. Teacher education: The South African context. *International Journal of Educational Sciences*, 14(1-2):167-173.
- Mavhunga, F, Ibrahim, B., Qhobela, M. & Rollnick, M. 2016. Student teachers' competence to transfer strategies for developing PCK for electric circuits to another Physical Sciences topic. *African Journal of Research in Mathematics, Science and Technology Education*, 20(3):299-313.
- McEvoy, P. & Richards, D. 2006. A critical realist rationale for using a combination of quantitative and qualitative methods. *Journal of Research in Nursing*, 11(1):66-78.
- McGuirk, P. M. & O'Neill, P. 2016. Using questionnaires in qualitative Human Geography. In I. Hay (Eds.), *Qualitative Research Methods in Human Geography* (pp. 246-273). Don Mills, Canada: Oxford University Press.
- Mentz, E. and De Beer, J., 2019. The affordances of change laboratories for improved sustainability and impact of in-service teacher professional development programmes. In *Proceedings of Teaching and Education Conferences* (No. 9611967). International Institute of Social and Economic Sciences.
<http://DOI:10.20472/TEC.2019.008.018>
- Merriam, S.B. 2001. Andragogy and Self-Directed Learning: Pillars of Adult Learning Theory. *New Directions for Adult and Continuing Education*, 89:3-13.

- Merritt, J. & Krajcik, J. 2013. 'Learning progression developed to support students' in G. Tsapalis & H. Sevan (eds.), *Concepts of Matter in Science Education*, pp. 11-45, Springer, Dordrecht.
- Merritt, J., Lee, M., Rillero, P. & Kinach, B. M. 2017. Problem-Based Learning in K–8 Mathematics and Science Education: A Literature Review. *Interdisciplinary Journal of Problem-Based Learning*, 11(2). <https://doi.org/10.7771/1541-5015.1674>
- Meyer, C.B. 2001. A case in case study methodology. *Field methods*, 13(4):329-352.
- Mohajan, H.K. 2018. Qualitative research methodology in social sciences and related subjects. *Journal of Economic Development, Environment and People*, 7(1):23-48.
- Morris, T.H. 2019a. Adaptivity through Self-Directed Learning to Meet the Challenges of Our Ever-Changing World. *Adult Learning*, 30(2):56-66. <https://doi.org/10.1177/1045159518814486>
- Morris, T.H. 2019b. Self-directed learning: A fundamental competence in a rapidly changing world. *International Review of Education*, 65:633-653. <https://doi.org/10.1007/s11159-019-09793-2>
- Morris, T.H. 2020. Creativity through self-directed learning: three distinct dimensions of teacher support, *International Journal of Lifelong Education*. <https://doi.org/10.1080/02601370.2020.1727577>
- Mota, A.R., dos Santos, J.B.L., Esperto, P. & Coutinho, I. 2019. Peer and Self-assessment: A Mathematical Model to Improve Students' Accountability in Laboratory Stations Model. *International Journal of Physics & Chemistry Education*, 11(1):7-11.
- Moutinho, S., Torres, J., Fernandes, I. & Vasconcelos, C. 2015. Problem-based learning and nature of science: A study with science teachers. *Procedia-Social and Behavioural Sciences*, 191:1871-1875.
- Mukungu, K. 2017. How can you write about a person who does not exist?: rethinking pseudonymity and informed consent in life history research. *Social Sciences*, 6(3):86-94. <https://www.mdpi.com/2076-0760/6/3/86>
- Nariman, N. & Chrispeels, J. 2016. PBL in the Era of Reform Standards: Challenges and Benefits Perceived by Teachers in One Elementary School. *Interdisciplinary Journal of Problem-Based Learning*, 10(1).
- National Education Association. 2010. Teacher assessment and evaluation: The national education association's framework for transforming education systems to support effective teaching and improve student learning. Washington, DC. <http://www.nea.org/home/41858.htm>.
- Naz, S. & Hussain, M.A. 2020. Trends in Self Directed Learning: Constraints and Opportunities. *Journal of Educational Sciences*, 7(1):63-75.
- Nganga, L. 2019. Preservice teachers perceptions of teaching for global mindedness and social justice: Using the 4Cs (Collaboration, Critical thinking, Creativity and Communication) in teacher education. *Journal of Social Studies Research*, 10:26-57.
- Nguyen, H.C. 2019. An investigation of professional development among educational policy-makers, institutional leaders and teachers. *Management in Education*, 33(1):32-36.
- Nursa'ban, E., Masykuri, M. & Yamtinah, S. 2019. Improving student learning outcomes in science subjects through the implementation of PBL-based module. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 5(2):269-276.

Ogegbo, A.A., Gaigher, E. & Salagaram, T. 2019. Benefits and challenges of lesson study: A case of teaching Physical Sciences in South Africa. *South African Journal of Education*, 39(1):1-9. <https://doi.org/10.15700/saje.v39n1a1680>

Ongardwanich, N., Kanjanawasee, S. & Tuipae, C. 2015. Development of 21st century skill scales as perceived by students. *Procedia-Social and Behavioural Sciences*, 191:737-741.

Osanloo, A. & Grant, C. 2016. Understanding, selecting, and integrating a theoretical framework in dissertation research: Creating the blueprint for your “house”. *Administrative issues journal: Connecting education, practice, and research*, 4(2):12-26.

Overton, T.L. & Randles, C.A. 2015. Beyond problem-based learning: Using dynamic PBL in chemistry. *Chemistry Education Research and Practice*, 16(2):251-259.

Owens, S.A. 2013. We Teach How We’ve Been Taught: Expeditionary Learning Unshackling Sustainability Education in US Public Schools. *Journal of Sustainability Education*, 5. <http://www.susted.org/>

Oyibe, O.A., Edinyang, S.D. & Effiong, V.N. 2015. Self-directed learning strategy: A tool for promoting critical thinking and problem solving skills among social studies students. *IOSR Journal of VLSI and Signal Processing*, 5(3):52-58.

Özmen, H. 2011. Effect of animation enhanced conceptual change texts on 6th grade students’ understanding of the particulate nature of matter and transformation during phase changes. *Computers & Education*, 57(1):1114-1126.

Papinczak, T., Young, L., Groves, M. & Haynes, M. 2007. An analysis of peer, self, and tutor assessment in problem-based learning tutorials. *Medical Teacher*, 29(5):e122-e132.

Partnership for 21st Century Learning. 2011. Framework for 21st Century Learning. www.p21.org

Partnership for 21st Century Learning. 2016. Framework for 21st Century Learning. <https://www.battelleforkids.org/networks/p21>

Partnership for 21st Century Learning. 2019. The Battelle for Kids P21 Framework for 21st Century Learning. Measuring SEL: Using Data to Inspire Practice. USA: Chicago. <https://measuringsel.casel.org>

Partnership for 21st Century Skills. 2009. P21 Framework Definitions. http://www.p21.org/storage/documents/P21_Framework_Definitions.pdf.

Paskevicius, M. 2018. Exploring Educators Experiences Implementing Open Educational Practices. Victoria: University of Victoria. (Thesis-PhD). <https://doi.org/10.5683/SP2/CA77BB>

Peen, T.Y. & Arshad, M.Y. 2017. Collaborative and self-directed learning processes: A case study in Malaysian Chemistry PBL lesson. *IJER-Indonesian Journal of Educational Review*, 4(1):1-13. <http://journal.unj.ac.id/unj/index.php/ijer>

Penn, M. & Ramnarain, U. 2019. South African university students’ attitudes towards Chemistry learning in a virtually simulated learning environment. *Chemistry Education Research and Practice*, 20(4):699-709.

Petersen, N., Golightly, A. & Dudu, W.T. 2019. ‘Engaging pedagogies to facilitate the border-crossing between the Natural Sciences and indigenous knowledge: Implications for science teacher education’, in J. De Beer (ed.), *The decolonisation of the curriculum project: The affordances of*

indigenous knowledge for self-directed learning (NWU Self-directed Learning Series Volume 2), pp. 143–180, AOSIS, Cape Town. <https://doi.org/10.4102/aosis.2019.BK133.06>

Petrova, E., Dewing, J. & Camilleri, M., 2016. Confidentiality in participatory research: Challenges from one study. *Nursing Ethics*, 23(4):442-454.

Phungsuk, R., Viriyavejakul, C. & Ratanaolarn, T. 2017. Development of a problem-based learning model via a virtual learning environment. *Kasetsart Journal of Social Sciences*, 38(3):297-306.

Pitjeng, R.J. 2015. Investigating the effect of an intervention on novice science teachers' topic specific pedagogical content knowledge. Johannesburg: WITS. (Thesis-PhD). <https://www.semanticscholar.org/paper/Investigating-the-effect-of-an-intervention-on-Pitjeng/5d262f8f7edb4dff60380373fdb4d7d1b8e1c2b0?p2df> Date of access: 10 February 2019.

Pitjeng-Mosabala, P. & Rollnick, M. 2018. Exploring the development of novice unqualified graduate teachers' topic-specific PCK in teaching the particulate nature of matter in South Africa's classrooms. *International Journal of Science Education*, 40(7):742-770. <https://doi.org/10.1080/09500693.2018.1446569>

Plucker, J. & Nowak, J. 1999. How to Use Problem-Based Learning in the Classroom/Problems as Possibilities: Problem-based learning for K-12 education. *Roeper Review*, 22(1):66-70.

Poë, J. C. 2015. 'Active Learning Pedagogies for the Future of Global Chemistry Education' in J. Garcia-Martinez & E. Serrano-Torregrosa (eds.), *Chemistry Education: Best Practices, Opportunities and Trends*, pp. 285-299, Wiley-VCH GmbH & Co. KGaA, Germany.

Poni, M. 2014. Research paradigms in education. *Journal of Educational and Social Research*, 4(1):407-413.

Prasetyo, S.A. & Hima, A.N., 2019. Student-based assessment vs. teacher assessment: Is there any consistency? *ELT Echo: The Journal of English Language Teaching in Foreign Language Context*, 4(2):158-133.

Pretorius, E.D, De Beer, J. & Lautenbach, G. 2014. Professional development of science teachers: The A-team hybrid ecology of learning practice. In UJ, Faculty of Science (Ed.) Proceedings of the ISTE First International Conference. (pp. 553–566). Johannesburg, South Africa: University of Johannesburg. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Professional+development+of+science+teachers%3A+The+A-team+hybrid+ecology+of+learning+practice&btnG= Date of access: 17 September 2020.

Pretorius, E.D. 2015. Learning Communities for the Professional Development of Science Teachers. Johannesburg: University of Johannesburg. (Thesis-PhD). <https://ujdigispace.uj.ac.za/>

Radojevich-Kelley, N. & Hoffman, D.L. 2012. Analysis of accelerator companies: An exploratory case study of their programs, processes, and early results. *Small Business Institute Journal*, 8(2):54-70.

Ramaphosa, M. C. 2020. *South Africa: National state of disaster declared in response to Coronavirus*. 15 March 2020, Union Buildings in Pretoria.

Ramli, N., Muljono, P. and Afendi, F.M., 2018. External Factors, Internal Factors and Self-Directed Learning Readiness. *Journal of Education and e-Learning Research*, 5(1):37-42.

- Ramnarain, U., & Schuster, D. 2014. The pedagogical orientations of South African Physical Sciences teachers toward inquiry or direct instructional approaches. *Research in Science Education*, 44:627–650. <https://doi.org/10.1007/s11165-013-9395-5>.
- Rana, S., Ardichvili, A. & Polesello, D. 2016. Promoting self-directed learning in a learning organization: Tools and practices. *European Journal of Training and Development*, 40(7):470-489. www.emeraldinsight.com/2046-9012.htm
- Rehman, A.A. & Alharthi, K. 2016. An introduction to research paradigms. *International Journal of Educational Investigations*, 3(8):51-59.
- Rifandi, R. & Rahmi, Y.L. 2019. STEM education to fulfil the 21st century demand: a literature review. In *Journal of Physics: Conference Series* (Vol. 1317, No. 1, p. 012208). IOP Publishing.
- Rist, R.C. 1977. On the relations among educational research paradigms: From disdain to detente. *Anthropology & Education Quarterly*, 8(2):42-49.
- Rizvi, S.N.A. & Bhardwaj, G. 2019. Role (Utility) of Research Design. *Journal of the Gujarat Research Society*, 21(5):24-34.
- Roberts, C., Jorm, C., Gentilcore, S. & Crossley, J. 2017. Peer assessment of professional behaviours in problem-based learning groups. *Medical Education*, 51(4):390-400.
- Robinson, J.D. & Persky, A.M. 2020. Commentary: Developing Self-Directed Learners. *American Journal of Pharmaceutical Education*, 84(3):292-296.
- Robson, D. & Mtika, P. 2017. Newly qualified teachers' professional learning through practitioner enquiry. *International Journal of Mentoring and Coaching in Education*, 6(3):242-260.
- Rollnick, M. 2017. Learning about semi-conductors for teaching - The role played by content knowledge in pedagogical content knowledge (PCK) development. *Research in Science Education*, 47(4):833-868.
- Rollnick, M., Davidowitz, B. & Potgieter, M. 2017. Is Topic-Specific PCK Unique to Teachers? In *Cognitive and Affective Aspects in Science Education Research* (pp. 69-85). Springer, Cham. http://DOI:10.1007/978-3-319-58685-4_6
- Roseth, C.J., Lee, Y.K. & Saltarelli, W.A. 2019. Reconsidering jigsaw social psychology: Longitudinal effects on social interdependence, socio-cognitive conflict regulation, motivation, and achievement. *Journal of Educational Psychology*, 111(1):149-169.
- Rovers, S.F., Clarebout, G., Savelberg, H.H. & van Merriënboer, J.J. 2018. Improving student expectations of learning in a problem-based environment. *Computers in Human Behaviour*, 87:416-423.
- Rusmansyah, R., Yuanita, L., Ibrahim, M., Isnawati & Prahani, B.K. 2019. Innovative Chemistry learning model: Improving the critical thinking skill and self-efficacy of pre-service Chemistry teachers. *Journal of Technology and Science Education*, 9(1):59-76. <https://doi.org/10.3926/jotse.555>
- Rusmansyah, R., Yuanita, L., Ibrahim, M., Rizkiana, F. & Kusuma, A.E. 2020, January. Effect of scientific critical thinking model to train critical thinking skills and student self-efficacy. In *Journal of Physics: Conference Series*, 1422(1):012015. IOP Publishing.
- Saavedra, A.R. & Opfer, V.D. 2012a. Learning 21st-century skills requires 21st-century teaching. *Phi Delta Kappan*, 94(2):8-13.

Saavedra, A.R. & Opfer, V.D. 2012b. *Teaching and learning 21st century skills: Lessons from the learning sciences*. A Global Cities Education Network Report. New York, Asia Society. <http://asiasociety.org/files/rand-0512report.pdf>

Saeid, N. & Eslaminejad, T. 2017. Relationship between Student's Self-Directed-Learning Readiness and Academic Self-Efficacy and Achievement Motivation in Students. *International Education Studies*, 10(1):225-232.

Saka, A.Z. & Kumaş, A. 2009. Implementation of problem-based learning in cooperative learning groups: An example of movement of vertical shooting. *Procedia-Social and Behavioural Sciences*, 1(1):1327-1336.

Saldaña, J. 2009. *The coding manual for qualitative researchers*. 1ST ed. Thousand Oaks, CA: Sage.

Salinitri, F.D., Lobkovich, A.M., Crabtree, B.L. & Wilhelm, S.M. 2019. Reliability and Validity of a Checklist to Evaluate Student Performance in a Problem-Based Learning Group. *American Journal of Pharmaceutical Education*, 83(8):1712-1722.

Samuel, K.B. & Dudu, W.T. 2018. In Search of a Working Strategy: The AHA... Moment in the Teaching of Science Subjects at Two South African High Schools. *EURASIA Journal of Mathematics, Science and Technology Education*, 14(8):1-17. <https://doi.org/10.29333/ejmste/91921>

Savery, J.R. 2015. 'Overview of Problem-based Learning: Definitions and Distinctions', in: Walker, A., Leary, H. Hmelo-Silver, C.E. & Ertmer, P.A. (eds.), *Essential Readings in Problem-Based Learning. Exploring and Extending the Legacy of Howard S. Barrows*, pp. 72-79, Purdue University Press, Indiana.

Savery, J.R. 2019. 'Comparative Pedagogical Models of Problem-Based Learning', in M. Moallem, W. Hung & N. Dabbagh (eds.), *The Wiley Handbook of Problem-Based Learning*, pp. 81-104, John Wiley & Sons, Inc., New Jersey.

Schwandt, T. 2015. *The SAGE dictionary of qualitative inquiry* (4th ed.). Thousand Oaks, CA: Sage Publications, Inc.

Scotland, J. 2012. Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms. *English Language Teaching*, 5(9):9-16. <http://dx.doi.org/10.5539/elt.v5n9p9>

Sebotsa, T., De Beer, J & Kriek, J. 2019. Self-Directed Learning and teacher professional development: an adapted profile of implementation. <https://doi.org/10.20472/TEC.2019.008.025>

Sekarini, A.P., Wiyanto, W. & Ellianawati, E. 2020. Analysis of Problem Based Learning Model with Mind Mapping to Increase 21st Century Skills. *Journal of Innovative Science Education*, 9(1):321-326. <http://journal.unnes.ac.id/sju/index.php/jise>

Selvaratnam, M. 2011. Competence of matric physical science teachers in some basic problem-solving strategies. *South African Journal of Science*, 107(1-2):1-7.

Servant-Miklos, V.F, Norman, G.R. & Schmidt, H.G. 2019. 'Problem Design in PBL', in M. Moallem, W. Hung & N. Dabbagh (eds.), *The Wiley Handbook of Problem-Based Learning*, pp. 3-24, John Wiley & Sons, Inc., New Jersey.

Servant-Miklos, V.F. 2019. Fifty years on: A retrospective on the world's first problem-based learning programme at McMaster University Medical School. *Health Professions Education*, 5(1):3-12.

Servant-Miklos, V.F., Woods, N.N. & Dolmans, D.H. 2019. Celebrating 50 years of problem-based learning: progress, pitfalls and possibilities. *Advances in Health Sciences Education*, 24:849–851.

Shulman, L. S. 1986. Those who understand: knowledge growth in teaching. *Educational Researcher*, 15(2):4-14.

Simamora, R.E., Sidabutar, D.R. & Surya, E. 2017. Improving learning activity and students' problem solving skill through problem based learning (PBL) in junior high school. *International Journal of Sciences: Basic and Applied Research (IJSBAR)*, 33(2):321-331.
<http://gssrr.org/index.php?journal=JournalOfBasicAndApplied>

Slavin, R.E. 1988. Student team learning: An overview and practical guide. NEA Professional Library, PO Box 509, West Haven, CT 06516. <https://files.eric.ed.gov/fulltext/ED295910.pdf>

Smith, K. & Tillema, H. 1998. Evaluating portfolio use as a learning tool for professionals. *Scandinavian Journal of Educational Research*, 42(2):193-205.

Smith, K. & Tillema, H. 2003. Clarifying different types of portfolio use. *Assessment & Evaluation in Higher Education*, 28(6):625-648. <https://doi.org/10.1080/0260293032000130252>

Smith, P.L., Harris C.M., Sammons, L., Waters, J., Jordan, D., Martin, D., Smith, N. & Cobb, P. 2001. Using Multimedia Portfolios to Assess Preservice Teacher and P-12 Student Learning. *Action in Teacher Education*, 22(4):28-39. <https://doi.org/10.1080/01626620.2001.10463027>

Stehle, S.M. & Peters-Burton, E.E. 2019. Developing student 21st Century skills in selected exemplary inclusive STEM high schools. *International Journal of STEM Education*, 6(39):1-15.

Stojcevski, A. & Du, X. 2020. 'Group Project Assessment in a PBL Environment', in X. Du, E. D. Graaff & A. Kolmos (eds.), *Research on PBL Practice in Engineering Education*, pp. 97-112, Sense Publishers, Rotterdam.

Strijbos, J.W. & Wichmann, A. 2018. Promoting learning by leveraging the collaborative nature of formative peer assessment with instructional scaffolds. *European Journal of Psychology of Education*, 33(1):1-9.

Stuckey, H.L. 2015. The second step in data analysis: Coding qualitative research data. *Journal of Social Health and Diabetes*, 3(1):7-10.

Suastra, I.W., Suarni, N.K. & Dharma, K.S. 2019. October. The effect of Problem-Based Learning (PBL) model on elementary school students' science higher order thinking skill and learning autonomy. In *Journal of Physics: Conference Series*, 1318(1):012084. IOP Publishing.

Sukrajh, V. 2018. The use of peer teaching to promote active learning amongst senior medical students. Stellenbosch: University of Stellenbosch. (M.Phil. Health Professions Education).
<https://scholar.sun.ac.za/handle/10019.1/103318>

Summerton, L., Hurst, G.A. & Clark, J.H. 2018. Facilitating active learning within green Chemistry. *Current Opinion in Green and Sustainable Chemistry*, 13:56-60.

Swart, A.J. & Havenga, M. 2019. Correlating Learning Outcomes to the Graduate Attributes of the International Engineering Alliance in a Problem-Based Learning Module. In 2019 IEEE Global Engineering Education Conference (EDUCON) (pp. 34-38). IEEE.

- Szyjka, S. 2012. Understanding research paradigms: Trends in science education research. *Problems of Education in the 21st Century*, 43:110-118.
- Talat, A. & Chaudhry, H.F. 2014. The effect of PBL and 21st century skills on students' creativity and competitiveness in private schools. *The Lahore Journal of Business*, 2:2 (Spring 2014):89–114.
- Tan, S. & Shen, Z. 2019. A survey on hybrid problem-based learning in a digital image processing course. In *Education and Training in Optics and Photonics* (11143:22). Optical Society of America.
- Tandogan, R.O. & Orhan, A. 2007. The Effects of Problem-Based Active Learning in Science Education on Students' Academic Achievement, Attitude and Concept Learning. *Online Submission*, 3(1):71-81.
- Taylor, P. C. 2016. Why is a STEAM curriculum perspective crucial to the 21st century? Retrieved from <http://researchrepository.murdoch.edu.au/id/eprint/37950/1/STEAM.pdf>
- Taylor, P.C. & Medina, M. 2011. Educational research paradigms: From positivism to pluralism. *College Research Journal*, 1(1): 1-16. <http://researchrepository.murdoch.edu.au/id/eprint/36978/>
- Teaching. *Journal of Applied Research in Higher Education*, 7(2):146-163.
- Thakur, P., Dutt, S. & Chauhan, A. 2018. Learning Biology through Problem Based Learning– Perception of Students. *i-Manager's Journal of Educational Technology*, 15(2):44.
- Thanh, N.C. & Thanh, T.T. 2015. The interconnection between interpretivist paradigm and qualitative methods in education. *American Journal of Educational Science*, 1(2):24-27.
- Thomas, D.R. 2006. A general inductive approach for analysing qualitative evaluation data. *American Journal of Evaluation*, 27(2):237-246.
- Tigere, M.T. 2016. The role of school management teams in managing factors that influence learner academic performance in Grade 12 examinations in KwaZulu-Natal. Pretoria: UNISA. (Dissertation-MEd).
- Tillema, H.H. 2001. Portfolios as developmental assessment tools. *International Journal of Training and Development*, 5(2):126-135.
- Tipton, J.M. 2019. Twenty-First Century Skill Building for Students with Special Needs through Problem-Based Learning: An Examination of Homeschool Teacher Blogs. Minneapolis: Walden University. (Thesis-PhD). <https://scholarworks.waldenu.edu/dissertations>
- Torre, D.M., van der Vleuten, C. & Dolmans, D. 2016. Theoretical perspectives and applications of group learning in PBL. *Medical Teacher*, 38(2):189-195.
- Tortorella, G. & Cauchick-Miguel, P.A. 2017. Teaching lean manufacturing at a postgraduate level: Integrating traditional teaching methods and problem-based learning approach. *International Journal of Lean Six Sigma*, 9(3):301-323.
- Tracy, S.J. 2013. *Qualitative research methods: Collecting evidence, crafting analysis, communicating impact*. John Wiley & Sons.
- Tran, V.D., Nguyen, T.M.L., Van De, N., Soryaly, C. & Doan, M.N. 2019. Does Cooperative Learning May Enhance the Use of Students' Learning Strategies? *International Journal of Higher Education*, 8(4):79-88.

- Turhan, N.S. 2019. Qualitative research designs: Which one is the best for your research? *European Journal of Special Education Research*, 4(2):124-136. www.oapub.org/edu
- Turiman, P., Wook, T.S.M.T. & Osman, K. 2019. 21st Century Skills Mastery amongst Science Foundation Programme Students. *International Journal on Advanced Science, Engineering and Information Technology*, 9(1):46-53.
- Turner III, D.W. 2010. Qualitative interview design: A practical guide for novice investigators. *The Qualitative Report*, 15(3):754-760.
- Urbani, J.M., Roshandel, S., Michaels, R. & Truesdell, E. 2017. Developing and modelling 21st-century skills with preservice teachers. *Teacher Education Quarterly*, 44(4):27-50.
- Usmeldi, Anggreini. & Amini, R. 2019. The Effect of the Implementation of Problem-Based Physics Learning to improve the students' Creativity. *Advances in Social Science, Education and Humanities Research*, 422:72-75. <http://creativecommons.org/licenses/by-nc/4.0/>
- Valdez, J., & Bungihan, M. 2019. Problem-based learning approach enhances the problem solving skills in chemistry of high school students. *Journal of Technology and Science Education*, 9(3): 282-294. <https://doi.org/10.3926/jotse.631>
- Van Driel, J.H., Verloop, N. & De Vos, W. 1998. Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 35(6):673-695.
- Van Heerden, S. 2019. Newly qualified teachers 'classroom practices as supported by initial teacher education. Cape Town: CPUT. (Thesis-PhD). http://etd.cput.ac.za/bitstream/handle/20.500.11838/2870/Sene_VanHeerden.pdf?sequence=1&isAllo wed=y Date of access: 11 April 2019.
- Van Mechelen, M., Gielen, M., Vanden Abeele, V., Laenen, A. & Zaman, B. 2014, June. Exploring challenging group dynamics in participatory design with children. In *Proceedings of the 2014 conference on interaction design and children* (pp. 269-272).
- Van Wyk, B. 2012. Research design and methods. Part I [PowerPoint presentation]. Lecture notes. Cape Town: University of Western Cape. https://www.uwc.ac.za/Students/Postgraduate/Documents/Research_and_Design_I.pdf
- Vogeltanz-Holm, N., Olson, L.M., Borg, K.E. & Hill, T.M. 2014. Implementation and Evaluation of a Team-Based Learning Approach Within a Hybrid Problem-Based Learning Medical Education Curriculum. *Medical Science Educator*, 24(1):125-133.
- Vygotsky, L. 1978. 'Interaction between learning and development', in M. Gauvain & M. Cole (eds.), *Readings on the development of children*, pp. 79-91, Harvard University Press, Cambridge.
- Wagner, T. 2015. 'The worst of times, the best of times', in J.A. Bellanca (ed.), *Deeper learning: Beyond 21st century skills*, pp. 159-175, Solution Tree Press: Bloomington, IN.
- Wahyu, W. & Syaadah, R.S. 2018, May. Implementation of problem-based learning (PBL) approach to improve student's academic achievement and creativity on the topic of electrolyte and non-electrolyte solutions at vocational school. *Journal of Physics: Conference Series* (Vol. 1013, No. 1, p. 012096). IOP Publishing.

- Wahyu, W. K. & Eli, R.N. 2016, February. Using problem-based learning to improve students' creative thinking skills on water purification. In *AIP Conference Proceedings* (Vol. 1708, No. 1, p. 040008). AIP Publishing LLC.
- Wahyuni, D. 2012. The research design maze: Understanding paradigms, cases, methods and methodologies. *Journal of Applied Management Accounting Research*, 10(1):69-80.
- Walsham, G. 1995. The emergence of interpretivism in IS research. *Information Systems Research*, 6(4):376-394. <https://www.jstor.org/stable/23010981>
- Wan Husin, W.N.F., Mohamad A, N., Othman, O., Halim, L., Rasul, M.S., Osman, K. & Iksan, Z. 2016. Fostering students' 21st century skills through Project Oriented Problem Based Learning (POPBL) in integrated STEM education program. *Asia-Pacific Forum on Science Learning & Teaching*, 17(1):60-77.
- Wark, N. & Ally, M. 2020. 'An Emergent Pedagogical Framework for Integrating Emergent Technologies into Curriculum Design', in R.C. Wei, L. Darling-Hammond & F. Adamson (eds.), *Emerging Technologies and Pedagogies in the Curriculum*, pp. 89-111, Springer, Singapore.
- Wei, R.C., Darling-Hammond, L. & Adamson, F. 2010. Professional Development in the United States: Trends and Challenges. Phase II of a Three-Phase Study. Technical Report. National Staff Development Council.
- Weiss, D.M. & Belland, B.R. 2018. PBL group autonomy in a high school environmental science class. *Technology, Knowledge and Learning*, 23(1):83-107.
- Whalen, C., Majocha, E., & Van Nuland, S. 2019. Novice teacher challenges and promoting novice teacher retention in Canada. *European Journal of Teacher Education*, 42(5):591-607.
- Whitehead, D. & Whitehead, L. 2016. Sampling data and data collection in qualitative research. <https://www.researchgate.net/publication/284371803>
- Willis, J. W. 2007. *Foundations of qualitative research: Interpretive and critical approaches*. Thousand Oaks, CA: Sage.
- Wood, D.F. 2008. Problem-based learning. *Acta Biochimica Polonica*, 51(2/2004): XXI-XXVI. <https://www.researchgate.net/publication/5395517>
- Wood, D.F., 2003. ABC of learning and teaching in medicine: Problem-based learning. *Bmj*, 326(7384):328-330.
- Wozniak, K. 2020. 'Personalized Learning for Adults: An Emerging Andragogy.' In S. Yu, M. Ally & A. Tsinakos (eds.), *Emerging Technologies and Pedagogies in the Curriculum, Bridging Human and Machine: Future Education with Intelligence*, pp. 185-198, Springer, Singapore.
- Wuli, J.T.R., Susilowati, S.M.E. & Prasetyo, A.P.B. 2017. The Influence of Self and Peer Assessment on Science Learning. *Journal of Primary Education*, 6(3):218-223.
- Wyness, L. & Dalton, F. 2018. The value of problem-based learning in learning for sustainability: Undergraduate accounting student perspectives. *Journal of Accounting Education*, 45:1-19.
- Xiao, Y. & Watson, M. 2019. Guidance on conducting a systematic literature review. *Journal of Planning Education and Research*, 39(1):93-112.

- Yakmaci-Guzel, B. and Adadan, E., 2013. Use of Multiple Representations in Developing Preservice Chemistry Teachers' Understanding of the Structure of Matter. *International Journal of Environmental and Science Education*, 8(1):109-130.
- Yasmin, M., Naseem, F. & Masso, I.C. 2019. Teacher-directed learning to self-directed learning transition barriers in Pakistan. *Studies in Educational Evaluation*, 61:34-40.
- Yilmaz, K. 2013. Comparison of quantitative and qualitative research traditions: Epistemological, theoretical, and methodological differences. *European Journal of Education*, 48(2):311-325.
- Yin, R.K. 1981. The case study as a serious research strategy. *Knowledge*, 3(1):97-114.
- Yin, R.K. 1994. Discovering the future of the case study. Method in evaluation research. *Evaluation Practice*, 15(3):283-290.
- Yin, R.K. 2003. Case study research design and methods third edition. *Applied social research methods series*, 5.
- Yin, R.K. 2014. *Case study research design and methods*. 5th ed. London: Sage.
- Yusof, K.M., Hassan, S.A.H.S., Jamaludin, M.Z. & Harun, N.F. 2012. Cooperative problem-based learning (CPBL): Framework for integrating cooperative learning and problem-based learning. *Procedia-Social and Behavioural Sciences*, 56:223-232.
- Zabit, M.N.M. 2010. Problem-based learning on students' critical thinking skills in teaching business education in Malaysia: A literature review. *American Journal of Business Education (AJBE)*, 3(6):19-32.
- Zainal, Z. 2007. Case study as a research method. *Journal Kemanusiaan*, 5(1):1-6.
- Zainuddin, Z. & Perera, C.J. 2018. Supporting students' self-directed learning in the flipped classroom through the LMS TES Blend Space. *On the Horizon*, 26(4):281-290.
<https://doi.org/10.1108/OTH-04-2017-0016>
- Zejnilić-Hajrić, M., Šabeta, A. & Nuić, I. 2015. The effects of problem-based learning on students' achievements in primary school chemistry. *Bulletin of the Chemists and Technologists of Bosnia and Herzegovina*, 44:17-22.
- Zhukova, O. 2017. Novice teachers' beliefs about Problem-Based Learning approach, and Teaching Practices. In *CBU International Conference Proceedings*, September. (Vol. 5, pp. 901-909).

APPENDICES

APPENDIX A: OPEN-ENDED QUESTIONNAIRE

OPEN-ENDED QUESTIONNAIRE

BACKGROUND DATA:

1. Grade taught: 10 - 12
2. Subjects taught: PHYSICAL SCIENCES
3. Average number of learners per class: 12
4. Number of years teaching: 3
5. Tertiary qualification(s): BACHELORS OF EDUCATION
6. Specialisation(s): PHYSICAL SCIENCE & MATHEMATICS
7. Number of years teaching FET Particulate Nature of Matter: 3
8. Number of years teaching GET Particulate Nature of Matter (If any): 1

QUESTIONS OF THE QUESTIONNAIRE:

1. How do you describe your teaching of Particulate Nature of Matter concepts?

THE TEACHING OF PARTICULATE NATURE OF MATTER IS QUIET
CHALLENGING AS IT REQUIRES DEEP UNDERSTANDING AND VISUALISATION
AND IN MOST CASES THERE IS JUST NEVER THE BEST APPROACH TO TEACH IT

2. What teaching approaches do you utilise while teaching Particulate Nature of Matter? (List all of them)

- RESEARCHING
- COOPERATIVE LEARNING
- DISCUSSION

3. Why do you use the teaching approach(es) stated at question 2 above?

THE METHODS STATED ABOVE ALLOW LEARNERS TO FIND INFORMATION
THEMSELVES WHERE THEY ANALYSE AND DISCUSS EACH INFORMATION AND
LET THE TEACHER GUIDE AND FACILITATE THROUGH ADDRESSING MISCONCEPTIONS

4. What other approaches do you know of, but do not utilise, to teach Particulate Nature of Matter? (List them)

- EXPERIMENTING.....

- LECTURING.....

.....

.....

5. Explain why you do not utilise those teaching approaches you mentioned in question 4.

TO EXPERIMENT ON PARTICULATE NATURE OF MATTER REQUIRES HI-TECH AND ADVANCED RESOURCES. WITH LIMITED OR IN MOST CASE NO RESOURCES IN OUR SCHOOLS IT BECOMES DIFFICULT TO PERFORM EXPERIMENT TO INVESTIGATE AND CLARIFY CONCEPTS ON NATURE OF MATTER.....

6. Explain the teaching approaches that were introduced to you during your studies to become a professional teacher in order to deliver science content effectively.

MOST OF THE APPROACHES ARE DIRECTED AT USING KNOWN INFORMATION TO ADDRESS UNKNOWN PROBLEMS AND ALSO USING THAT INFORMATION AND RELATE IT TO REAL LIFE PROBLEMS. FOR EXAMPLE TO EXPERIMENT ON SOMETHING IN A WAY THAT YOU SOLVE A REAL LIFE PROBLEM.....

7. Explain how satisfied are you with your teaching approaches?

I COULD SAY I AM PARTIALLY SATISFIED WITH MY APPROACHES AS LEARNERS CONTINUOUSLY STRUGGLE WITH NATURE OF MATTER WHICH IS THE BASIS FOR THE TEACHING AND LEARNING OF PHYSICAL SCIENCES.....

8. What is your understanding of Problem-Based Learning?

I WOULD ASSUME THAT PROBLEM BASED LEARNING IS THE METHOD OF USING A PROBLEM AT HAND TO GATHER INFORMATION, ANALYSE AND INTERPRET THAT INFORMATION TO SOLVE THE PROBLEM AND LEARNING ALONG THE PROCESS

9. What role do you think Problem-Based Learning plays in teaching Particulate Nature of Matter?

IT PLAYS A MAJOR ROLE BECAUSE IT TEACHES LEARNERS TO BE DISCOVERERS OF INFORMATION AND BE INDEPENDENT OF THE TEACHER.

10. What knowledge do you have of utilising Problem-Based Learning while teaching Particulate Nature of Matter?

JUST BASIC KNOWLEDGE. THERE HAS NOT BEEN MUCH EXPOSURE OR RATHER EXPLORATION OF PROBLEM-BASED LEARNING.

11. What is the role of the teacher when utilising Problem-Based Learning?

THE TEACHER ACTS AS A FACILITATOR AND GUIDES LEARNERS THROUGH THEIR DISCOVERIES.

12. What is the role of the learners when utilising Problem-Based Learning?

LEARNERS BECOME THEIR OWN TEACHERS. THEY LOOK FOR INFORMATION AND MAKE MEANS TO USE THAT INFORMATION TO ADDRESS THE PROBLEM.

13. List five 21st century skills that you know.

CRITICAL THINKING, COMMUNICATION, TECHNOLOGY, COOPERATIVE LEARNING, INFORMATION LITERACY

14. Explain how you inculcate and develop the 21st century skills (if any) you mentioned in question 13 above in your learners.

THE USE OF TECHNOLOGY IN TEACHING SUCH AS SIMULATIONS, OVERHEAD PROJECTING, USE CRITICAL THINKING IN SOLVING PROBLEMS DURING PROJECTS AND INVESTIGATIONS

15. Describe ways (if any) in which you inculcate your learners to apply 21st century skills on science principles and generalisation on new problems and situations.

THE USE OF PROJECTS TO ALLOW LEARNERS' CREATIVITY TO BE TESTED AND ALLOW THEM TO PERFORM EXPERIMENTS UNDER GUIDANCE TO LET THEM SOLVE PROBLEMS THEMSELVES.

16. Which concepts, in teaching of Particulate Nature of Matter have you used to instil 21st century skills?

TEACHING STATES OF MATTER AND THE PROCESSES INVOLVED

17. Describe ways in which your learners exhibit self-directed characteristics.

LEARNERS IF NOT ALL, ARE ABLE TO BUILD MODEL WHICH SHOWS THEIR CREATIVE SENSE ALSO THEY PARTIALLY CAN PERFORM EXPERIMENTS AND USING CRITICAL THINKING SOLVE PROBLEMS.

18. How do you promote Self-Directed Learning in your learners while teaching PNM?

ALLOW LEARNERS TO BE INDEPENDENT AND SELF DISCOVERIES ON UTILISING AND OPERATING EQUIPMENT, GATHER INFORMATION, RECORD IT AND ANALYSE IT SO AS TO SOLVE PROBLEMS

19. Which teaching approaches do you use to enhance critical thinking in your learners?

DURING LESSONS, ASKING QUESTIONS THAT ALLOW LEARNERS TO REFLECT ON WHAT THEY ALREADY ATTAINED AS BACKGROUND INFORMATION

20. Which teaching approaches do you use to enhance collaboration among your learners?

COOPERATIVE LEARNING METHOD. ALLOWING LEARNERS TO
WORK EITHER IN GROUPS OR IN PAIRS TO SOLVE
PROBLEMS. THEY ARE EXPOSED TO GETTING TO WORK TOGETHER
TO REACH A DESIRED GOAL.

21. Which 21st century skills do you think will enhance Self-Directed Learning in your learners?

CREATIVITY. WHEN LEARNERS ARE ALLOWED TO DEVELOP A
MODEL OR A PROTOTYPE THAT IS AIMED AT SOLVING AN
EXISTING PROBLEM, IT IS BASICALLY AN INDEPENDENT METHOD OF
LEARNING.

22. Explain ways or circumstances in which your learners have exhibited skills mentioned in
question 21?

BY ALLOWING THEM TO BUILD MODELS IN ~~MOD~~ PROJECTS
SUCH AS USING STICK AND BALLS TO DESCRIBE MATTER OR
TO BUILD A STRUCTURE OF AN ATOM ALLOW THE
DEVELOPMENT OF THE LEARNERS CREATIVITY.

APPENDIX B: 21ST CENTURY SKILLS OBSERVED DURING PBL

6. 21st-century skills observed during the PBL Lesson

Tic k	Skill	Comment
	Collaboration	
	Critical thinking	
	Communicatio n	
	Creativity	

APPENDIX C: INTERVIEW QUESTIONS

INTERVIEW A QUESTIONS

NB: The following questions are reflective on the intervention programme and implementation of PBL while teaching PNM.

1. How can you describe your experience/exposure on PBL, 21st-century skills and SDL?
2. Explain the impact of this exposure on your teaching regarding PBL.
3. Did you benefit from this exposure? Please explain.
4. What can you say about your teaching before the workshop and after the workshop?
5. How would you describe utilising PBL in teaching PNM?
6. What negative impacts can you describe which you experienced while utilising
7. What would you change AND improve in utilising PBL while teaching PNM?
8. What do you think was beneficial on your learners while utilising PBL?
9. Do you think PBL promoted SDL (learn on their own) amongst your learners?
Explain
10. How could you tell that 21st-century skills (collaboration, critical thinking, creativity, and communication) were enhanced on your learners while utilising PBL?

APPENDIX D: INTER-RATER RELIABILITY COEFFICIENTS – FOR TEACHER-BASED ASSESSMENT RUBRIC FOR PBL

INTER-RATER RELIABILITY COEFFICIENTS - For the teacher-based assessment rubric for the PBL activity

Areas	Kappa (κ) coefficients
Demarcation of the problem	0.9812
Formulation of learning objectives	0.9473
The scope and quality of provisional research	0.9315
Identification and recommendation of possible solutions for the problem	0.9656
Writing skills	0,9782

APPENDIX E: INTER-RATER RELIABILITY COEFFICIENTS – FOR OVERALL LEVEL OF PROFICIENCY OF PBL

INTER-RATER RELIABILITY COEFFICIENTS - For overall level of proficiency of PBL implementation

Principles	Kappa (κ) coefficients
Content knowledge being taught	0.9814
PBL implementation	0.9365
Instructions adapted to meet diverse learners	0.9748
21st-century skills observed	0,9632
Assessment of learners' work to improve enhancement of 21st-century skills	0.9871
Reflections and professional development	0.9881

APPENDIX F: EXAMPLE OF INTERVIEW TRANSCRIPT

EXAMPLE OF INTERVIEW TRANSCRIPT - INTERVIEW D

NB: The following questions are reflective on the intervention programme and implementation of PBL while teaching PNM.

1. How can you describe your exposure on PBL, 21st-century skills and SDL?

I experienced that using PBL helped me very much when it comes to teaching because many teachers when they start teaching, including myself, we tend to teach the same way that we were taught, and 21st-century skills are not the skills that our teachers were equipped with. Therefore, being exposed to PBL and 21st-century skills helped me as I discovered things I did not know before, especially another approach that I can use to teach PNM and other topics. I believe that this will lead to learners being self-directed. I think it is good to have self-directed learners.

2. Explain the impact of this exposure on your teaching regarding PBL.

It helped me to approach teaching PNM and teaching in general in a different way because since I started teaching I have been using teacher-centred approach whereby I stand in front of learners and give them information. But with the use of PBL, I learned that it is easy for learners to construct their own knowledge. It is amazing the things that one will discover that learners know or can come with, when they are given a chance.

3. Did you benefit from this exposure? Please explain.

As a teacher, I am supposed to be a life-long learner. Therefore, I have developed in terms of PCK, 21st-century skills and the concept instilling self-directedness on my learners.

4. What can you say about your teaching before the workshop and after the workshop?

Before, I was teacher-centred because of the CAPS curriculum pace-setter. It was difficult to try to explore different approaches. Therefore, I was more teacher-centred in order to cover the ATP in a given time. But after being exposed to PBL in the workshop, I allowed learners to develop their own knowledge. I could allow learners to work ahead such that I can give them problems before the lesson because they are self-directed. That way I could discover the learners' prior-knowledge, where they struggle and the misconceptions that they might have.

5. How would you describe utilising PBL in teaching PNM?

I gave learners the PBL problem, and allowed learners to explore different areas in the problem of the Kinetic Molecular theory and come up with their own knowledge draw solutions. In our discussion I also used simulations for some of PNM concepts such as diffusion, Kinetic Molecular Theory and etc. observing what happens to molecules or particles when the temperature changes. Then we through some concepts such as diffusion, KMT, etc.

Finally, learners could focus researching more information to come up with the solutions.

6. What negative impacts can you describe which you experienced while utilising PBL?

When learners were working in groups and I wanted to correct or motivate one learner, I had to do it in a manner that does not embarrass him/her. Sometimes one learner has a misconception, it is difficult to clear it in a way that is “civil” and encouraging such that, that learner understands that he/she is wrong but also know that it is okay to be wrong; this was a challenge. Another challenge was the noise that learners made during the lesson.

7. What would you change AND improve in utilising PBL while teaching PNM?

There is nothing that I would change since this was my first time using PBL.

8. What do you think was beneficial on your learners while utilising PBL?

PBL developed critical-thinking and teamwork skills on my learner. These were important skills to develop because as science learners, they must know that as scientists they will not work as individuals; many science careers require teamwork. Therefore, it is important for my learners to develop these skills while in school. Learners were able to show critical-thinking, which is a good skill which boosted their performance. These are skills that will be beneficial for the real-world.

9. Do you think PBL promoted SDL (learn on their own) amongst your learners? Explain

Yes, because the learners came up with the solutions independently and their questions and answers during lesson showed that they were self-directed.

10. How could you tell that 21st-century skills (collaboration, critical thinking, creativity, and communication) were enhanced on your learners while utilising PBL?

Because they could communicate ideas, thinking critically to come up with solutions. And they were creative coming up with solutions. They also managed to work together cooperatively.

APPENDIX G: ETHICS APPROVAL LETTER



3 October 2019

To Whom It May Concern

I hereby confirm that the ethics application, as stated below, is approved by the members of the Ethics Committee of the Faculty of Education on 3 October 2019 and will be minuted at the Ethics Committee meeting on 24 October 2019.

Ethics number: NWU-01611-19-A2

Project head: Prof W Dudu

Project team: MJ Sebatana (MEd student - 24240672); Dr A Mutsvangwa; Prof A Golightly; Ms J Steenkamp

Title: Enhancing the use of Problem-Based Learning by beginner Physical Sciences teachers while teaching Particulate Nature of Matter

Period: 3 October 2019 – 3 October 2020

Clearance given for only one year. Extension can be requested after a year.

Risk level: Low

Should you have further enquiries in this regard, you are welcome to contact Prof Jako Olivier at 018 285 2078 or by email at Jako.Olivier@nwu.ac.za or Ms Erna Greyling at 018 299 4656 or by email at Erna.Greyling@nwu.ac.za.

Yours sincerely



Prof J Olivier
Chair Edu-REC

APPENDIX H: PERMISSION TO CONDUCT RESEARCH



education

Lefapha la Thuto la Bokone Bophirima
Noord-Wes Onderwys Departement
North West Education Department
NORTH WEST PROVINCE

Garona Building, Mmabatho
1st Floor, East Wing,
Private Bag X2044,
Mmabatho 2735
Tel.: (018) 388-3433
Fax: 086-514-0128
e-mail: molhabanej@nwpg.gov.za

OFFICE OF THE SUPERINTENDENT-GENERAL

Enq. : Dr T Phorabatho
Tel. : 018 388 3071/3433

To: Prof Eashington Dudu
North West University (Potchefstroom Campus)
Faculty of Education

From: Mrs S M Semaswe
Superintendent-General

Date : 07 October 2019

PERMISSION TO CONDUCT RESEARCH: MR MJ SEBATANA

Permission is hereby granted to you to conduct research in the department as requested, subject to the following conditions:

- You contact the relevant School Principals for your target schools about your request with this letter of permission;
- Considering that your research will involve both Educators and Learners, the general functionality of the school should not be compromised by the research process.
- The participation in your project will be voluntary.
- The principles of informed consent and confidentiality will be observed in strictest terms, and
- The findings of your research should be made available to the North West Department of Education and Sport Development upon request.

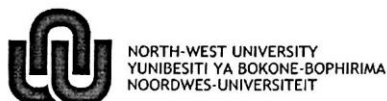
Best wishes

Mrs S M Semaswe
Superintendent-General



"Towards Excellence in Education and Sport Development"

APPENDIX I: CONFIDENTIALITY UNDERTAKING



CONFIDENTIALITY UNDERTAKING

entered into between:

I, the undersigned

Prof. / Dr. / Mr. / Ms. Siso Mabileko

Identity Number: 9101017477081

Address: 1467 Makhele Road, Mmabatho

hereby undertake in favour of the **NORTH-WEST UNIVERSITY**, a public higher education institution established in terms of the Higher Education Act No. 101 of 1997

Address: Office of the Institutional Registrar, Building C1, 53 Borchard Street, Potchefstroom, 2520

(hereinafter the "NWU")

Title of study/project: Enhancing the utilization of Problem-Based Learning by beginner Physical Sciences teachers in the teaching of Particulate Nature of Matter.

Ethics number: NWU-01611-19-A2

1 Interpretation and definitions

1.1 In this undertaking, unless inconsistent with, or otherwise indicated by the context:

1.1.1 "Confidential Information" shall include all information that is confidential in its nature or marked as confidential and shall include any existing and new information obtained by me after the Commencement Date, including but not be limited in its interpretation to, research data, information concerning research participants, all secret knowledge, technical information and specifications, manufacturing techniques, designs, diagrams, instruction manuals, blueprints, electronic artwork, samples, devices, demonstrations, formulae, know-how, intellectual property, information concerning materials, marketing and business information generally, financial information that may include remuneration detail, pay slips, information relating to human capital and employment contract, employment conditions, ledgers, income and expenditures and other materials of whatever description in which the NWU has an interest in being kept confidential; and

1.1.2 "Commencement Date" means the date of signature of this undertaking by myself.

1.2 The headings of clauses are intended for convenience only and shall not affect the interpretation of this undertaking.

2 Preamble

2.1 In performing certain duties requested by the NWU, I will have access to certain Confidential Information provided by the NWU in order to perform the said duties and I agree that it must be kept confidential.

2.2 The NWU has agreed to disclose certain of this Confidential Information and other information to me subject to me agreeing to the terms of confidentiality set out herein.

3 Title to the Confidential Information

I hereby acknowledge that all right, title and interest in and to the Confidential Information vests in the NWU and that I will have no claim of any nature in and to the Confidential Information.

4 Period of confidentiality

The provisions of this undertaking shall begin on the Commencement Date and remain in force indefinitely.

5 Non-disclosure and undertakings

I undertake:

5.1 to maintain the confidentiality of any Confidential Information to which I shall be allowed access by the NWU, whether before or after the Commencement Date of this undertaking. I will not divulge or permit to be divulged to any person any aspect of such Confidential Information otherwise than may be allowed in terms of this undertaking;

5.2 to take all such steps as may be necessary to prevent the Confidential Information falling into the hands of an unauthorised third party;

5.3 not to make use of any of the Confidential Information in the development, manufacture, marketing and/or sale of any goods;

5.4 not to use any research data for publication purposes;

5.5 not to use or disclose or attempt to use or disclose the Confidential Information for any purpose other than performing research purposes only and includes questionnaires, interviews with participants, data gathering, data analysis and personal information of participants/research subjects;

5.6 not to use or attempt to use the Confidential Information in any manner which will cause or be likely to cause injury or loss to a research participant or the NWU; and

5.7 that all documentation furnished to me by the NWU pursuant to this undertaking will remain the property of the NWU and upon the request of the NWU will be returned to the NWU. I shall not make copies of any such documentation without the prior written consent of the NWU.

6 Exception

The above undertakings by myself shall not apply to Confidential Information which I am compelled to disclose in terms of a court order.

7 Jurisdiction

This undertaking shall be governed by South African law be subject to the jurisdiction of South African courts in respect of any dispute flowing from this undertaking.

8 Whole agreement

8.1 This document constitutes the whole of this undertaking to the exclusion of all else.

8.2 No amendment, alteration, addition, variation or consensual cancellation of this undertaking will be valid unless in writing and signed by me and the NWU.

Dated at NWU this 19/09/ 2019

Witnesses:

1 M. Moko
2 K. Kgale
(Signatures of witnesses)

[Signature]
(Signature)

3 S.C

APPENDIX J: CONSENT FORM



(Name and address of the school)

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: <http://www.nwu.ac.za>

Faculty of Education

Self-Directed Learning
E-mail: SDL@nwu.ac.za
Tel: +27 (0)18 299 4780

Tel: 018 389 2191
Email: Judicial.Sebatana@nwu.ac.za

Date: 15 August 2019

PARTICIPATION INFORMATION AND CONSENT FORM

I herewith wish to request your consent to participate in this research, which involves answering a questionnaire about teaching of a topic particulate nature of matter, taking part on a 1-day development programme, implementing the problem-based learning teaching strategy while teaching this topic in your class and compiling a portfolio, and participating in an interview. Before you give consent, please acquaint yourself with the information below.

The details of the research are as follows:

TITLE OF THE RESEARCH PROJECT:

Enhancing the use of Problem-Based learning by beginner Physical Sciences teachers while teaching Particulate Nature of Matter.

ETHICS APPLICATION NUMBER: NWU-01611-19-A2

PROJECT SUPERVISOR: Prof Washington Dudu
CO-SUPERVISOR: Dr Andrew Mutsvangwa
ADDRESS: NWU Mafikeng Campus, A9, Room 105
CONTACT NUMBER: 018 389 2340

MEMBER OF PROJECT TEAM MEd-Student: Mr Motlhale Sebatana
ADDRESS: NWU Mafikeng Campus, A2, Room G205
CONTACT NUMBER: 018 389 2191

FACULTY OF EDUCATION RESEARCH ETHICS COMMITTEE

Contact person: Ms Erna Greyling, E-mail: Erna.Greyling@nwu.ac.za, Tel. (018) 299 4656

This study has been approved by the Research Ethics Committee of the Faculty of Education of the North-West University and will be conducted according to the ethical

guidelines of this committee. Permission was also obtained from the provincial Department of Basic Education.

What is this research about?

The aim of this study is to enhance Physical Sciences beginner teachers to utilise Problem-Based Learning in enhancing 21st Century Skills in order to promote Self-Directed Learning in the teaching and learning of Particulate Nature of Matter.

Participants

- Beginner Physical Sciences teachers.

What is expected of the participants?

Participants are expected to fill in the questionnaire, participate in the development programme, implement a Problem-Based Learning strategy while teaching chemistry and participate in an interview.

Benefits to the participants

Participants will be exposed to effective teaching strategies which might enhance self-directed learning and 21st century skills amongst their learners, thus produce better results.

Risks involved for participants

None.

Confidentiality and protection of identity

The participants in the study will be requested to complete an informed consent form and be informed that their privacy and right to remain anonymous will be respected throughout the research; and that information they share will be treated as confidential. The researcher will respect and safeguard the safety, dignity and self-worth of all the research participants by being mindful of the cultural, religious, gender and other significant differences present in the research population.

Dissemination of findings

The findings of the study will be used for studies research purposes.

If you have any further questions or enquiries regarding your participation in this research, please contact the researchers for more information.

Yours Sincerely

Mothale J. Sebatana

.....

DECLARATION BY PARTICIPANT:

By signing below, I agree to give permission for the research to take place with my participation in the study entitled:

Enhancing the use of Problem-Based learning by beginner Physical Sciences teachers while teaching Particulate Nature of Matter.

I declare that:

- I have read this information and consent form and understand what is expected of the participants in the research.
- I have had a chance to ask questions to the researcher and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and participants will not be pressurised to take part.
- Participants may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- Participants may be asked to leave the research process before it is completed, if the researcher feels it is in their best interests, or if they do not follow the research procedures, as agreed to.

Signed at (place) _____ on (date) _____ / _____ /20 _____

Signature of participant

APPENDIX K: ASSESSMENT RUBRIC FOR THE PBL ACTIVITY

Physical Sciences Assessment rubric for the PBL activity (Chemistry-PNM)

Criteria	Weight (Marks)	Excellent	Good	Efficient	Inefficient
Demarcation of the Problem	4	The demarcation of the problem has been very well done and complete. (4)	The demarcation of the problem has been satisfactory (3)	The demarcation of the problem shows gaps and needs further attention (2)	The demarcation of the problem is poor and vague and need to be redone (1).
Formulating of the learning objectives	12	The learning purpose is well defined and formulated completely. (10-12)	The learning purpose has been defined to satisfactory (6-9)	The learning purpose is incomplete and not well defined. (3-5)	The learning purpose is poorly defined and incomplete. The learning purpose need to be reformulated. (1-2)
The scope and quality of the provisional research	20	Exceptionally well-developed description was given of the chemistry issues that are found in the CAPS document. It shows a good understanding of the problem. (16-20)	A satisfactory developed description was given of the chemistry issues that are found in the CAPS document. Which shows a good understanding of the topic. (11-15)	The description of the chemistry problems in the real-life situation in South Africa should be further developed since there are gaps in the understanding of the problem. (6-10)	Poorly developed description of the chemistry problems in South Africa which leads to a poor understanding of the problem. It need to be redone. (1-5)
Identification and recommendation of possible solutions for the problem	20	A complete and exceptionally well formulated solutions and recommendations were made for the problem. (16-20)	Complete and well formulated solutions and recommendations were made for the problem. (11-15)	Only certain solutions and recommendations is applicable to the problem. (5-10)	Very weak formulated solutions and recommendations were made. (1-4)
Writing skills	4	The report is impartial and highly professionally written. (4)	The report is impartial and professionally written. (3)	Parts of the report does not testify to impartiality and professionalism. Spelling mistakes are common. (2)	The report does not testify of impartiality and professionalism. Too many spelling mistakes. Report need to be rewritten. (1)
Total	60				

Adapted

APPENDIX L: PROBLEM-SOLVING RUBRIC

#1: PROBLEM SOLVING RUBRIC

Student:	1 Limited	2 Developing	3 Proficient	4 Advanced	5 Exemplary	Self	Team
Identifies Relevant Facts (“What do we know?”)	Cannot identify facts, or mixes facts with opinions.		Identifies most relevant facts.		Helps distinguish facts from opinions/inferences.		
Asks Relevant Questions (“What more do we want to know?”)	Asks no questions or ones unrelated to script.		Asks basic kinds of “who, what, where, when” questions.		Asks higher-level questions which reflect depth of thought.		
Organizes Questions for Research	Is unable to organize questions into categories.		Organizes questions into appropriate categories.		Identifies questions that fit into multiple categories.		
Selects Useful Information from Appropriate Sources	Cannot locate information to answer research questions.		Obtains relevant information from key sources provided.		Obtains reliable and wide-ranging information from sources beyond those provided.		
Organizes and Presents Information Effectively	Does not organize information to clearly present answers to research question(s).		Organizes information to clearly present answers to research question(s)		Summarizes information from many sources; presentation is concise accurate, and insightful.		
Identifies Major Problem(s) and Stakeholders	Cannot state a major problem or identify important stakeholders.		Identifies major problem and major stakeholders.		Distinguishes between major & minor problems; identifies direct & indirect stakeholders.		
Develops Multiple Solutions to Major Problem(s)	States only one (obvious) course of action to major problem.		Develops two or more solutions to the major problem(s)		Develops multiple solutions based on pros/cons and stakeholder perspectives.		
Chooses a Course of Action and Supports Choice	Cannot select or support a course of action.		Selects and supports a course of action based on ethics <u>or</u> risks/benefits to one stakeholder		Selects a solution based both ethics and risks/benefits to multiple stakeholders		

#2: PBL TEAMWORK AND TEAM PROCESSING RUBRIC

Team Members:	1 Limited	2 Developing	3 Proficient	4 Advanced	5 Exemplary	Self	Team
Distribute Tasks	Do not distribute tasks equally.		Distribute tasks equally.		Distribute tasks based on team members' skills.		
Collaborate and Contribute Equitably	Let one or two team members do most of the work.		Ensure that all team members contribute fully.		Know and encourage each other's strengths to do quality work.		
Manage Conflict	Do not recognize or take action to reduce conflict		Resolve conflicts to continue to stay "on task."		Identify and actively use "win-win" solutions to manage conflict.		
Use Brainstorm "Rules"	Do not use brainstorm "rules"; allow others to block the process.		Follow brainstorming "rules" and contribute ideas equally.		Develop new "rules" as needed to facilitate the brainstorming process.		
Effectively Reflect on Teamwork	Do not contribute to discussions about their work as a team.		Use the results of this rubric to suggest ways to improve teamwork.		Regularly monitor and assess teamwork of individuals and group as a whole.		
Build Consensus	Do not attempt consensus process.		Use consensus process to work effectively.		Seek out feedback and process this information to improve teamwork.		
Manage Time	Do not monitor their progress or recognize time constraints.		Use time efficiently and complete all tasks on time.		Regularly monitor and assess progress to exceed task expectations.		
Produce Quality Work	Show no, or limited, attention to making quality products.		Create high school products that meet expectations		Create products that resemble practicing professionals "in the field."		
Stay on Task	Are easily distracted or frequently go "off task."		Use time in focused & productive ways.		Create work-plan agenda and monitor progress.		
Come Prepared	Are not consistently prepared with needed materials.		Are consistently prepared with needed materials.		Take time daily to assure that materials are ready for next work session.		
Maintain Positive Attitude	Exhibit negative behaviors; use "put down" expressions.		Exhibits positive attitudes/behaviors towards work and others.		Assist others in maintaining positive attitudes and behaviors.		

PBL Problem Solving and Teamwork Reflection Questions:

1. Describe a specific example of something you learned from your PBL team (e.g., information or a problem solving or teamwork skill) that you probably would not have learned on your own.
2. Describe a specific example of something that your team members learned from you (e.g., information or a problem solving or teamwork skill) that they probably would not have learned without you on their team.
3. Suggest one specific, practical change the team could make that would improve the team's learning, problem solving or teamwork skills.

APPENDIX M: BEGINNER TEACHERS' PBL PORTFOLIO RUBRIC

Scoring criteria: 4 = Clear, convincing and consistent evidence; 3 = Clear evidence; 2 = limited evidence; 1 = No evidence

INTASC Principle	Indication Checklist	Portfolio parts/sections	Score
1. Content Knowledge being taught	✓ Clear illustration of PNM central concepts being taught ✓ Understands the content knowledge and CAPS curriculum goals ✓ Understands unanticipated teaching-learning situations	• Lesson Plan • PBL Problem	
2. PBL Implementation	✓ Understands how learners should learn and develop ✓ Provides a learning opportunity and environment that adheres to PBL approach to support learners' cognitive, social and personal development	• Teacher's role (facilitator) • Learners' roles • Learners' work	
3. Instructions adapted to meet diverse learners	✓ Understands learners' diversity ✓ Facilitates and guide learners ✓ Brings multiple perspectives to learners' discussions	• Details of what happened during the lesson	
4. 21 st -century skills observed	✓ Observed at least one 21st-century skill among the learners during PBL implementation	• 21st-century skills observed template • Learner-based assessment	
5. Assessment of learners' work to improve enhancement of 21 st -century skills	✓ Use of teacher-based assessment rubric to evaluate learners' work ✓ Use of learner-based assessment rubric for self-evaluation by learners	• Teacher-based assessment • Learner-based assessment	
6. Reflections and professional development	✓ Continued observation of PBL process for self and others during implementation ✓ Noted challenges experienced by self and learners during PBL implementation	• Reflection and challenges experienced with the implementation of PBL activities in Chemistry	

Adapted from: Smith, Harris, Sammons, Waters, Jordan, Martin, Smith and Cobb (2001:29)

Beginner teacher: _____ Overall level of proficiency (score) of PBL utilization.

APPENDIX N: TURNITIN REPORT

22232184:Motlhale_Judicial_Sebatana.pdf			
ORIGINALITY REPORT			
14%	13%	7%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS
PRIMARY SOURCES			
1	lifesciences.envmed.rochester.edu Internet Source	2%	
2	repository.nwu.ac.za Internet Source	1%	
3	www.tandfonline.com Internet Source	1%	
4	library.oapen.org Internet Source	1%	
5	journals.cz Internet Source	1%	
6	scholar.sun.ac.za Internet Source	1%	
7	Poë, Judith C.. "Active Learning Pedagogies for the Future of Global Chemistry Education", Chemistry Education, 2015. Publication	<1%	
8	Submitted to University of Witwatersrand Student Paper	<1%	

APPENDIX O: CERTIFICATE OF LANGUAGE EDITING



Office: 0183892451

FACULTY OF EDUCATION

Cell: 0729116600

Date: 21st August, 2020

TO WHOM IT MAY CONCERN

CERTIFICATE OF EDITING

I, **Muchativugwa Liberty Hove**, confirm and certify that I have read and edited the entire dissertation, **Enhancing the utilization of Problem-Based Learning by beginner Physical Sciences teachers in the teaching of Particulate Nature of Matter**, by **Motlhale Judicial Sebatana**, [Orcid.org/0000-0001-6520-423X](https://orcid.org/0000-0001-6520-423X), submitted in fulfilment of the requirements for the degree *Master of Education in Physical Sciences* at the North-West University

Motlhale Judicial Sebatana was supervised by **Professor WT Dudu**, and co-supervised by **Dr A Mutsvangwa**, with **Professor A Golightly** as assistant supervisor.

I hold a PhD in English Language and Literature in English and am qualified to edit such a thesis for cohesion and coherence. The views expressed herein, however, remain those of the researcher/s.

Yours sincerely

Professor M.L. Hove (PhD, MA, PGDE, PGCE, BA Honours – English)

