

**Antecedents of High School Geometry Achievements:  
A Case Study of 2008 Grade 8 and Grade 9 Learners  
at Sol Plaatje Secondary School, Mmabatho, South  
Africa**



060013141G

North-West University  
Mafikeng Campus Library



**Anthony Tweneboah Koduah**

**Antecedents of High School Geometry Achievements: A  
Case Study of 2008 Grade 8 and Grade 9 Learners at Sol  
Plaatje Secondary School, Mmabatho, South Africa**

by

**Anthony Tweneboah Koduah**

A Mini-Dissertation Submitted in Partial Fulfillment of the Requirement for the  
Degree of Master of Education (M.Ed Mathematics/Science) in the Faculty of  
Education at the North West University, Mafikeng Campus

**Supervisor**

**Prof. Willy Mwakapenda**

November 2008

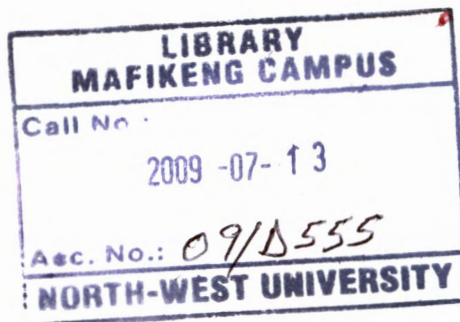
**DECLARATION**

---

I, Anthony Tweneboah Koduah, declare that this thesis is my own work. It contains no material which has been accepted for the award of any other degree, certificate, or diploma in any university.

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgment has been made.

Sign : .....  
Date : 16/03/09 .....





## **ACKNOWLEDGEMENT**

---

The point of view expressed in this research would never have been developed without the assistance of my supervisor Prof. Willy Mwakapenda. I am very grateful for his patience, motivation, encouragement and the valuable advice throughout the duration of the course. Thanks for dedicating most of your precious time and making very useful comments during the design and implementation of the research.

My greatest thanks go to Mr. Johnson Arkaah and family for their sleepless nights and support, and their encouragement for making this piece of work a reality. Rino, I say, God bless you.

I would also like to say thank you to Mr. Seth Awudetsey for his moral support and dedication that kept me going. I say, gentleman, keep up the good work and more grease to your elbow.

Lastly, thanks to all the lovely educators at Sol Plaatje Secondary School, teaching and non-teaching staff, as well as the learners for their prayers during and after all hectic times of my course. I say keep up the good work.

God bless you all.

A. Tweneboah Koduah

## ABSTRACT

Learner achievement in Mathematics, in general, and in geometry in particular has been of great concern to researchers involved in mathematics education as well as principals of high schools and educationalists. This concern has led in research seeking to investigate, for instance, the antecedents that positively or negatively contribute to learner achievement in geometry. Many of the reported work have investigated the antecedents within the context of mathematics teaching and learning in general. However, very few researchers have investigated the antecedents contributing to learner achievement in geometry. The present study fills this gap in the literature by investigating the extent to which selected socioeconomic variables, sociodemographic variables, learner opinions and perception about geometry, learner attitude toward geometry, and learner perception about geometry educator affect learner achievement in geometry. The study further investigates how these construct determine learner achievement in written geometry test.

The participants in the study were 328 Grade 8 and Grade 9 learners sampled from the population of 844 learners enrolled in at Sol Plaatje Secondary School in Mmabatho, South Africa. The instruments used to measure the study constructs were quantitative survey questionnaire instrument and a written geometry test administered to learners in the two grades. Research questions formulated for the study were tested using simple descriptive statistics, correlation analysis, Analysis of Variance (ANOVA), and logistic regression analysis techniques.

The correlation analyses revealed evidence of significant correlation achievements in geometry and age, household wealth quintile, ownership of telephone, household ownership of TV, household ownership of refrigerator, and household access to tap water. The ANOVA test revealed significant differences in the geometry achievement grades and age, ethnicity, household wealth quintile, household ownership of TV, household ownership of refrigerator,

household access to telephone, and household access to tap water. By using logistic regression modelling method, gender was found to decrease the odds of achieving a 'fairly poor' or 'poor' grade in geometry compared to achieving a 'very good' grade; age was found to increase the odds of achieving a 'fairly poor' or 'poor' grade in geometry comparing to achieving a 'very good' grade.

Of the number of recommendations provided in the main text, the most prominent are that it would be desirable for future research to include the perceptions of mathematics educators and that it would also be meaningful for future studies to include achievement outcomes in other areas of mathematics including algebra, calculus, probability, and simple statistical analysis.

# TABLE OF CONTENTS

<b>CHAPTER 1: THESIS ORIENTATION</b>	<b>1</b>
1.1 Study Background	1
1.2 Problem Statement	4
1.3 Rationale for the Research	6
1.4 Research Objectives	7
1.5 Research Questions	8
1.6 Significance of the Research	9
1.7 Research Boundaries	10
1.7.1 Assumptions	10
1.7.2 Limitations	11
1.7.3 Delimitations	12
1.8 Ethical Considerations	13
1.9 Research Structure	13
<b>CHAPTER 2: LITERATURE REVIEW</b>	<b>14</b>
2.1 Introduction	14
2.2 Conceptual Framework	15
2.2.1 Presage Factors	17
2.2.2 Process Factors	18
2.2.3 Product Factors	18
2.3 The Geometry-Mathematics Linkage	19
2.4 Geometry as a Subject Matter	20
2.4.1 Geometry Defined	21
2.4.2 Aims of Geometry	22
2.4.3 Importance of Geometry	23
2.4.4 Role of Geometry in Mathematical Problem Solving	25

2.5	Teaching and Learning Geometry	26
2.6	The Teaching and Learning of Proof in Geometry	28
2.6.1	Resources for Teaching and Learning of Geometry	29
2.6.2	Concept Formation in Geometry Teaching	30
2.6.3	Teacher Knowledge of Geometry and Attitude to Geometry	31
2.7	Geometry Theories, Concepts and Principles	32
2.7.1	Theories of Learning Geometry	33
2.7.2	The van Hiele Theory	33
2.7.3	Fischbein's Theory	34
2.7.4	The Hilbert Principle of Geometry	36
2.7.5	Wertheimer-Kohler Theory of Effective Reasoning	37
2.8	Concluding Remarks	38
<b>CHAPTER 3: RESEARCH METHODOLOGY</b>		<b>39</b>
3.1	Introduction	39
3.2	Data and Research Methods	39
3.2.1	Data Source	40
3.2.2	Target Population	40
3.2.3	Sample	40
3.2.4	Instrumentation	40
	3.2.4.1 Quantitative Data Gathering Instrument	41
	3.2.4.2 Written Geometry Achievement Assessment Instrument	42
3.3	Data Management	43
3.4	Instrument Suitability	43
3.5	Concluding Remarks	43
<b>CHAPTER 4: DATA ANALYSES, RESULTS AND DISCUSSIONS</b>		<b>44</b>
4.1	Introduction	44
4.2	Exploratory Data Analysis	45
4.2.1	Learner Opinions about Learning Practices and Norms	45
4.2.2	Learner Opinion about Environment for Teaching and Learning of Geometry	49
4.2.3	Learner Attitudes toward Geometry	53
4.2.4	Learner Perception about Geometry Educator	56

4.3	Exploring Learner Background Characteristics	59
4.3.1	Learner Distribution by Grade and Gender	59
4.3.2	Learner Age Distribution by Grade and Gender	60
4.3.3	Learner Distribution by Ethnicity	61
4.3.4	Learner Distribution by Home Language	61
4.4	Exploring Learner Socioeconomic and Sociodemographic Characteristics	62
4.4.1	Learner Distribution by Place of Residence	62
4.4.2	Mode of Transportation to School	63
4.4.3	Type of House Lived In	64
4.4.4	Heads of Learner Households	65
4.4.5	Parent/Guardian Highest Level of Education	66
4.4.6	Marital Status of Parents/Guardian	67
4.4.7	Employment Status of Parents/Guardian	68
4.4.8	Wealth Quintile of Learners' Household	69
4.4.9	Household Asset Ownership	70
4.5	Exploring Learner Opinions about Learning Practices and Norms	72
4.6	Exploring Learner Opinions about the Environment for Learning Geometry	74
4.7	Exploring Learner Attitudes toward Geometry	77
4.8	Exploring Learner Views about Geometry Educators	79
4.9	Exploring Learner Scores for Written Geometry Test	81
4.10	Examining Significant Relationships	84
4.10.1	Research Question 1	84
4.10.2	Research Question 2	84
4.10.3	Research Question 3	85
4.10.4	Research Question 4	86
4.10.5	Research Question 5	87
4.10.6	Research Question 6	88
4.11	Examining Differences in Geometry Test Scores	89
4.11.1	Research Question 7	89
4.11.2	Research Question 8	90
4.11.3	Research Question 9	91
4.11.4	Research Question 10	91
4.11.5	Research Question 11	92

4.12	Predicting Learner Achievement in Geometry	93
4.12.1	Prediction and Effects from Background-Socioeconomic Construct	93
4.12.2	Prediction and Effects from Views on Learning Practices and Norms Construct	95
4.12.3	Prediction and Effects from Learning Environment Construct	97
4.12.4	Prediction and Effects from Attitude toward Geometry Construct	99
4.12.5	Prediction and Effects from Perception about Subject Educator Construct	101
4.12	Concluding Remarks	102
<b>CHAPTER 5: DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS</b>		<b>103</b>
5.1	Introduction	103
5.2	Validity and Reliability of the Constructs	103
5.3	Learner Background, Socioeconomic and Sociodemographic Characteristics	104
5.4	Relationship between Learner Achievement in Geometry and the Constructs	105
5.5	Differences in Learner Achievement in Geometry and the Constructs	107
5.6	Predicting Learner Achievement in Geometry	108
5.7	Recommendations and Suggestions for Future Research	111
5.8	Concluding Remarks	112
	REFERENCES	113
	APPENDIX 2A	119
	APPENDIX 2B	124
	APPENDIX 3A	126
	APPENDIX 3B	128
	APPENDIX 4A	130
	APPENDIX 4B	132
	APPENDIX 5A	134
	APPENDIX 5B	136
	APPENDIX 6A	137
	APPENDIX 6B	138
	Survey Questionnaire and Written Geometry Assessment Test	139

## ACRONYMS

DGE	Dynamic Geometry Environment
SDA	Statistical Discriminant Analysis
ANOVA	Analysis of Variance
MSA	Measure of Sampling Adequacy
TIMSS	Third International Mathematics and Science Study
TIMSS-R	Third International Mathematics and Science Study - Revised
NCTM	National Council of Teachers of Mathematics
GIS	Geographic Information Systems
JMC	Joint Mathematical Council

## List of Tables

Table 4.1	Construct Sufficiency – Learner Perception about Geometry	45
Table 4.2	Eigenvalues of the Correlation Matrix - Learner Perception about Geometry Construct	46
Table 4.3	Factor Loadings - Learner Perception about Geometry Construct	47
Table 4.4	Internal Consistency of Construct – Learner Perception about Geometry	48
Table 4.5	Discriminant Analysis Cross-Validation Results Learner Perception about Geometry	49
Table 4.6	Construct Sufficiency – Learner Opinion about Environment for Teaching and Learning of Geometry	50
Table 4.7	Eigenvalues of the Correlation Matrix – Learner Opinion about Environment for Teaching and Learning of Geometry	51
Table 4.8	Factor Loadings – Learner Opinion about Environment for Teaching and Learning of Geometry	51
Table 4.9	Internal Consistency of Construct – Learner Opinion about Environment for Teaching and Learning of Geometry	52
Table 4.10	Discriminant Analysis Cross-Validation Results Learner Opinion about Environment for Teaching and Learning of Geometry	53
Table 4.11	Construct Sufficiency – Learner Attitudes toward Geometry	54
Table 4.12	Eigenvalues of the Correlation Matrix – Learner Attitudes toward Geometry	54
Table 4.13	Factor Loadings – Learner Attitudes toward Geometry	55
Table 4.14	Internal Consistency of Construct – Learner Opinion about Environment for Teaching and Learning of Geometry	55
Table 4.15	Discriminant Analysis Cross-Validation Results - Learner Opinion about Environment for Teaching and Learning of Geometry	56
Table 4.16	Construct Sufficiency – Learner Perception about Geometry Educator	57
Table 4.17	Eigenvalues of the Correlation Matrix – Learner Perception about Geometry Educator	57

Table 4.18	Factor Loadings – Learner Perception about Geometry Educator	57
Table 4.19	Internal Consistency of Construct – Learner Perception about Geometry Educator	58
Table 4.20	Discriminant Analysis Cross-Validation Results - Learner Perception about Geometry Educator	58
Table 4.21	Distribution of Learners by Grade and Gender	59
Table 4.22	Distribution of Learners' Age by Grade and Gender	60
Table 4.23	Distribution of Learners' Ethnicity by Grade and Gender	61
Table 4.24	Distribution of Learners' Home Language by Grade and Gender	62
Table 4.25	Distribution of Learners' Place of Residence by Grade and Gender	63
Table 4.26	Distribution of Mode of Transport by Grade and Gender	64
Table 4.27	Distribution of Type of House by Grade and Gender	65
Table 4.28	Learners' Caretakers at Home	66
Table 4.29	Parents'/Guardians' Highest Level of Education	67
Table 4.30	Marital Status of Parent/Guardian by Grade and Gender	68
Table 4.31	Employment Status of Parent/Guardian by Grade and Gender	68
Table 4.32	Household Wealth Quintile by Grade and Gender	69
Table 4.33	Household Asset Ownership by Grade and Gender	71
Table 4.34	Practices Leading to Learner Success in Geometry	72-73
Table 4.35	Class Environment for Successful Learning of Geometry	75
Table 4.36	Learner Attitude toward Geometry	77-78
Table 4.37	Assessing Learner Views about Geometry Educators	80
Table 4.38	Descriptive Statistics for Test Scores	82
Table 4.39	Descriptive Statistics for Test Scores by Level	83
Table 4.40	Correlation between Learner Background Characteristics and Geometry Test Grade	84

Table 4.41	Correlation between Learner Background Characteristics and Geometry Test Grade	85
Table 4.42	Correlation between Learning Practices and Norms and Geometry Test Grade	86
Table 4.43	Correlation between Learning Environment and Geometry Test Grade	87
Table 4.44	Correlation between Learners' Attitudes toward Geometry and Geometry Test Grade	88
Table 4.45	Correlation between Perception about Subject Educator and Geometry Test Grade	88
Table 4.46	ANOVA Tests of Differences between Geometry Achievements by Virtue of Learner Background and Household Socioeconomic Status	89
Table 4.47	ANOVA Tests of Differences between Geometry Achievements by Virtue of Learning Practices and Norms	90
Table 4.48	ANOVA Tests of Differences between Geometry Achievements by Virtue of Environment	91
Table 4.49	ANOVA Tests of Differences between Geometry Achievements by Virtue of Learner Attitudes toward Geometry	92
Table 4.50	ANOVA Tests of Differences between Geometry Achievements by Virtue of Learner views about Geometry Educator	93
Table 4.51	Final Multinomial Logistic Regression Results using Background Construct	94
Table 4.52	Final Multinomial Logistic Regression Results using Learning Practices and Norms Construct	96
Table 4.53	Final Multinomial Logistic Regression Results using Learning Environment Construct	98
Table 4.54	Final Multinomial Logistic Regression Results using Attitude towards Geometry Construct	100
Table 4.55	Final Multinomial Logistic Regression Results using Perception about Subject Educator Construct	102

## List of Figures

Figure 2.1

3P-Learning Conceptual Framework

16

## CHAPTER ONE

### ORIENTATION

#### 1.1 Study Background

Education is 'the development of knowledge, skills, ability, or character by teaching, training, study, or experience' ('Education', 1982). In our society, school and university teachers are the primary deliverers of education. It is estimated that a student will spend some 7,000 hours learning while at primary school, complete 15,000 hours of learning up to the end of high school, and 20,000 hours in pursuit of knowledge by the time they finish their university course (Fraser, 2001). However, education is not restricted to the delivery of factual material. It also consists of involvement in the environment where that learning takes place – the experience of learning.

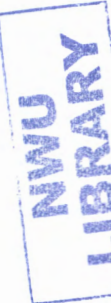
Education has changed considerably since the early 1800s when just being able to read or write was an achievement. A rapid explosion of information and knowledge has accompanied the transition through the mass education of the 1900s where the end product was a good assessment mark. In the 21st century, the amount of knowledge to be learned is such that learning how to learn and understanding the need to be a lifelong learner is the necessary and favoured outcome. Graduates of the school system now are expected to be able to identify and solve problems, to adapt and apply their learning, and to make a contribution to society (Bransford et al. 1999).

Learning mathematics can be more than just learning facts. It can bring about the sort of mathematics literacy that enables people to use mathematics principles and processes in making personal decisions and to participate in discussions of mathematics issues that affect society (Marlino, 1997). Marlino continued to argued that one of the consequences of learning mathematics properly was the acquiring of valuable

transferable skills such as problem solving, thinking critically, working cooperatively, using technology effectively, and valuing life-long learning. If learners choose not to learn mathematics, however, these outcomes become less achievable.

Past research has shown that there is an association between learners' perceptions of their learning environment, and cognitive and affective learning outcomes in a variety of settings and education levels and using a variety of instruments (Fraser, 1998). In 1972, Shulman and Tamir (cited by Henderson et al. 1998) suggested that affective outcomes are equally as important as cognitive ones in education. For many of the early years of educational research, the focus was on cognitive outcomes as a measure of achievement. The past three decades, though, have brought increased interest in learners' attitudes as a major part of the important affective domain (Henderson et al. 1998).

High school learners experience a myriad of conflicts and problems as they encounter the differing situations that society in general, and education in particular, present to them. Identifying and meeting the specific needs of learners during those years has been a concern for school systems for some time (Ferguson and Fraser, 1999). Speering and Rennie (1996) that to focused on the transition from primary to secondary schools and the problems that the move brings, with some studies drawing particular attention to the deterioration in learners' attitudes at this time. Speering and Rennie (1996) research ,conducted on mathematics learning environments and found that the decline in attitude to mathematics seemed to be connected to the changes in learners-teacher relationships experienced in the early high school mathematics classroom. The transition from primary to secondary school usually meant a change from a non-specific environment, where students had the one classroom and the one teacher, to one that is subject focused with many physical rooms and many teachers. They also suggested that it is during the first and second year of secondary school that learners form their attitude to mathematics subjects and that those attitudes can have a lasting effect on ongoing



mathematics interest. Findings such as these and an interest in the impact of learner-teacher relationships within the learning environment prompted the present study.

Teacher-learner interaction is a critical aspect of the instructional programme. Though research has been conducted that provides some useful data to assist educators in improving the curriculum, it does not precisely indicate how this process has affected instruction as it is interwoven into the strata of the individual geometric classroom. Educators, parents, researchers, and, in many cases, learners are questioning whether schools are providing a good education, one that is adequate to meet the myriad needs demanded by the complexities of society. The concerns about quality education are reflected in the growing emphasis upon minimal competency in the core or skill areas of the educational curriculum.

A teacher is seen as a person who possesses specific and adequate content knowledge, ready to impart this to learners. Teacher knowledge and the possible role it plays in the classroom are well documented in authors like Ernest (1989), Koehler and Grouws (1992), and Kong and Kwok (1999), but what and how much knowledge a teacher needs to be successful remains a subject for debate. In their published paper, Jaworski and Wood (1999) noted that in various countries the need to improve the experience of classroom mathematical learning through the development of teachers' knowledge of mathematics and knowledge of pedagogy is still relevant.

The current state of South African primary school (Grades 1-7) teachers' content knowledge and the impact on classrooms have previously been investigated by a number of South African researchers including Webb et al (1998), in subjects such as science and mathematics. These studies brought the state of South African teachers' knowledge to the fore, but none focussed solely on geometry, a problematic topic in many high schools (Grades 8-12) in South Africa.

In recent times, there has been a consistent decline in popularity in the teaching of geometry to high school students in South Africa. As history dictates, South Africa inherited its geometry from England at a time when it was adopting a very conservative approach and followed the work of Euclid (Webb et al. 1998). Euclid was an ancient Greek mathematician. But as it should have been, subsequent changes effected in the Great Britain system did not filter through to the South African system.

In his research paper, Shulman (1986) argued that the goal of teaching the formal structure of geometry in the United States of America for most of the twentieth century had failed. And that learners needed to develop a strong geometric intuition but when Euclidean geometry is poorly taught, not enough is done to help learners develop this type of intuition. It therefore appeared that even if Euclidean geometry is understood at a high school level, there was a lack of transfer of ideas to other branches of mathematics at a university level. Mvoro (1994) observes how learners at high school level are required to write proofs in mathematics with no general perspective of proof or methods of proof. It seems that adopting a learning level approach to the acquisition of knowledge in geometry in general would be most appropriate. In 1959, two scholars, Pierre and Dina van Hiele, devised a theory of learning levels relevant to geometry. The theory initially involved five stages but was later reduced to three levels by Pierre van Hiele (1986).

This research generally explores the antecedents of Grade 8 and Grade 9 learner achievement in geometry in Sol Plaatje Secondary School in Mafikeng, South Africa.

## **1.2 Problem Statement**

Research has indicated some factors which influence achievement are ability, motivation, and health. Available research findings overly generalized how a teacher perceives those factors that affect the capability of the learner.

These perceptions (perception refers to the popular meaning, ‘the act, state or faculty of receiving knowledge of external things by the senses’) may affect a learner's success; they may also affect a teacher's success in transmitting his/her expectations. Willson (1977) defined perceptions in an educational mode as a reflective, socially-derived interpretation of that which the teacher encounters; this interpretation then serves as a basis for the actions he or she constructs. It is a combination of beliefs and behaviour continually modified by social interaction that enables the teacher to make sense of his or her world, interpret it, and act rationally within it.

Therefore, perceptions shall be defined and utilized in both constructs of the educational and formal applications noted above. The teaching/learning process includes a number of variables such as abilities, needs and interests that affect the success of a teacher in the classroom. As cited in the New York Regents Report of 1983:

*What has become increasingly clear is that school experiences must be planned in terms of life goals of adolescent boys and girls, rather than the traditional academic patterns, and that these goals must be suited to the astonishing diversity that exists in respect to abilities, needs and interests. Some years ago the success of the secondary school might have been estimated from subsequent college careers of its learners; today the criterion must be sought in relevance of high school offerings to the needs of the entire population.*

The purpose of the study would be to examine learners’ perceptions and attitudes about geometry and their effects on Grade 8 and Grade 9 learners’ achievement in geometry.

At these two grades, the five core areas of geometry a learner is supposed to be familiar with are:

- Angle at a point;

- Adjacent angles in a straight line;
- Right and vertical opposite angles;
- Correspondence, alternate, and co-interior angles; and
- Angle properties of triangle and quadrilateral angles.

### 1.3 Rationale for the Research

Geometry knowledge is critical in the interpretation and understanding of real-life situations. In our everyday activities, people continue to use geometric ideas, principles, and properties of objects even though they may not have any formal knowledge about geometry. In these present times, angle, triangle, rectangle, parallel, and perpendicular are common terms used in everyday life, and this illustrates the growing importance of geometry in making sense of the environment. Most products and constructions of these modern days are all related to geometry and geometric reasoning. The spatial reasoning that is associated with human intellect is a core learning outcome of geometry (National Council of Teachers of Mathematics, 1989).

In South Africa, even though reasoning and proof is a key learning outcome in the education systems (Department of Education – DoE, 2002), learners persistently demonstrate poor performance in geometry problem solving. Although the research problem for this study originated in the context of South Africa, it seems that the problem is persistent in other countries. In mathematics education, researchers have individually and collectively acknowledged this issue of poor achievement levels of learners in geometry. Thus, there is a need to investigate the antecedents of this problem.

Although a large number of research studies have been done regarding similar issues, especially in general mathematics, much attention has not been directed into

investigating learner perceptions, attitudes, and environmental factors as they relate to learner achievement in geometry. This research addresses issues related to learner achievement in geometry in the context of four themes – learner perception about geometry, learner opinion about environment for teaching geometry, learner attitudes toward geometry, and learner perception about geometry educator – as well as a written test on geometry.

#### **1.4 Research Objectives**

Researchers including Fraser and Tobin (1998), Goh and Fraser (1998), Waldrip and Fisher (2003) and Wubbels (1993) have identified the important relationship between teacher-student interpersonal relationships and the outcome of attitude in different settings and different subject areas. One of the main areas of influence on attitude was the helpfulness/friendliness of the teacher. This was also identified as a characteristic of an exemplary teacher.

The primary objective of this study is to explore the antecedents of Grade 8 and Grade 9 learners' geometry achievement at Sol Plaatje Secondary School in Mmabatho, South Africa. The researcher's interest in only Grade 8 and Grade 9 learners stemmed from the direct observance on the part of researcher regarding the problems confronting learners in these two grades in geometry, backed by the fact that the researcher is a subject educator in these two grades. Specific objectives include:

- Exploring learner background characteristics;
- Exploring learner socioeconomic and sociodemographic characteristics;
- Exploring learner opinions about learning practices and norms;
- Exploring learner opinions about the environment for learning geometry;
- Exploring learner attitudes toward geometry;
- Exploring learner views about geometry educators; and

- Exploring learner scores for written geometry test.

## 1.5 Research Questions

Flowing from the objectives discussed above, the following research questions have also been formulated for investigation:

- i. Are there any significant relationships between learner background characteristics and learner achievement in geometry?
- ii. Are there any significant relationships between socioeconomic characteristics of learners and learner achievement in geometry?
- iii. Are there any significant relationships between practices and norms and learner achievement in geometry?
- iv. Are there any significant relationships between constructs of learning environment and learner achievement in geometry?
- v. Are there any significant relationships between constructs of learner attitude toward geometry and learner achievement in geometry?
- vi. Are there any significant relationships between constructs of learner views about subject educator and learner achievement in geometry?
- vii. Are there any differences in the geometry achievements in relation to learner background and socioeconomic characteristics?
- viii. Are there any differences in the geometry achievements in relation to learning practices and norms?
- ix. Any there any differences in the geometry achievements in relation to classroom environment?

- x. Are there any differences in the geometry achievements in relation to learner attitude towards geometry?
- xi. Are there are differences in the geometry achievements in relation to learner views about geometry educators?
- xii. Can learner achievement in geometry be predicted from learner background and socioeconomic characteristics as well as predicting the effects of such factors on learner geometry achievement grade?
- xiii. Can learner achievement in geometry be predicted from the construct of learning practices and norms as well as predicting the effects of such factors on learner geometry achievement grade?
- xiv. Can learner achievement in geometry be predicted from the construct of classroom environment as well as predicting the effects of such factors on learner geometry achievement grade?
- xv. Can learner achievement in geometry be predicted from the construct of learner attitude towards geometry as well as predicting the effects of such factors on learner geometry achievement grade?
- xvi. Can learner achievement in geometry be predicted from learner views about geometry educators as well as predicting the effects of such factors on learner geometry achievement grade?

## **1.6 Significance of the Research**

A significance of this study is an awareness of the array of perceptions about and attitudes toward geometry by Grade 8 and Grade 9 learners, and how these affect their (learners) achievement in the topic (geometry). The information, therefore, may be

utilized by the authorities in dealing with issues related to learner achievements in geometry in the school. It may be also applied to aid and assist geometry learners and in communicating with educators, peers, and parents.

The Findings of this study may assist teachers in their selection of methods when teaching geometry. The study, therefore, explores a range and congruence of learner perception in relation to educational outcomes of the teaching-learning processes in geometry. The findings should be of value in citing areas and concerns for additional research and study. Finally, findings from the study should enable the school authorities to make informed decisions about teaching/learning changes in the geometry curriculum and classroom which will be meaningful and enduring to learners and educators.

## **1.7 Research Boundaries**

The study will concentrate on two particular grades in Sol Plaatje Secondary School in Mmabatho, South Africa. Use of these two grades in a case study such as this will ensure depth in information gathering regarding the subject matter and that selection of these grades is exceptional, a situation referred to by Spear (1998) as a unique sample.

### **1.7.1 Assumptions**

Best and Kahn (1993) defined assumptions as 'statements of what the researcher believes to be facts but cannot verify'. In the context of this study, the following assumptions were made:

- All participants in the survey were assumed to have answered the survey questions frankly and candidly.
- Every participant was able to understand English to interpret the survey questions.

- There was a similarity of range of perceptions across learning environments in the two grades used in this research.
- The differences in academic preparation in these two grades and socioeconomic differences among learners would be randomly distributed across the population studied.

### 1.7.2 Limitations

Limitations are constraints upon the study that are acknowledged in order to avoid misrepresentation of findings. Best and Kahn (1993) better defined limitations as ‘those conditions beyond the control of the researcher that may place restrictions on the conclusion of the study and their application to other situations’. The following were the limitations that bore on this study:

- The results of this study are limited to only Sol Plaatje Secondary in Mmabatho, South Africa. Any generalizations that might be drawn from the results of the study are limited because of the area studied. The investigation may not be representative, though it may be typical, for the two grades under investigation in Sol Plaatje Secondary School.
- This study is further limited in that it does not involve a comprehensive evaluation of the specific geometry curriculum, the time allocation per class in each grade, or the school under study. Rather, the attempt was to explore the antecedents of learner achievements in geometry in the two selected grades in Sol Plaatje Secondary School.
- There may be measurement error in the survey responses that can be attributed to dishonesty on the part of some learners who would participate in the study.

### 1.7.3 Delimitations

According to Best and Kahn (1993), delimitations are the boundaries that the researcher places on the study. For this study, some of the delimitations are as follows:

- The two grades under investigation were not classified according to size and location, which might impact on the findings.
- This study would only include learners from Grade 8 and Grade 9 in Sol Plaatje Secondary School in Mmabatho, South Africa. Learners from these two grades might differ in some ways from learners and from other grades. If so, the results might be affected in an unknown manner.
- Learners might not be candid in their responses to the instrument. If so, this might affect the findings of the study in some way.
- The survey instrument used might also carry certain limitations. It is possible that the researcher have not included all the elements necessary to understand and investigate fully the subject matter.

To be doubly sure of the validity or reliability of the survey instrument, tests would be conducted to check whether the existence of any limitation has an insignificant effect on the findings. The existence of insignificant limitation might not affect the findings in any unpredictable fashion.

Despite the fact that these delimitations might exist, this research is worthwhile investigated. Findings from this study were expected to add new insight into the literature on the perception, attitude, and opinion of learners and their impacts on learner achievement in high school geometry.

## **1.8 Ethical Considerations**

The study was conducted in a manner that takes into consideration a number of ethical procedures including the following:

- The working guidelines for the study were closely outlined and explained to all learners included in the study.
- Permission was sought from principal of Sol Plaatje Secondary School to personally observe and administer the questionnaires.
- Confidentiality of participants was strictly observed by the researcher.
- The rights of all authors cited in the study were observed by referencing where needed.
- Findings from the study were fairly and accurately reported by the researcher to reflect participants' opinions and understanding.

## **1.9 Research Structure**

The thesis comprises of five chapters. Chapter 1 focuses on the orientation of the study while Chapter 2 reviews the relevant literature. Chapter 3 concentrates on the research methodology and exploration of constructs with the view of addressing the research objectives. Chapter 4 focuses on the analysis of the data as well as discussions based on the results. Here, some statistical methods have been used to address the research hypotheses. Chapter 5 presents a summary of the findings as well as recommendations and suggestions on areas for further investigation.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Introduction

Geometry is an important area of mathematics to teach. It is made up of interesting problems and surprising theorems. It is open to many different approaches in terms of addressing a particular problem. Geometry has a long history, intimately connected with the development of mathematics. Natural as it is, geometry appeals to human visual, aesthetic and intuitive senses. Consequently, it can be a topic that captures the interest of learners, especially those learners who often find other areas of mathematics challenging and boring rather than encouraging excitement and creativity. Teaching geometry well can mean enabling more learners to find success in mathematics. Teaching geometry well involves knowing how to recognise interesting geometrical problems and theorems, visualizing, and understanding the many and varied uses to which geometry is linked. Teaching geometry means appreciating what benefits and importance geometry education can offer to learners in mathematics in general.

According to Kepler who was born in 1571 said, “where there is matter there is geometry”, and by using geometry and the astronomical observations, Kepler showed that the planets travelled in elliptical and not circular orbits around the sun and in doing so destroyed a belief that was more than 2000 years old (World Book, 1999). In support to this assertion, Zachos (1994), a mathematician and author, also argued that:

*“All the centuries of progress of mapping the earth and with the mathematics associated with it allows us to think about mapping the universe and understanding the pictures that we come up with, to look out there you see the galaxies: ... but you can't put them all together without the geometry to analyze what it is that you are seeing’ (Shape of the World Exploration).*

In his textbook entitled 'Elements', Euclid, often referred to as the father of geometry, used five axioms or postulates (statements accepted as true without proof) and used them logically to demonstrate 467 propositions of plane and solid geometry. For instance, areas like engineering, architecture, carpentry, navigation, and metalwork rely heavily on Euclidean geometry.

Depending on the postulates cited above, geometry may be Euclidean or non-Euclidean. For instance, Riemann's non-Euclidean geometry uses the first four of Euclid's postulates as well as a different fifth postulate while analytic geometry is derived from the same postulates as Euclidean geometry but uses algebraic methods in working with figures. Analytical geometry is very important in trigonometry and calculus. The concept of Euclidean geometry includes the use of shapes, sizes, and position of plane shapes, solids, and the application of congruence, similarity, and parallel lines. The importance of geometry cannot, therefore, be overemphasized. This chapter presents a thorough review of the literature relevant to this study. The remainder of the chapter is structured as follow.

Section 2.3 discusses the linkage between geometry and mathematics while Section 2.4 focuses on concept formation of mathematics teaching, the general area where the geometry concept resides. Section 2.5 discusses the role of geometry in mathematical problem solving while Section 2.6 tackles the teaching and learning of geometry. In Section 2.7, attention shifts to geometry theories, concepts and principles while Section 2.8 concludes the chapter.

## **2.2 Conceptual Framework**

A good amount of the current research work on learner achievement has been attributed to the work of Biggs (1987), the so-called 3P-factor framework – presage factors, process factors, and product factors. Similar frameworks had been developed by other researchers including Prosser and Trigwell (1999), Sadler-Smith (1996), Vermetten,

et al (1999). Close to the work of Biggs (1994) is a more closer framework developed by Entwistle, et al. (2000).

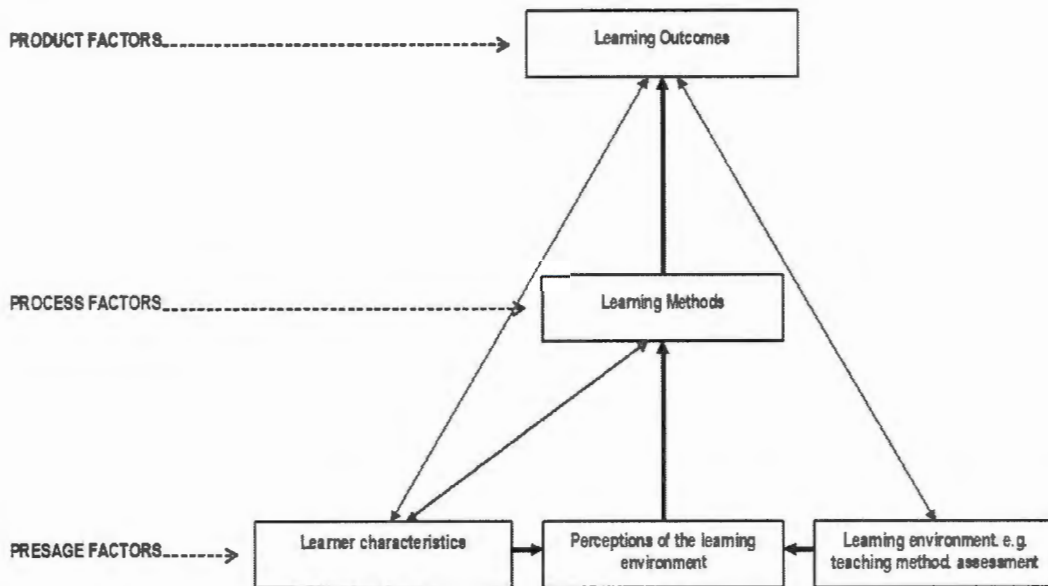


Figure 2.1: The 3P-Learning Conceptual Framework (Biggs, 1994)

This research project appeals to the joint conceptual frameworks of Prosser and Trigwell (1999) and Biggs (1987), summarized in Figure 2.1. This conceptual framework highlights the relationships between the learner characteristics, perceptions of the learning environment, methods of learning, and learning outcomes.

As shown by the arrows, the framework is conceived as an interactive system (Prosser and Trigwell, 1999; Biggs, 1987). The bold arrows indicate that learner characteristics and the learning environment (presage factors) jointly determine the learners' perceptions of the learning environment. This perception influences the learning method adopted by the learners (process factor). In effect, the learning outcome (product factor) is dependent on the learning method. As observed from the conceptual framework, the red arrows complete the remaining connections in which the reverse arrows indicate

relationships are reversal, so it was difficult to distinguish cause and effect (Biggs, 1993). But since the focus in this study generally is on the predictors of learner performance in geometry, the attention will be on the unidirectional relationships.

### **2.2.1 Presage Factors**

Biggs (1987) defined presage factors as those which are present before learning takes place. He identified two presage factors: learner characteristics and learning environment.

Learner characteristics are relatively stable features of learners, which could directly influence the approach to learning adopted by a student as well as general performance in class. These characteristics include gender, personality, age, as well as general demographics characteristics.

The learning environment, or context, includes the situational factors ranging from classroom setting, how teaching is handled, teaching style, and involvement of learners during teaching (Ramsden, 1988). At the teaching level, decisions are made about various aspects of the learning environment such as the subject contents, the roles of the teacher and the learner, the degree of cooperation between learners, class size, the degree of self-regulation, workload and assessment. These can lead to the implementation of a specific instructional approach with the view of yielding higher academic achievement. The point of contact between the learner and the learning environment is the perceived learning environment, depicting a characteristic between these two domains (Ramsden, 1988). It is, however, evident that it is the learners' perceived learning environment, rather than the true learning environment, that influences learning (Prosser and Trigwell, 1999). As the perceptions of the learning environment are influenced by learners' characteristics, it implies that these characteristics have both direct and indirect effects on the learning methods.

### **2.2.2 Process Factors**

In Biggs (1989), the author described process factors as the way learners experience and deal with learning situations. In this context, two kinds of learning methods are important - surface and deep learning.

A surface method of learning is based on a motive or intention that is extrinsic to the real purpose of the task. Here, learners see the task as a demand to be met, rely on memorization, and avoid personal or other meanings the task may have. Even though this method of learning may be successful in certain learning situations, the drawback is that after a test the acquired knowledge is quickly forgotten, application of the knowledge for existing situations is hardly developed and learners are not skilled in applying knowledge to new situations (Biggs, 1989).

On the other hand, the deep method of learning is based on a perceived need, such as intrinsic interest, to engage with the task appropriately and meaningfully. Its focus is on underlying meaning, making the task meaningful to the learner's own experience and integrating aspects of the task into a whole. Learners who learn in this way are capable of applying knowledge in new situations and in this way are better prepared for professional life.

Neither of the two learning methods are necessarily stable. At one point in time, a learner may use a surface approach in one situation, but the same learner may apply a deep method of learning in another situation, depending on the perceived requirements of the situation.

### **2.2.3 Product Factors**

According to Biggs (1987), product factors describe the outcomes of the learning process and these are made up of three groups – Group 1, Group 2, and Group 3. Group 1 refers to quantitative outcomes, which are the amount of knowledge and skills a learner

has acquired. This group is mostly reflected in examination, test, and assignment results. Group 2 involves qualitative outcomes, which refer to the integration of newly learned information with previously learned information and the structure of knowledge. Group 3 describes affective outcomes, which are learners' feelings in terms of their motivation and satisfaction with the course.

### **2.3 The Geometry-Mathematics Linkage**

Geometry has always been associated with practical situations, both in ancient and modern times. For example, in the ancient days, the Babylonians, Egyptians and Greeks all used geometry to create structures and measure land areas. It is, therefore, reasonable that geometry is, today, mainly associated in the minds of most individuals, with practical situations. It will, therefore, be proper to argue that whether we look to the past or the present, geometry plays an important role in development.

The geometric terminology that occurs in algebra and analysis shows the manner in which geometric intuition penetrates all of mathematics. This relevance of geometry to the study of mathematics was first recognized by the Russians in the 1960s and then by the Americans in the 1970s, who, having accepted the importance of geometry in the study of all mathematics, increased its prominence in all levels of mathematics study in schools (Hoffer, 1988; Teppo, 1991).

In a geometry study undertaken in Jamaica by Mitchelmore (1982), the author reported that only 8 out of 70 teachers interviewed at one school put geometry as their preferred mathematics topic and that teachers saw geometry as 'complicated and uninteresting' and did 'not like or enjoy teaching geometry'. In a similar study by Fey (1984), the author also argued that geometry was 'the most troubled and controversial topic in school mathematics today', a finding that was a year later supported by the study done by Suydam (1985).

In a comparative study of the 1964 and 1978 Third International Mathematics and Science Study (TIMSS) by Rosier (1980), the author established a slight decline in student performance, especially in geometry. From the 1996 results, a conclusion drawn by the same author was that 'geometry continues to be a problem area and that there is a positive correlation between liking Mathematics and achievement in Mathematics. To further support the existence of problems in geometry in a number of countries, the International Commission on Mathematical Instruction (1995), referred to in Chinnappan (1998), argued that students do not seem to perform as well as expected in tasks involving the solution of geometry problems.

In a survey of 22 primary schools in South Wales, Brodie (1992) also found 'a significant difference in teacher attitude to number and geometry; teacher attitude to geometry being significantly less positive than teacher attitude to number'. In course of his study, Lawrie (1998), when administering a test to students who had no prior knowledge of geometry, the researcher was welcomed with a perceptible dismay among the students, clearly revealing the level of uneasiness about the subject by the students. The overall conclusion, according to Brodie (1992) was that teachers tend to rate geometry the least-liked strand out of number, measurement and geometry while Lawrie's (1998) findings suggested that students who were soon to be primary school teachers had little understanding of the processes involved in learning geometry and had a dislike for it.

#### **2.4 Geometry as a Subject Matter**

Around 300 BC much of the accumulated knowledge of geometry was codified in a text that became known as Euclid's Elements. In the 13 books that comprise the Elements, and on the basis of 10 axioms and postulates, several hundred theorems were proved by deductive logic. The Elements came to epitomise the axiomatic-deductive method for many centuries. It is likely that no other works, except the Christian Bible and the Muslim

Koran have been more widely used, edited, or studied, and probably no other work has exercised a greater influence on scientific thinking. While some parchments do exist from the 9th century, it is said that over a thousand editions of Euclid's Elements have appeared since the first printed edition in 1482, and for more than two millennia this work dominated all aspects of geometry, including its teaching.

In the nineteenth century, geometry, like most academic disciplines, went through a period of growth that was near cataclysmic in proportion. Since then the content of geometry and its internal diversity has increased almost beyond recognition. The geometry of Euclid became little more than a subspecies of the vast family of mathematical theories of space. If you do a search for geometry using the web version of the Encyclopedia Britannica, you get the following messages: did you mean differential geometry, hyperbolic geometry, Lobachevskian geometry, projective geometry, elliptic geometry, algebraic geometry, Euclidean geometry, analytic geometry, plane geometry, Riemannian geometry, or co-ordinate geometry? It is possible today to classify more than 50 geometries (see Malkevitch 1991). This illustrates the richness of modern geometry but, at the same time, creates a fundamental problem for curriculum designers: what geometry should be included in the mathematics curriculum?

The question of what geometry includes can be applied to the curriculum at any level; from pre-school to university. In order to approach this problem it is worth returning to the question of what geometry is and to consider the aims of teaching geometry.

#### **2.4.1 Geometry Defined**

A useful contemporary definition of geometry is attributed to the highly-respected British mathematician, Sir Christopher Zeeman, who states '*geometry comprises those branches of mathematics that exploit visual intuition (the most dominant of our senses) to*

*remember theorems, understand proof, inspire conjecture, perceive reality, and give global insight'* (Royal Society, 2001). These are transferable skills that are needed for (but not taught by) all other branches of mathematics (and science)'.

#### **2.4.2 Aims of Geometry**

The Royal Society (2001) Report suggests that the aims of teaching geometry can be summarised as follows:

- To develop spatial awareness, geometrical intuition and the ability to visualise;
- To provide a breadth of geometrical experiences in 2 and 3 dimensions;
- To develop knowledge and understanding of and the ability to use geometrical properties and theorems;
- To develop useful ICT skills in specifically geometrical contexts;
- To encourage the development and use of conjecture, deductive reasoning and proof;
- To develop skills of applying geometry through modelling and problem solving in real world contexts;
- To engender a positive attitude to mathematics; and
- To develop an awareness of the historical and cultural heritage of geometry in society, and of the contemporary applications of geometry.

Given the above definition of geometry, and a consideration of the aims of teaching geometry, it is appropriate to say it should be included in the school mathematics curriculum.

### 2.4.3 Importance of Geometry

The study of geometry contributes to helping students develop the skills of visualisation, critical thinking, intuition, perspective, problem-solving, conjecturing, deductive reasoning, logical argument and proof. Geometric representations can be used to help students make sense of other areas of mathematics: fractions and multiplication in arithmetic, the relationships between the graphs of functions (of two and three variables), and graphical representations of data in statistics. Spatial reasoning is important in other curriculum areas as well as mathematics: science, geography, art, design and technology. Working with practical equipment can also help develop fine motor skills.

Geometry provides a culturally and historically rich context within which one can do mathematics. There are many interesting, sometimes surprising or counter-intuitive results in geometry that can stimulate students to want to know more and to understand why. Presenting geometry in a way that stimulates curiosity and encourages exploration can enhance students' learning and their attitudes towards mathematics. By encouraging students to discuss problems in geometry, articulate their ideas and develop clearly structured arguments to support their intuitions can lead to enhanced communication skills and recognition of the importance of proof. The contribution of mathematics to students' spiritual, moral, social and cultural development can be effectively realised through geometry.

We live on a solid planet in a 3-dimensional world and, as much of our experience is through visual stimulus, this means that the ability to interpret visual information is fundamental to human existence. To develop an understanding of how spatial phenomena are related and to apply that understanding with confidence to solve problems and make sense of novel situations has to be part of the educational experience of all learners. Geometry offers a rich way of developing visualisation skills.

Visualisation allows students a way of exploring mathematical and other problems without the need to produce accurate diagrams or use symbolic representations. Manipulating images in the head can inspire confidence and develop intuitive understanding of spatial situations. Sharing personal visual images can help to develop communication skills as well as enabling students to see that there are often many ways of interpreting an image or a written or spoken description.

Numerous current applications of mathematics have a strong geometric component. In many cases, the problem includes getting 'geometric' information into a computer in a useful format, solving geometric problems, and outputting this solution as a visual or spatial form, as a design to be built, as an action to be executed, or as an image to entertain. Solving these problems requires substantial geometric knowledge. Here, briefly, are a few illustrative examples as suggested by Whitely (1999):

- **Computer Aided Design and Geometric Modelling:** A basic problem is to describe, design, modify, or manufacture the shapes we want: cars, planes, buildings, manufactured components, etc. using computers. The descriptions need to be accurate enough to directly control the manufacturing and to permit simulation and testing of the objects, usually prior to making any physical models. For example, the most recent Boeing aeroplane was entirely designed using CAD.
- **Robotics:** To use a robot, we must input a geometric model of the environment. The whole issue of what geometric vocabulary is used, and how the information is structured is a major area of research in a field called 'computational geometry'.
- **Medical Imaging:** Generating non-intrusive measurements requires the construction of an adequate three-dimensional image of parts of the body. This can involve, for example, a series of projections or images from ultra sound, or magnetic resonance imaging from several directions or points.

Further areas where geometric problems arise are in chemistry (computational chemistry and the shapes of molecules), material physics (modelling various forms of glass and aggregate materials), biology (modelling of proteins, ‘docking’ of drugs on other molecules), Geographic Information Systems (GIS), and most fields of engineering.

#### **2.4.4 Role of Geometry in Mathematical Problem Solving**

Euclidean deductive geometry has long been applied in mathematical problem solving because mathematics educators in the field of mathematics believe strongly that the Euclidean deductive system is effective in minimizing learning difficulties. According to the Royal Society of UK (2001), the following core reasons form the basis of why geometry is used as an approach in mathematical problem solving.

- Geometry enables pupils to engage in proof as it contains familiar objects to students such as angles, parallel lines, and triangles.
- The existence of the situation and related mathematical relationships are meaningful to learners as they are in visual form although they are abstract.
- The statements are readily accessible for verification. For instance, learners can verify the validity of a statement such as ‘the sum of angles of a triangle is  $180^\circ$ ’.
- The logical methods involved in geometry at high school level tend to be less subtle -they involve fewer quantifiers.
- Proof in geometry is seen as an early start, because learners develop their logical skills as soon as they emerge.
- Geometry provides the taste of higher mathematics without the serious approach of axiomatic approaches that other branches of mathematics do.
- Proof with geometry develops practices in learners not having to take things on trust, as all geometric relationships are generally proved.

- It has a surprising effect, as there is a situation where a small number of plausible assured points lead to a large number of surprising and appealing results.

Within geometry, the Euclidean system provides rules and guidelines for reasoning that underlie proof development. Solving problems using this system is regarded as a valuable learning opportunity. In fact:

*Geometry ... is not a mere collection of facts, but a logical system. ... it is the first and the greatest example of such a system, which other sciences have tried, and are still trying to imitate (Polya, 1973).*

In a sense, the Euclidean logical deductive system thus provides a strong base for learners to develop formal mathematical deductive proof. Geometry is, therefore, suitable for introducing the complex process of mathematical proof. It is also useful for activating and developing reasoning skills to recognize intermediate steps in proof related problems. This reasoning process can be extended to planning strategies, implementing them and achieving a set of sub-goals that lead to the final goal. It is relatively easy to solve problems in which the solution is not immediately obvious but reachable by memorized algorithms.

## **2.5 Teaching and Learning of Geometry**

There is a considerable amount of research in mathematics education which concerns the teaching and learning of geometry. It is neither sensible nor feasible to attempt to summarise it all (Clements, 2001). Instead, a selection of issues is addressed below covering theories of geometric thinking, learning, and teaching. In order to teach geometry more effectively, and give some coherence to classroom tasks, it is helpful if in one's preparation and teaching, one keeps in mind, and highlights where appropriate key ideas in geometry. These include invariance, symmetry, and transformation.

**Invariance:** In 1872, the mathematician, Felix Klein, revolutionised geometry by defining it as the study of the properties of a configuration that are invariant under a set of transformations (Clements, 2001). Examples of invariance proposition are all the plane angle theorems and the theorems involving triangles, such as the sum of the angles of a plane triangle is 180 degrees. Learners do not always find it straightforward to determine which particular properties are invariant. The use of dynamic geometry software can be very useful in this respect.

**Symmetry:** Symmetry, of course, is not only a key idea in geometry but throughout mathematics, yet it is in geometry that it achieves its most immediacy. Technically, symmetry can be thought of as a transformation of a mathematical object which leaves some property invariant. Symmetry is frequently used to make arguments simpler, and usually more powerful. An example from plane geometry is that all the essential properties of a parallelogram can be derived from the fact that a parallelogram has half-turn symmetry around the point of intersection of the diagonals.

Symmetry is also a key organising principle in mathematics. For example, the best way of defining quadrilaterals, except for the general trapezium, which is not an essential quadrilateral in any case, since there are no interesting theorems involving the trapezium that do not also hold for general quadrilaterals, is via their symmetries.

**Transformation:** Transformation permits students to develop broad concepts of congruence and similarity and apply them to all figures. For example, congruent figures are always related either by a reflection, rotation, slide, or glide reflection. Studying transformations can enable students to realise that photographs are geometric objects, that all parabolas are similar because they can be mapped onto each other.

Transformations also play a major role in artwork of many cultures, for example, they appear in pottery patterns, tiling, and friezes.

## **2.6 The Teaching and Learning of Proof in Geometry**

Research invariably shows that learners fail to see the need for proof and are unable to distinguish between different forms of mathematical reasoning such as explanation, argument, verification and proof. Even high-achieving learners have been found to get little meaningful mathematics out of the traditional, proof-oriented high school geometry course.

Corresponding difficulties with proof have also been found with mathematics graduates. A number of reasons have been put forward for these students' difficulties with proof. Amongst these reasons is that learning to prove requires the co-ordination of a range of competencies each of which is individually far from trivial. Teaching approaches tend to concentrate on verification and devaluation or omit exploration and explanation. Learning to prove involves students making the difficult transition from a computational view of mathematics to a view that conceives of mathematics as a field of intricately related structures. Further reasons are that students are asked to prove using concepts to which they have just been introduced and to prove things that appear to be so obvious that they cannot distinguish by intuition what is given from what is to be proved.

Nevertheless, given the sheer complexity of learning to prove and the wealth of evidence suggesting how difficult it can be for students, there are a few studies that show that students can learn to argue mathematically. One promising approach is developed by de Villiers (de Villiers 1999) in which the author points out that proof has a range of functions including communication, discovery, intellectual challenge, verification, and systematisation. The author further argues that these various functions

have to be communicated to learners in an effective way if proof and proving are to be meaningful activities for them.

### **2.6.1 Resources for Teaching and Learning of Geometry**

There can be a tendency to teach geometry by informing learners of the properties associated with plain or solid shapes, requiring them to learn the properties and then to complete exercises which show that they have learned the facts. Such an approach can mean that little attempt is made to encourage students to make logical connections and explain their reasoning. Whilst it is important that students have a good knowledge of geometrical facts, if they are to develop their spatial thinking and geometrical intuition, a variety of approaches are beneficial.

To teach geometry effectively to students of any age or ability, it is important to ensure that students understand the concepts they are learning and the steps that are involved in particular processes rather than the students solely learning rules. More effective teaching approaches encourage students to recognise connections between different ways of representing geometric ideas and between geometry and other areas of mathematics. The evidence suggests that this is likely to help students to retain knowledge and skills and enable them to approach new geometrical problems with some confidence.

When planning approaches to teaching and learning geometry, it is important to ensure that the provision in the early years of secondary school encourages students to develop enthusiasm for the subject by providing them with opportunities to investigate spatial ideas and solve real life problems. There is also the need to ensure that students have the basic concepts and language of geometry in order to provide foundations for future work to enable them to consider geometrical problems and communicate ideas. Students should be encouraged to use descriptions, demonstrations and justifications in

order to develop the reasoning skills and confidence needed to underpin the development of their ability to follow and construct geometrical proofs.

### **2.6.2 Concept Formation in Geometry Teaching**

At the secondary school level, geometry is very much concerned with the investigation of certain spatial properties of objects. These objects may be visible or imagined, and either way they are usually represented as lines on paper, the geometry diagram. Properties of geometry may be given in advance, determined by inspection of the diagram, or established by logical deduction. These two types of cognitive structure - the diagram and its properties, image and concept – constitute the raw material for geometrical thinking. In geometrical reasoning, both types of representation are necessary, and both are referred to herein by the single term image.

A basic mechanism for concept construction in geometry based on Piaget's empirical abstraction has been discussed in Dubinsky (1991) and Mitchelmore (2002) where a child is shown a number of images of triangle and thereafter abstracts the concept 'triangle'. A generalization of this concept is extended in various forms which are also described in Mitchelmore (2002). Other forms of abstraction and generalization have also been made. More sophisticated concept formations and Sfard's (1991) interiorization-condensation-reification model have been discussed in Dubinsky (1997) and Czarnocha et al (1999). The common ground for the construction of new conceptual objects is based on action rather than perception, and is, therefore, constructivist. In his paper, Tall (1999) presented a critique of the application of these action-based models of concept formation to geometry.

Winslaw (2000) has a different perspective; he proposes an alternative mechanism for the acquisition of mathematical knowledge; he assumes that mathematical concepts are hardwired into the human brain. The purpose of this investigation is not to judge the

various theories of images and concepts in cognitive psychology, but rather the aim is a functional description of certain phenomena when image data are permitted in geometrical reasoning. A major inspiration in this regard was the work of Fischbein (1993), which comes close to the type of theoretical framework this thesis is reaching for. The prior discussion utilizes many of Fischbein's own references, and is included to provide at least some indication of how to think about these crucial notions of images and concepts. The investigation of concept formation finishes with a discussion of Fischbein (1993), which leads naturally into the rest of the thesis.

Fischbein (1993) proposed that image and concept were indivisibly linked in geometrical reasoning, the two together forming a unitary third entity called a figural concept. Fischbein and Nachlieli (1998) enriched the notion with further research. Fischbein (1993) requires his concepts to exist within a formal, axiomatic framework. However, the characteristic feature of image-based reasoning is that it allows informal, non-axiomatic geometrical arguments, and it is necessary, therefore, to allow concepts to exist outside of the formal framework. Secondly, Fischbein does not clearly specify that the image-concept pair should allow flexible conceptualization of image data.

A paradigm example of this desirable flexibility is the image of a square, which may be conceptualized as a rhombus, a rectangle, a parallelogram, and a quadrilateral, to name but a few possibilities. It was a clarification of this second concern in particular that precipitated the proposed theoretical framework.

### **2.6.3 Improving the Teaching of Geometry**

Brodie (1992) believed that the key to improving the understanding of geometry by students lies in improving learner-teacher's and teachers' knowledge and attitude to geometry. The author's belief is supported by the following quotations from the report of the Joint Mathematical Council Working Group (2001):

*“To be effective, teachers must know and understand deeply the mathematics they are teaching and be able to draw on that knowledge with flexibility in their teaching tasks” and by the report in 2002 on TIMSS-R (1998) in which it is stated, ... that effective teaching depends on the pedagogical content knowledge of teachers” (p. 160).*

It is supported by the work of van Hiele and van Hiele-Geldof (1958) in which the author suggested that teaching is crucial to student development in geometry. Noteworthy is the work of Fuys, Geddes and Tischler (1988) who, at the end of their extensive research into the van Hiele levels, concluded that ‘it is not surprising that results of research on the (van Hiele) levels should have implications for research on classroom teaching of geometry, namely, curriculum and instruction’. Pegg and Davey (1991) who also did extensive research in Australia concluded that the van Hiele levels are basic to improving the teaching of geometry.

For some years, researchers (Relich et al. 1994) and others have suggested that the attitude of teachers to a subject have an effect on the attitude of their students to that subject. Phillips (1973) found that teachers with a positive attitude to mathematics caused favourable attitudes to mathematics in their students. Bishop and Nickson (1983) suggested that a positive teacher attitude resulted in high achievement in their students. TIMSS-R (1998) indicates that teacher attitude to geometry is poor and its results support the findings of earlier researchers, namely, that attitude is linked to success. Moreover, prior research and theory have identified attitude as an important variable in the learning and teaching of geometry.

## **2.7 Geometry Theories, Concepts and Principles**

This section presents brief discussions of some theories and principles related to geometry and cited in the literature. It specifically discusses the van Hiele Theory, the Fischbein Theory, the Poncelet Principle of Continuity, the Hilbert Principle of Geometry, and the Wertheimer-Kohle: Theory of Mathematical Reasoning.

### **2.7.1 Theories of Learning Geometry**

Of the range of theoretical work concerned with geometrical ideas, those of Piaget and the van Hiele's are probably the most well-known. The Piagetian work has two major themes. The first theme is that our mental representation of space is not a perceptual 'reading off' of what is around us. Rather, we build up from our mental representation of our world through progressively reorganising our prior active manipulation of that environment.

Secondly, the progressive organisation of geometric ideas follows a definite order and this order is more experiential (and possibly more mathematically logical) than it is historical. That is, initially topological relations, such as connectedness, enclosure, and continuity, are constructed, followed by projective (rectilinearity) and Euclidean (angularity, parallelism, and distance) relations.

### **2.7.2 The van Hiele Theory**

In the literature of geometry, a lot has been said about the theory of van Hiele. This theory is basically a learning model that describes the geometric thinking students go through as they move from a holistic perception of geometric shapes to a refined understanding of geometric proof (van Hiele, 1986).

Pierre M. van Hiele, and his wife Dina M. van Hiele, developed this theory out of the frustrations both they and their students experienced with the teaching and learning of geometry. The postulation of this theory stemmed from a situation when van Hiele (1986), when teaching his geometry students, always seemed as though he was speaking a different language. Van Hiele wanted to understand why his students experienced difficulty in learning geometry and how he could remedy those difficulties. This led to the postulation of the theory of different levels of thinking. The authors basically came up with five levels of thinking - visualization, analysis, abstraction, deduction, and rigour.

At this visualization level, the student reasons about basic geometric concepts such as simple shapes, primarily by means of visual considerations of the concept as a whole without explicit regard to properties of its components whereas at this level, the student reasons about geometric concepts by means of informal analysis of component parts and attributes. Necessary properties of the concept are established (Burger and Shaughnessy, 1986).

At the abstraction level, the author argues that student logically orders the properties of concepts, forms abstract definitions, and can distinguish between the necessity and sufficiency of a set of properties in determining a concept while at the deduction level the student reasons formally within the context of a mathematical system, complete with undefined theorems, axioms, an underlying logical system, definition, and theorems (Burger and Shaughnessy, 1986). At the rigour level, the student can compare systems based on different axioms and can study various geometries in the absence of concrete models.

In their research paper, Burger and Shaughnessy (1986) used the van Hiele levels to interpret interviews conducted with 14 students ranging from kindergarten to college age. The interviews consisted of eight open-ended tasks dealing with geometric shapes in the areas of drawing, identifying and defining, sorting, and logical reasoning. Using the task-based interviews, the pair established what students are capable of at the first four van Hiele levels. Based on their results, the researchers were able to develop a list of specific characteristics of students' thinking exhibited at each of the four levels and termed this list 'The Level Indicators'.

### **2.7.3 Fischbein's Theory**

Fischbein (1993) influenced primarily by Gestalt theory argues that the objects of investigation and manipulation in geometrical reasoning are the mental entities called *figural concepts* and reflect both spatial properties and conceptual qualities:

- *spatial properties* - shape, position, magnitude; and
- *conceptual qualities* - abstractness, generality, perfection

According to the Fischbein Theory, the *Didactical Implication* is that successful geometric reasoning can be achieved when we stop considering only two distinct categories of mental entities (images and concepts) and we deal apart from them with a third type of mental objects - figural concepts. A major obstacle in geometrical reasoning is the tendency to neglect the definition under the pressure of figural constraints. Thus, the teaching should emphasize building figural concepts in student's mind rather than ways of productive reasoning (Fischbein, 1993). The author argues that geometers work with image and concept. The image is the result of perception, an intuitive, visual instantiation of a geometric object, typically a geometric diagram. The concept, on the other hand, is a conceptual representation of the same geometric object, consisting of properties imposed by, or derived from definitions in the realm of a certain axiomatic system. Fischbein's notion of concept assumes that concepts exist in a formal framework. Fischbein (1993) argues that both image and concept are necessary for geometrical reasoning. The author exemplifies this with what can be identified as a variation of the proof of Euclid's Proposition 5 which states that the angles opposite equal sides of a triangle are themselves equal.

Fischbein (1993) interprets some difficulties that learners often have with geometry as an imperfect fusion of image and concept. For example, a square cannot be seen as a parallelogram because the dominance of the image of the square in the figural concept prevents access to the conceptual component of the figural concept that would allow conceptualization of 'parallelogram'.

#### 2.7.4 The Hilbert Principle of Geometry

Hilbert (1971) devised the first complete axiomatization of Euclidean geometry. In Hilbert's formalization of Euclid's geometry, there is no place for intuitive conceptualization of image data. Formal geometry is mechanical, involving axioms, definitions, and the rules of logical inference. As Greaves (2002) puts it:

*'The possibility of diagrammatic methods in formal proofs . . . in geometry has always been primarily dependent on the characteristics of the metaphysical and ontological theories under which they are carried out" (pp. 4-5, author's italics).*

According to the author, the denial of the validity of any diagrammatic inferences implies that there is no ultimate subject matter of geometry in Hilbert's system. The formal approach dominates mathematics at the tertiary level. The mathematician's attitude, as Freudenthal (1973) puts it, is that the 'quicksand of reality is no basis to build a mathematical system; mathematics should be protected against any contamination with non-deductive germs'. In its favour, formal geometry guarantees a complete generality within its boundaries. But the formalization does place limits on geometrical truth.

As has already been discussed, there is nothing to suggest that every true proposition is deducible from the axioms. Why, therefore, should the geometer follow Hilbert in discounting spatial intuition as a guide to geometrical truth? Should the perspective of higher mathematics affect curriculum content in secondary schools? If we are to give any credence to the van Hiele levels, discussed later in this study, then it is absolutely clear that axiomatic geometry should not and cannot be taught to students unless they first have a strong foundation in spatial, intuitive geometry.

Freudenthal (1973) concurs with van Hiele's analysis that geometrical ideas should be introduced by intuitive means. He claims that it is pointless to introduce geometric objects by definitions, because a definition cannot make sense unless it is known at the

outset what is being defined. The author argues that the real objective of geometry is grasping the space in which we live and breathe and move.

According to Freudenthal (1973), geometry can only be meaningful if it exploits the relation of geometry to the experienced space. If an educator shirks this duty, he throws away an irretrievable chance. Geometry is one of the best opportunities which exist to learn how to mathematize reality. The reader may agree with Freudenthal (1973) that axiomatic geometry is simply too complex for students; there are many axioms to memorize, and often they seem either trivial or obscure. The whole is so impenetrable that nobody would try working within the axiomatic system; no discoveries can be made within the axiomatic system and proving propositions is a difficult thing to do (*ibid.*, p. 448). Zeitler (1991) analyzes the various axiom systems that could be used for school geometry and comes to the same conclusion as Freudenthal that suggests that geometry requires less abstraction, less formalism or-better still-no axiomatics.

### **2.7.5 Wertheimer-Kohler Theory of Effective Reasoning**

Max Wertheimer and Kohler (Wertheimer, 1986) were the first to be involved with mathematic reasoning in relation with the perception. The most important aspect of their theory is that in the process of problem solving the solution will never occur unless we add to the given situation some certain other facts which eventually change the original meaning and make us see the right procedure immediately. These emerge only when our attention has the right direction for their appearance. This is what also leads to insight in thinking which can only be achieved once we mentally change, amplify or restructure the given material.

Wertheimer (1986) has put forward some principles in order to account for the way that humans organise perceptual stimuli. The following three principles are really important in geometric reasoning and can be helpful in the design of the tutoring component of a Dynamic Geometry Environment (DGE):

- i. The principle of *proximity*, which explains why humans tend to organise elements which are close;
- ii. The principle of *similarity* which predicts that elements which have a similar structure are perceived together; and
- iii. The principle of *good form* by which in a complex diagram with multiple configurations humans tend to perceive only the ones that form closed shapes.

## **2.8 Concluding Remarks**

In this chapter, we reviewed the empirical literature relevant to this study. Particular attention was paid to the role of geometry in mathematical problem solving, teaching and learning of geometry, and geometry theories, concepts, and principles.

Chapter Three focuses on the methodology used in the study as well as a thorough exploratory analysis of the responses provided by participating learners.

## **CHAPTER THREE**

### **RESEARCH METHODOLOGY**

#### **3.1 Introduction**

This chapter focuses on presenting the research methodology used in the study as well as conducting exploratory data analysis with the aim of addressing the research objectives outlined in Chapter 1. The remainder of the chapter is structured as follow.

Section 3.2 presents the research design used followed in this study. In Section 3.3, the task was to explore the background of learners who participated in this study while Section 3.4 explores the socioeconomic and sociodemographic characteristics of learners. Section 3.5 conducts an exploratory analysis of learners' opinions on learning practices and norms that may directly affect learner achievement in geometry whereas Section 3.6 explores learner opinions about the environment for learning geometry. In Section 3.7, the task shifts to exploring the learner attitudes toward geometry while Section 3.8 conducts exploratory analyses of the views about geometry educators that may directly affect achievements in geometry. Section 3.9 explores the scores obtained by learners in the written geometry test. Section 3.10 concludes the chapter.

#### **3.2 Data and Research Methods**

In every research study, the method employed forms the crux of the study, allowing others to see the inner structure of the research project and give meaning and credibility to the findings. This section seeks to clearly discuss the research methods of the study and thereby reinforce its credibility. The study would employ two instruments – survey questionnaire instrument and a test. The data collected from these instruments serves as the foundation upon which the research questions would be addressed.

### **3.2.1 Data Source**

Data for this study would be collected from Grade 8 and Grade 9 high-school learners from Sol Plaatje Secondary School in Mmabatho, South Africa. Sol Plaatje Secondary School, a public high school, has diverse cultural and socioeconomic settings.

### **3.2.2 Target Population**

The target population in this research is Grade 8-12 learners at Sol Plaatje Secondary School in Mafikeng, South Africa, as geometry is taught at these grades. As indicated earlier, the researcher, as a subject educator at the two grades in the school under investigation, has identified the problems confronting learners in these two grades in this area of Mathematics, hence the justification of investigating specifically these particular grades in the selected school. This population is a mixed school made up of 844 learners - 380 are boys and 464 girls. Sol Plaatje Secondary School is a highly competitive and selective school in the North West Province of South Africa. The school uses English as the language of instruction at all grades.

### **3.2.3 Sample**

The sample for this study provides an excellent representation of the population of the learners in Grade 8 and Grade 9, except that 15 learners were not present during the conduct of the interview and test. The diversity of gender and socioeconomic characteristics of learners have the potential of allowing the study to yield a broad view of the perceptions about geometry as well as Grade 8 and Grade 9 learners' achievement in geometry in the high school under study.

### **3.2.4 Instrumentation**

As highlighted earlier, two instruments were used to gather data for the analyses of this study. These instruments, which is a four-point Likert scale, would assess learner



perceptions of geometry in general, learner opinion about environment for teaching and learning geometry, learner attitude toward geometry, learner perception about geometry educators, and the predictors of achievement in geometry. Surveys were distributed and completion was supervised by the researcher in two days. Because of the uniqueness of this study, it was felt that the researcher, himself a mathematics teacher at the school in question, could appropriately collect the data without compromise or bias. The remainder of this section gives a more detailed account of the two instruments used – Quantitative Data Instrument and Written Geometry Achievement Test.

#### **3.2.4.1 Quantitative Data Gathering Instrument**

The ‘Quantitative Data Instrument’ is made up of four constructs – Learner Perception about Geometry, Learner Opinion about Environment for Teaching Geometry, Learner Attitudes toward Geometry, and Learner Perception about Geometry Educator.

##### ***The ‘Learner Perception about Geometry’ Construct***

The purpose of this construct was to gather as much information as possible about learners’ general perceptions about geometry. The 9-item construct has a four-point Likert scale with responses ranging from ‘almost never’ to ‘almost always’. All the nine items are positively phrased. A copy of this construct is attached to this proposal.

##### ***The ‘Learner Opinion about Environment for Teaching Geometry’ Construct***

This construct’s purpose was to obtain learners opinion about the environment for teaching and learning of geometry in class in particular, and in school in general. This 10-item construct has a four-point Likert scale with responses ranging from ‘almost never’ to ‘almost always’. All the ten items are positively phrased. A copy of this construct is attached to this proposal.

### ***The ‘Learner Attitudes toward Geometry’ Construct***

The ‘Learner Attitudes toward Geometry’ construct is meant to obtain as much information as possible about learner’s attitudes’ toward geometry in general. The 7-item construct has a four-point Likert scale with responses ranging from ‘almost never’ to ‘almost always’. All the seven items are positively phrased. A copy of this construct is attached to this proposal.

### ***The ‘Learner Perception about Geometry Educator’ Construct***

The purpose of this construct was to obtain learners’ perception about geometry educators in the school. The 3-item construct has a four-point Likert scale with responses ranging from ‘almost never’ to ‘almost always’. All the three items are positively phrased. A copy of this construct is attached to this proposal.

#### **3.2.4.2 Written Geometry Achievement Assessment Instrument**

In order to assess the geometry achievement levels of learners, a ‘Written Geometry Achievement Test’ was also administered. This achievement test, presented as part of the instrument, included 9 questions covering all the five areas of geometry taught at those grades. By using the achievement test, it is reasonable to expect Grade 9 learners will be able to demonstrate that they possess a greater understanding of the subject matter than Grade 8 learners. Of course, even though a single assessment cannot be expected to predict completely the future performance of a learner, in the absence of other valid instruments which may assess performance levels of learners in this area of mathematics, the Written Geometry Achievement Test was viewed to be extremely reliable as a predictor of the current performance of Grade 8 and Grade 9 learners in geometry.

### **3.3 Data Management**

The quantitative data collected from the learners would be entered into a Microsoft Excel spreadsheet and rechecked for accuracy and errors. Before any detailed analyses are conducted the quantitative data will first be screened for construct sufficiency, adequacy, reliability, and validity. The purpose of the application of this quartet is to ensure the suitability of the data and its appropriateness for addressing the desired research questions.

### **3.4 Instrument Suitability**

As indicated above, each of the four areas of the quantitative instruments would be assessed for sufficiency, adequacy, reliability, and validity. Constructs' adequacy would be assessed applying the Keiser measure of sampling adequacy (Carmines and Zeller, 1979; De Vellis, 2003; Nunnally, 1978) while the sufficiency (internal structure) would be assessed by using the correlation matrix eigenvalues - a factor analysis method (Carmines and Zeller, 1979; De Vellis, 2003; Nunnally, 1978). Reliability would be assessed through the Cronbach alpha coefficient while validity for each instrument would be determined using Statistical Discriminant Analysis (SDA).

### **3.5 Concluding Remarks**

This chapter has briefly discussed the methodology followed in this research study, paying particular attention to the research method used, the target population, sample, the instrumentation, and the analytic methods.

The next chapter shifts focus to the analysis of the data as well as the discussions of the results.

## CHAPTER FOUR

### DATA PRESENTATION, ANALYSES AND INTERPRETATION

#### 4.1 Introduction

Once the reliability and validity of the research instrument used have been verified, the next step was to address the research questions. This chapter attempts to address the research hypotheses by applying three statistical techniques – correlation analysis, one-way Analysis of Variance (ANOVA), and multinomial logistic regression. The remainder of the chapter is structured as follow.

Section 4.2 conducts an exploratory data analysis with the intent of assessing the capacity and capability of the components of the instrument for measuring various constructs of the study. Of clear interest in this exercise is to ensure that all constructs measure what they intended to and display good psychometric properties (sufficiency, adequacy, reliability, and validity) to address all the research questions raised in the study. In Section 4.3, the task was to explore the background of learners who participated in this study while Section 4.4 explores the socioeconomic and sociodemographic characteristics of learners. Section 4.5 conducts an exploratory analysis on learners' opinions on learning practices and norms that may directly affect learner achievement in geometry whereas Section 4.6 explores learner opinions about the environment for learning geometry.

In Section 4.7, the task shifts to exploring the learner attitudes toward geometry while Section 4.8 conducts exploratory analyses of learners' views about geometry educators that may directly affect their achievements in geometry. Section 4.9 explores the scores obtained by learners in the written geometry test while Section 4.10 examines the significant relationships between learner achievement in geometry and the various constructs that contain factors that may relate to learner achievements in geometry.

In Section 4.11, attention shifts to investigating the differences in learner achievement in geometry in relation to the various constructs, while Section 4.12 focuses on predicting learning achievement in geometry on the basis of the various constructs, as well as investigating the effects of such factors that may affect learner achievement in geometry. Section 4.13 concludes the chapter.

## 4.2 Exploratory Data Analysis

This section explores the sufficiency, adequacy, reliability, and validity constructs with the aim of ensuring that they have the capacity and capability address all the research questions raised in the study.

### 4.2.1 Learner Opinions about Learning Practices and Norms

#### **Construct Sufficiency**

An unrotated factor analysis was conducted on the nine measures of ‘Learner Opinions about Learning Practices and Norms’. From Table 4.1, the MSA values of each of the items are all over the acceptable cut-off value of 0.5 (50%).

Table 4.1: Construct Sufficiency – Learner Perception about Geometry

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0,75703259	
Item	MSA
Geometry tests examine what is done in class	0.67606299
Geometry assessment similar to what is taught in class	0.73499098
Aware of how geometry assessment is marked	0.75477697
Geometry educator explains how assessment is used	0.83498570
Understand what is needed in geometry assessment tasks	0.74268062
Geometry educator tells in advance when going to be assessed	0.76633699
Geometry educator tells in advance what going to be assessed	0.73701613
Clear about what geometry educator wants in assessment tasks	0.79132232
When confused about geometry assessment tasks, educator allows another way to answer it	0.80819764

Furthermore, the overall MSA of 0.75703259 (80%) was sufficiently high to suggest that no additional items are required to measure this construct. A commonly used rule is that there should be at least three (3) items or variables per construct. Thus, the number of items constituting this construct is sufficient.

### **Construct Adequacy**

Next, we investigate the number of factors that must be used for further assessment using the eigenvalue correlation analysis matrix reported in Table 4.2.

Table 4.2: Eigenvalues of the Correlation Matrix - Learner Perception about Geometry Construct

Total = 9 Average = 1				
Number	Eigenvalue	Difference	Proportion	Cumulative
1	2.84311091	1.63114565	0.3159	0.3159
2	1.21196526	0.12055998	0.1347	0.4506
3	1.09140528	0.24078610	0.1213	0.5718
4	0.85061918	0.05046085	0.0945	0.6663
5	0.80015833	0.16281738	0.0889	0.7553
6	0.63734094	0.07367771	0.0708	0.8261
7	0.56366324	0.05281908	0.0626	0.8887
8	0.51084416	0.01995146	0.0568	0.9455
9	0.49089270		0.0545	1.0000

The matrix suggests that three (3) factors are adequate for further analysis (that is, factors 1, 2, and 3 have eigenvalues above 1.0). Together, the three factors accounts for 0.5718 (57%) of the common variance of this construct.

Table 4.3 reports the factor loadings for the nine items. For Factor 1, all items have factor loadings above the recommended cut-off value of 0.35 (Hair et al. 1998). This suggests that no items under this construct must be dropped at this stage. However, as observed from the remaining two factors, Factor 2 clearly loads significantly on three items,

namely, 'Aware of how geometry assessment is marked' (0.49980 or 50%), 'Understand what is needed in geometry assessment tasks' (0.49296 or 50%), and 'Clear about what geometry educator wants in assessment tasks' (0.38321 or 38%).

Table 4.3: Factor Loadings - Learner Perception about Geometry Construct

Factor Pattern			
	Factor1	Factor2	Factor3
Geometry tests examine what is done in class	0.50849	-0.41678	<b>0.52613</b>
Geometry assessment similar to what is taught in class	0.58793	-0.29542	<b>0.48637</b>
Aware of how geometry assessment is marked	0.49598	<b>0.49980</b>	0.11236
Geometry educator explains how assessment is used	0.50797	0.08024	-0.10110
Understand what is needed in geometry assessment tasks	0.54837	<b>0.49296</b>	0.26705
Geometry educator tells in advance when going to be assessed	0.61728	-0.43117	-0.23556
Geometry educator tells in advance what going to be assessed	0.59921	-0.33341	-0.44196
Clear about what geometry educator wants in assessment tasks	0.64043	0.38321	-0.06071
When confused about geometry assessment tasks, educator allows another way to answer it	0.53282	0.08849	-0.47892

Similarly, Factor 3 loads significantly on two items, namely, 'Geometry tests examine what is done in class' (0.52613 or 53%) and 'Geometry assessment similar to what is taught in class' (0.48637 or 49%). The corroboration of the Kaiser MSA, eigenvalues, factor loadings, percentage variance give us the confidence in the power of this construct to measure 'Learner Perception about Geometry' in class.

### **Construct Reliability**

In assessing the internal consistency of the data, Cronbach alpha analysis was used. The Cronbach coefficient analysis results are summarized in Table 4.4. The Cronbach alpha analysis results indicate a strong overall internal consistency in the items measuring learner perception about geometry judging from the standardized coefficient of 0.727015 (or 73%).

Table 4.4: Internal Consistency of Construct – Learner Perception about Geometry

Cronbach Coefficient Alpha				
Raw Items: 0.723899		Standardized Items: 0.727015		
Cronbach Coefficient Alpha with Deleted Variable				
Deleted Variable	Raw Variables		Standardized Variables	
	Correlation with Total	Alpha	Correlation with Total	Alpha
Geometry tests examine what is done in class	0.351775	0.709825	0.353683	0.711283
Geometry assessment similar to what is taught in class	0.434523	0.692977	0.428668	0.698032
Aware of how geometry assessment is marked	0.338548	0.710567	0.344514	0.712876
Geometry educator explains how assessment is used	0.362181	0.705785	0.360482	0.710097
Understand what is needed in geometry assessment tasks	0.397428	0.699870	0.394027	0.704201
Geometry educator tells in advance when going to be assessed	0.447352	0.691338	0.447707	0.694606
Geometry educator tells in advance what going to be assessed	0.427415	0.694850	0.429125	0.697950
Clear about what geometry educator wants in assessment tasks	0.474432	0.686195	0.477929	0.689116
When confused about geometry assessment tasks, educator allows another way to answer it	0.367197	0.705702	0.373505	0.707817

Furthermore, the deletion of individual items from the analysis resulting in the coefficients lying between 0.689116 (or 69%) and 0.712876 (or 71%) suggests that each of the nine items measuring learner perception about geometry was stable. Judging from the fact that the Cronbach alpha coefficients do not differ much from the recommended cut-off value of 0.70 (or 70%) (Carmines and Zeller, 1979; De Vellis, 2003; Nunnally, 1978), it therefore suggests that no items must be dropped from this scale that measures learner perception about geometry in school.

### **Construct Validity**

In this section, the purpose was to assess the validity of the ‘Learner Perception about Geometry’ instrument. Appealing to Statistical Discriminant Analysis (SDA), this purpose

is the same as predicting the class in which observations fall, and in the context of this investigation, our class was 'Grade 9'. Table 4.5 reports the cross-validation results from a discriminant validity assessment of the items.

Table 4.5: Discriminant Analysis Cross-Validation Results Learner Perception about Geometry

Number of Observations and Percent Classified into Grade			
From Grade	Grade 8 Learners	Grade 9 Learners	Total
Grade 8 Learners	114 67.06	56 32.94	170 100.00
Grade 9 Learners	63 39.87	95 60.13	158 100.00
Total	177 53.96	151 46.04	328 100.00
Priors	0.51829	0.48171	
Error Count Estimates for Grade			
	Grade 8 Learners	Grade 9 Learners	Total
Rate	0.3294	0.3987	0.3628
Priors	0.5183	0.4817	

The results indicate that about 33% (rate=0.3294) of the Grade 8 observations were wrongly classified, leaving 67% correct classification rate. Similarly, about 40% (rate=0.3987) of the Grade 9 observations were wrongly classified, leaving 60% correct classification rate. The overall classification error rate is about 36% (0.3628). This means that the overall correct rate of classification is 64%. The fact that more than 60% of the observations were correctly classified under this construct suggests that the instrument's capacity to distinguish between and to predict the membership of the Grades was acceptable.

#### 4.2.2 Learner Opinion about Environment for Teaching and Learning Geometry

This section investigates the suitability and appropriateness of the 'Learner Opinion about Environment for Teaching and Learning Geometry' construct.

### Construct Sufficiency

The Kaiser's MSA values reported in Table 4.6 shows an overall MSA value of 0.7215 (about 72%). Individual MSA's are also all above the 0.50 threshold. These findings suggest that the construct was sufficient and that no further items might be required to measure learner opinion about the environment for teaching and learning geometry.

Table 4.6: Construct Sufficiency – Learner Opinion about Environment for Teaching and Learning of Geometry

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.72152649	
Variable	MSA
I am friendly to geometry classmates	0.65808703
I work well with other geometry classmates	0.83109115
Learners in my geometry class like me	0.83836010
My geometry educator goes all out to assist me	0.73684597
My geometry educator has interest in my geometry-related problems	0.76155997
We discuss ideas in geometry class	0.71663033
I freely give my opinions during geometry class	0.56417898
I ask my geometry educator questions in class	0.61661574
I pay attention during geometry class	0.77044786
I always try to understand the work in geometry class	0.77300447

### Construct Adequacy

The eigenvalues from an exploratory factor analysis of the items that measure learner opinion about environment for teaching and learning of geometry reported in Table 4.7 suggest that three (3) factors would be adequate for further analysis (i.e., the first three eigenvalues are all above 1.0). Factor loadings reported in Table 4.8 show Factor 1 having all its loadings above the 0.35 cut-off point suggested by (Hair et al. 1998), suggesting no items under this construct may be dropped.

Table 4.7: Eigenvalues of the Correlation Matrix – Learner Opinion about Environment for Teaching and Learning of Geometry

Total = 10 Average = 1				
Number	Eigenvalue	Difference	Proportion	Cumulative
1	3.24909073	1.78851227	0.3249	0.3249
2	1.46057847	0.30454892	0.1461	0.4710
3	1.15602955	0.27051224	0.1156	0.5866
4	0.88551731	0.05931915	0.0886	0.6751
5	0.82619815	0.17822148	0.0826	0.7577
6	0.64797668	0.05934893	0.0648	0.8225
7	0.58862775	0.12070542	0.0589	0.8814
8	0.46792234	0.07351590	0.0468	0.9282
9	0.39440643	0.07075384	0.0394	0.9676
10	0.32365260		0.0324	1.0000

Table 4.8: Factor Loadings – Learner Opinion about Environment for Teaching and Learning of Geometry

Item	Factor Pattern		
	Factor 1	Factor 2	Factor 3
I am friendly to geometry classmates	0.42795	-0.52173	<b>0.45691</b>
I work well with other geometry classmates	0.58909	-0.12621	<b>0.43279</b>
Learners in my geometry class like me	0.56786	0.04671	0.29593
My geometry educator goes all out to assist me	0.62035	0.09341	-0.50893
My geometry educator has interest in my geometry-related problems	0.69056	0.11879	-0.47956
We discuss ideas in geometry class	0.62256	0.03395	-0.15684
I freely give my opinions during geometry class	0.49400	<b>0.68728</b>	0.17593
I ask my geometry educator questions in class	0.47898	<b>0.55135</b>	0.32230
I pay attention during geometry class	0.60804	-0.38435	-0.06029
I always try to understand the work in geometry class	0.55137	-0.47138	-0.14262

Furthermore, Factor 2 loads significantly on the items ‘I freely give my opinions during geometry class’ (0.68728) and ‘I ask my geometry educator questions in class’ (0.55135) while Factor 3 loads significantly on the items ‘I am friendly to geometry classmates’ (0.45691) and ‘I work well with other geometry classmates’ (0.43279).

### Construct Reliability

The overall standardized Cronbach coefficient alpha of 0.764800 (about 76%) reported in Table 4.9 indicates a strong overall internal consistency in this construct. The individual standardized alphas are all above the 0.7 (70%) threshold. This means the reliability of this construct cannot be doubted.

Table 4.9: Internal Consistency of Construct – Learner Opinion about Environment for Teaching and Learning of Geometry

Cronbach Coefficient Alpha				
Raw Items: 0.763816		Standardized Items: 0.764800		
Cronbach Coefficient Alpha with Deleted Variable				
Deleted Variable	Raw Variables		Standardized Variables	
	Correlation with Total	Alpha	Correlation with Total	Alpha
I am friendly to geometry classmates	0.293801	0.760054	0.307470	0.761309
I work well with other geometry classmates	0.457054	0.740824	0.463719	0.740394
Learners in my geometry class like me	0.436863	0.743020	0.439990	0.743643
My geometry educator goes all out to assist me	0.463902	0.739073	0.459125	0.741025
My geometry educator has interest in my geometry-related problems	0.542653	0.727796	0.535492	0.730403
We discuss ideas in geometry class	0.480006	0.736531	0.479685	0.738192
I freely give my opinions during geometry class	0.384301	0.751108	0.363516	0.753936
I ask my geometry educator questions in class	0.370177	0.753379	0.360514	0.754335
I pay attention during geometry class	0.456721	0.740382	0.468318	0.739761
I always try to understand the work in geometry class	0.395344	0.748374	0.406498	0.748184

### Construct Validity

Table 4.10 presents the cross-validation analysis results from a discriminant validity assessment of the items under this construct. As observed from the results, nearly 67% of Grade 8 observations and 59% of Grade 9 observations were correctly classified.

The overall correct-classification rate of about 63% (overall error rate is 0.3700 or 37%) further show the construct's capacity to distinguish between and to predict the membership of the Grade was acceptable or valid.

Table 4.10: Discriminant Analysis Cross-Validation Results  
Learner Opinion about Environment for Teaching and Learning of Geometry

Number of Observations and Percent Classified into Grade			
From Grade	Grade 8 Learners	Grade 9 Learners	Total
Grade 8 Learners	113 66.86	56 33.14	169 100.00
Grade 9 learners	65 41.14	93 58.86	158 100.00
Total	178 54.43	149 45.57	327 100.00
Priors	0.51682	0.48318	
Error Count Estimates for Grade			
	Grade 8 Learners	Grade 9 Learners	Total
Rate	0.3314	0.4114	0.3700
Priors	0.5168	0.4832	

#### 4.2.3 Learner Attitudes toward Geometry

This section assesses the suitability and appropriateness of the 'Learner Attitudes toward Geometry' construct.

##### **Construct Sufficiency**

From Table 4.11, the Kaiser's overall MSA value of 0.85386 (about 85%) and the fact that all the individual MSA's are above the 0.50 threshold is indicative that construct is sufficient enough and that no further items might be required to measure learner attitudes toward geometry.

Table 4.11: Construct Sufficiency – Learner Attitudes toward Geometry

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.85386062	
Variable	MSA
I always look forward to geometry class	0.84757865
Geometry lessons are fun	0.81057607
I enjoy the activities we do during geometry class	0.85915484
I feel pleased with what I learn in geometry	0.88882250
I can do even the hardest work in geometry if I try	0.85931826
Even if geometry is hard, I can learn it	0.87161283
I am certain I can figure out how to do the difficult geometry tasks	0.84792337

### Construct Adequacy

Table 4.12 presents the eigenvalues from an exploratory factor analysis of the items that measure learner attitudes toward geometry. The correlation matrix eigenvalues suggest that two (2) factors were adequate for further analysis (i.e., the first two eigenvalues were all above 1.0). The factor loadings in Table 4.13 show Factor 1 having all its loadings above the 0.35 cut-off point suggested by (Hair et al. 1998). This indicates that no items under this construct may be dropped at this stage. In addition, Factor 2 loads significantly on items 'I can do even the hardest work in geometry if I try' (0.40593) and 'I am certain I can figure out how to do the difficult geometry tasks' (0.53227).

Table 4.12: Eigenvalues of the Correlation Matrix – Learner Attitudes toward Geometry

Eigenvalues of the Correlation Matrix: Total = 7 Average = 1				
Number	Eigenvalue	Difference	Proportion	Cumulative
1	3.78698880	2.77436366	0.5410	0.5410
2	1.01262515	0.41599108	0.1447	0.6857
3	0.59663407	0.07620533	0.0852	0.7709
4	0.52042874	0.08138712	0.0743	0.8452
5	0.43904162	0.08818927	0.0627	0.9080
6	0.35085235	0.05742309	0.0501	0.9581
7	0.29342926		0.0419	1.0000

Table 4.13: Factor Loadings – Learner Attitudes toward Geometry

	Factor Pattern	
	Factor 1	Factor 2
I always look forward to geometry class	0.73740	-0.43001
Geometry lessons are fun	0.77111	-0.46331
I enjoy the activities we do during geometry class	0.79830	-0.27882
I feel pleased with what I learn in geometry	0.77152	0.08308
I can do even the hardest work in geometry if I try	0.70646	<u>0.40593</u>
Even if geometry is hard, I can learn it	0.70059	0.28343
I am certain I can figure out how to do the difficult geometry tasks	0.65284	<u>0.53227</u>

### Construct Reliability

Table 4.14 presents a summary of the Cronbach coefficient alphas. The overall standardized Cronbach coefficient alpha of 0.857608 (about 86%) suggests a strong overall internal consistency in the seven items under this construct. The individual standardized alphas ranging between 0.827611 (about 83%) and 0.849287 (about 85%) mean a very high reliability level for this construct.

Table 4.14: Internal Consistency of Construct – Learner Opinion about Environment for Teaching and Learning of Geometry

Cronbach Coefficient Alphas				
Raw Items: 0.857280		Standardized Items: 0.857608		
Cronbach Coefficient Alphas with Deleted Variable				
Deleted Item	Raw Items		Standardized Items	
	Correlation with Total	Alpha	Correlation with Total	Alpha
I always look forward to geometry class	0.619769	0.837668	0.618563	0.838280
Geometry lessons are fun	0.653948	0.832673	0.656239	0.832877
I enjoy the activities we do during geometry class	0.694516	0.827311	0.692468	0.827611
I feel pleased with what I learn in geometry	0.665406	0.831102	0.665872	0.831484
I can do even the hardest work in geometry if I try	0.596809	0.840985	0.597529	0.841264
Even if geometry is hard, I can learn it	0.589976	0.841804	0.589720	0.842366
I am certain I can figure out how to do the difficult geometry tasks	0.539393	0.849128	0.540146	0.849287

Table 4.15: Discriminant Analysis Cross-Validation Results - Learner Opinion about Environment for Teaching and Learning of Geometry

Number of Observations and Percent Classified into Grade			
From Grade	Grade 8 Learners	Grade 9 Learners	Total
Grade 8 Learners	104 61.54	65 38.46	169 100.00
Grade 9 Learners	63 39.87	95 60.13	158 100.00
Total	167 51.07	160 48.93	327 100.00
Priors	0.51682	0.48318	
Error Count Estimates for Grade			
	Grade 8 Learners	Grade 9 Learners	Total
Rate	0.3846	0.3987	0.3914
Priors	0.5168	0.4832	

### **Construct Validity**

The cross-validation analysis results from a discriminant validity assessment of the items under this construct are presented in Table 3.18. The results show that about 61% of Grade 8 observations and 60% of Grade 9 observations were correctly classified. The overall rate of correct classification, 61% (overall error rate is 0.3914 or 39%), supports the view that this construct's capacity to distinguish between and to predict the membership of the Grade was unquestionable.

#### **4.2.4 Learner Perception about Geometry Educator**

This section examines the sufficiency, reliability, adequacy and validity of the 'Learner Perception about Geometry Educator' construct.

### **Construct Sufficiency**

Table 4.16 presents a summary of the Kaiser's measure of sampling adequacy. The overall MSA value of 0.6004 (about 60%) and the fact that all the individual MSA's are

above the 0.50 threshold suggests that the construct was sufficient enough and that no further items might be required to measure learner perception about geometry educator.

Table 4.16: Construct Sufficiency – Learner Perception about Geometry Educator

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.60042752	
Item	MSA
My current geometry educator knows and teaches the subject extremely well	0.60849232
My success in geometry depends on the subject educator	0.61381661
My confidence in my geometry ability increases when I have a subject educator who teaches the subject well	0.58405764

### Construct Adequacy

In Table 4.17, the eigenvalues from an exploratory factor analysis of the items that measure learner attitudes toward geometry suggest that only one (1) factor was adequate for further analysis (i.e., the first one eigenvalue were all above 1.0). The factor loadings in Table 4.18 are all above the 0.35 cut-off point, suggesting that no items under this construct might be dropped at this stage.

Table 4.17: Eigenvalues of the Correlation Matrix – Learner Perception about Geometry Educator

Eigenvalues of the Correlation Matrix: Total = 3 Average = 1				
Number	Eigenvalue	Difference	Proportion	Cumulative
1	1.48118911	0.68277152	0.4937	0.4937
2	0.79841759	0.07802428	0.2661	0.7599
3	0.72039330		0.2401	1.0000

Table 4.18: Factor Loadings – Learner Perception about Geometry Educator

Factor Pattern	
	Factor 1
My current geometry educator knows and teaches the subject extremely well	0.68866
My success in geometry depends on the subject educator	0.68032
My confidence in my geometry ability increases when I have a subject educator who teaches the subject well	0.73763

### Construct Reliability

The Cronbach coefficient alphas of the items under this construct are reported in Table 4.19. The individual standardized alphas are not too encouraging. However, the overall standardized Cronbach coefficient alpha of 0.486629 (about 49%) suggests an acceptable level of overall internal consistency in the three items under this construct. This means that no items under this construct might be dropped at this stage.

Table 4.19: Internal Consistency of Construct – Learner Perception about Geometry Educator

Cronbach Coefficient Alpha				
Raw Items: 0.480832		Standardized Items: 0.486629		
Cronbach Coefficient Alpha with Deleted Item				
Deleted Item	Raw Variables		Standardized Variables	
	Correlation with Total	Alpha	Correlation with Total	Alpha
My current geometry educator knows and teaches the subject extremely well	0.288896	0.400907	0.293409	0.406872
My success in geometry depends on the subject educator	0.285733	0.414919	0.287654	0.416608
My confidence in my geometry ability increases when I have a subject educator who teaches the subject well	0.333980	0.334673	0.334440	0.335842

Table 4.20: Discriminant Analysis Cross-Validation Results - Learner Perception about Geometry Educator

Number of Observations and Percent Classified into Grade			
From Grade	Grade 8 Learners	Grade 9 Learners	Total
Grade 8 Learners	117 70.48	49 29.52	166 100.00
Grade 9 Learners	66 41.77	92 58.23	158 100.00
Total	183 56.48	141 43.52	324 100.00
Priors	0.51235	0.48765	
Error Count Estimates for Grade			
	Grade 8 Learners	Grade 9 Learners	Total
Rate	0.2952	0.4177	0.3549
Priors	0.5123	0.4877	

### Construct Validity

The results of the cross-validation analysis of the items under this construct presented in Table 4.20 show that about 70% of Grade 8 observations and 58% of Grade 9 observations were correctly classified. The overall rate of correct classification, 65% (overall error rate is 0.3549), further suggests that this construct's capacity to distinguish between and to predict the membership of the Grade was reliable.

### 4.3 Exploring Learner Background Characteristics

In this section, the objective is to present the distributions of learner background characteristics. Of particular interest is the application of simple statistical techniques including frequencies, simple percentages, bar and pie charts.

#### 4.3.1 Learner Distribution by Grade and Genders

In all 328 learners were involved in the study. As reported in Table 4.21, 52% (170) were in Grade 8 and 48% (158) were in Grade 9 and that the majority of these learners were girls (211 or 64%). Of the 170 Grade 8 learners, about 64% (109) were girls and 36% (61) were boys and of the 158 Grade 9 learners, about 65% (102) were girls and 35% (56) were boys.

Table 4.21: Distribution of Learners by Grade and Gender

Learner Distribution by Grade and Gender	Gender				TOTAL	
	Girls		Boys			
	Count	Percent	Count	Percent	Count	Percent
Grade						
Grade 8	109	64.1	61	35.9	170	52.0
Grade 9	102	64.6	56	35.4	158	48.0
TOTAL	211	64.3	117	35.7	328	100.0

### 4.3.2 Learner Age Distribution by Grade and Gender

As reported in Table 4.22, the ages of learners involved in this study range between 13 years and 17 years. Most of the learners were 14-year olds (170 or 52.3%) and 15-year olds (106 or 32.3%). All 29 13-year-old learners were in Grade 8. Of these, 59% (17) were girls and the remaining 41% (12) were boys.

Table 4.22: Distribution of Learners' Age by Grade and Gender

Learner Age Distribution by Grade and Gender	Grade				Gender				TOTAL COUNT	
	Grade 8		Grade 9		Girls		Boys		Count	Percent
	Count	Percent	Count	Percent	Count	Percent	Count	Percent		
<b>Age</b>										
13 years old	29	100.0	.	.	17	58.6	12	41.4	29	8.9
14 years old	123	72.4	47	27.6	122	71.8	48	28.2	170	52.3
15 years old	14	13.2	92	86.8	65	61.3	41	38.7	106	32.6
16 years old	1	5.3	18	94.7	6	31.6	13	68.4	19	5.8
17 years old	.	.	1	100.0	.	.	1	100.0	1	0.3
<b>TOTAL</b>	167	51.4	158	48.6	210	64.6	115	35.4	325	100.0

- The majority (123 or 72%) of the 170 14-year old learners were in Grade 8. On gender basis, the majority (122 or 72%) of them were girls.
- Of the 106 15-year old learners, the majority (92 or 87%) were in Grade 9 while the majority (65 or 61%) of them were girls.
- Of the 19 16-year old learners who participated in the study, the majority (18 or 95%) were in Grade 8 while the majority (13 or 68%) were boys.
- The only 17-year old learner who participated in the study was in Grade 9 and was a boy.

### 4.3.3 Learner Distribution by Ethnicity

As depicted in Table 4.23, the majority (296 or 90%) of the 328 learners were of African origin. Coloureds form about 4% while Indians form about 3% of the learners who participated in the study.

- Of the 296 learners of African descent, the majority (150 or 51%) were in Grade 8 while majority (189 or 64%) of them were girls.
- Of the 13 Coloured learners, the majority (7 or 54%) were in Grade 8 while majority (7 or 54%) of them were girls.
- Of the 10 learners of Indian descent, the majority (7 or 70%) were in Grade 8 while majority (8 or 80%) of them were girls.

Table 4.23: Distribution of Learners' Ethnicity by Grade and Gender

Learner Ethnicity Distribution by Grade and Gender	Grade				Gender				TOTAL COUNT	
	Grade 8		Grade 9		Girls		Boys			
	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
<b>Ethnicity</b>										
Black/African	150	50.7	146	49.3	189	63.9	107	36.1	296	90.2
Coloured	7	53.8	6	46.2	7	53.8	6	46.2	13	4.0
White	2	50.0	2	50.0	2	50.0	2	50.0	4	1.2
Indian	7	70.0	3	30.0	8	80.0	2	20.0	10	3.0
Other	4	80.0	1	20.0	5	100.0	.	.	5	1.5
<b>TOTAL</b>	170	51.8	158	48.2	211	64.3	117	35.7	328	100.0

### 4.3.4 Learner Distribution by Home Language

About 82% (269) of the 328 learners who participated in this study indicated Tswana was the main language spoken at home (Table 4.24). Nearly 9.5% (31) selected English as the

main home language. The majority (138 or 51%) of the 269 who selected Tswana as the main home language were in Grade 8 and the majority (175 or 65%) of them were girls.

Table 4.24: Distribution of Learners' Home Language by Grade and Gender

Learner Home Language Distribution by Grade and Gender	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Home language</b>										
Tswana	138	51.3	131	48.7	175	65.1	94	34.9	269	82.0
Afrikaans	7	70.0	3	30.0	3	30.0	7	70.0	10	3.0
English	16	51.6	15	48.4	20	64.5	11	35.5	31	9.5
Other	9	50.0	9	50.0	13	72.2	5	27.8	18	5.5
<b>TOTAL</b>	<b>170</b>	<b>51.8</b>	<b>158</b>	<b>48.2</b>	<b>211</b>	<b>64.3</b>	<b>117</b>	<b>35.7</b>	<b>328</b>	<b>100.0</b>

#### 4.4 Exploring Learner Socioeconomic and Sociodemographic Characteristics

In this section, the task is to present the distributions of learner socioeconomic and sociodemographic characteristics. Of particular interest is the application of simple statistical techniques including frequencies and simple percentages.

##### 4.4.1 Learner Distribution by Place of Residence

Most (250 or 76%) of the learners indicated they lived in Mafikeng/Mmabatho (Table 4.25). Only about 4% (12) indicated they lived in an informal settlement around Mafikeng/Mmabatho.

- The two grades share almost equally the 250 learners who indicated they lived in Mafikeng/Mmabatho but most (164 or 66%) of this group of learners were girls.
- Of the eight (8) learners from informal settlements, 67% (8) were in Grade 8 with four (4) being girls and the remaining 4 being boys.

- The majority of the 66 learners who indicated they lived in villages around Mafikeng/Mmabatho were in Grade 8. Most (41 or 62%) of this group of learners were girls.

Table 4.25: Distribution of Learners' Place of Residence by Grade and Gender

Learner Place of Residence Distribution by Grade and Gender	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys		TOTAL	
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Place of Residence</b>										
Mafikeng/Mmabatho resident	124	49.6	126	50.4	164	65.6	86	34.4	250	76.2
Reside in village around Mafikeng	38	57.6	28	42.4	41	62.1	25	37.9	66	20.1
Reside in informal settlement around Mafikeng	8	66.7	4	33.3	6	50.0	6	50.0	12	3.7
<b>TOTAL</b>	<b>170</b>	<b>51.8</b>	<b>158</b>	<b>48.2</b>	<b>211</b>	<b>64.3</b>	<b>117</b>	<b>35.7</b>	<b>328</b>	<b>100.0</b>

#### 4.4.2 Mode of Transportation to School

Learners were also requested to indicate the method of transportation used to and from school. The distributions are reported in Table 4.26. Of the 326 who responded, the majority (157 or 48%) indicated that they use public transport while quite a large proportion of them also indicated that family cars (111 or 34%) are used as a form of transportation to and from school.

- Most (89 or 57%) of the learners who use public transport to school were in Grade 9 while the majority (58 or 52%) of learners who use family cars were in Grade 8.
- Of the 46 who walk to school, the majority (30 or 65%) were in Grade 8 while all 9 who indicated they use other forms of transportation were in Grade 8.
- Most (103 or 66%) of the learners who use public transport to school were in girls while the majority (78 or 70%) of learners who use family cars were in boys.

- Of the 46 who walk to school, the majority (26 or 57%) were boys while the majority of the 9 who indicated they use other forms of transportation were girls.

Table 4.26: Distribution of Mode of Transport by Grade and Gender

Learner Mode of Transport to School	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Mode of transport to school</b>										
Family car	58	52.3	53	47.7	78	70.3	33	29.7	111	34.0
Public transport	68	43.3	89	56.7	103	65.6	54	34.4	157	48.2
By foot	30	65.2	16	34.8	20	43.5	26	56.5	46	14.1
On bicycle	3	100.0	.	.	2	66.7	1	33.3	3	0.9
Other	9	100.0	.	.	6	66.7	3	33.3	9	2.8
<b>TOTAL</b>	168	51.5	158	48.5	209	64.1	117	35.9	326	100.0

#### 4.4.3 Type of House Lived In

Learners were asked to indicate the type of house they live in and distribution of responses reported in Table 4.27. As observed, the majority (155 or 47%) said they lived in 3-bedroom houses while 19% (63) said they lived in two-bedroom houses (Figure 4.8). Only 4% (14) said they lived in 1-bedroom houses. The remaining 29% (96) indicated they lived in 'other' types of houses.

- The 155 learners living in 3-bedroom houses are shared roughly equally between Grade 8 (52%) and Grade 9 (48%). The majority (40 or 64%) of those living in 2-bedroom houses were in Grade 8. All 14 learners living in 1-bedroom houses were in Grade 8.
- Of the 155 learners living in 3-bedroom houses, the majority (99 or 64%) were girls. Similarly, of the 63 learners living in 2-bedroom houses, the majority (40 or 64%) were girls. Only 3 of the 14 learners living in 1-room houses were boys.

Table 4.27: Distribution of Type of House by Grade and Gender

Type of House Lived In	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
Type of house live in										
1-bedroom	14	100.0	.	.	11	78.6	3	21.4	14	4.27
2-bedroom	40	63.5	23	36.5	40	63.5	23	36.5	63	19.21
3-bedroom	80	51.6	75	48.4	99	63.9	56	36.1	155	47.26
Other	36	37.5	60	62.5	61	63.5	35	36.5	96	29.27
TOTAL	170	51.8	158	48.2	211	64.3	117	35.7	328	100.00

- Most (63%) of the 96 learners who indicated they lived in ‘other’ types of houses were in Grade 9 and the majority (64%) were girls.
- Most (60%) of the 169 Grade 8 learners said they were being taken care of by the mothers/fathers followed by those being taken care by their brothers/sisters (15.4%).

#### 4.4.4 Heads of Learner Households

Table 4.28 reports the distribution of learners according to who takes care of them at home. Of the 327 learners who indicated who their caretakers are at home, nearly 75% (244) said they were being taken care of by their mothers/fathers followed by those being taken care of by their brothers/sisters (27 or 8.3%).

- Of the 158 Grade 9 learners who indicated who cared for them at home, about 91% (143) said they were being taken of by their mothers/fathers followed by those being taken of by their grandmothers/grandfathers (9 or 5.7%).

Table 4.28: Learners' Caretakers at Home

	Grade				Gender				COMBINED	
	Grade 8		Grade 9		Girls		Boys			
	Count	%	Count	%	Count	%	Count	%	Count	%
<b>Caretaker at home</b>										
Nobody	14	8.3	1	0.6	12	5.7	3	2.6	15	4.6
Mother/Father	101	59.8	143	90.5	161	76.3	83	71.6	244	74.6
Grandmother/Grandfather	13	7.7	9	5.7	12	5.7	10	8.6	22	6.7
Brother/Sister	26	15.4	1	0.6	15	7.1	12	10.3	27	8.3
Aunt/Uncle	13	7.7	4	2.5	9	4.3	8	6.9	17	5.2
Other	2	1.2	.	.	2	0.9	.	.	2	0.6
<b>TOTAL</b>	<b>169</b>	<b>100.0</b>	<b>158</b>	<b>100.0</b>	<b>211</b>	<b>100.0</b>	<b>116</b>	<b>100.0</b>	<b>327</b>	<b>100.0</b>

- Most (161 or 76.3%) of the 211 female learners said they were being taken of by their mothers/fathers followed by 7.1% (15) who said they were taken of by their brothers/sisters.
- Nearly 72% of the 116 males said they were being taken care of by their mothers/fathers followed by 10.3% (12) who said they were taken of by their brothers/sisters.

#### 4.4.5 Parent/Guardian Highest Level of Education

As revealed in Table 4.29, 40% (127) of the learners indicated that their parents/guardians had certificate/diploma education or had first degree followed by 30% (99) who indicated that their parents/guardians had postgraduate degrees.

- The majority (39.5%) of the 167 Grade 8 learners who responded to this question indicated that their parents/guardians were holders of college certificate/diploma or first degree followed by 19.2% (32) who said their parents/guardians had no formal education or had some primary education.

Table 4.29: Parents'/Guardians' Highest Level of Education

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Highest education level of parent/guardian</b>										
None/Some primary	32	19.2	1	0.6	19	9.1	14	12.0	33	10.2
Primary	22	13.2	4	2.5	17	8.2	9	7.7	26	8.0
Secondary/Some tertiary	18	10.8	22	13.9	31	14.9	9	7.7	40	12.3
Certificate/Diploma/1st degree	66	39.5	61	38.6	74	35.6	53	45.3	127	39.1
Postgraduate degree	29	17.4	70	44.3	67	32.2	32	27.4	99	30.5
<b>TOTAL</b>	<b>167</b>	<b>100.0</b>	<b>158</b>	<b>100.0</b>	<b>208</b>	<b>100.0</b>	<b>117</b>	<b>100.0</b>	<b>325</b>	<b>100.0</b>

- The bulk (44.3%) of the 158 Grade 9 learners who answered this question indicated that their parents/guardians were holders of postgraduate degrees followed 38.6% who indicated that their parents/guardians were college certificate/diploma or first degree holders.
- Of the 208 female learners who responded to this question, the majority (74 or 35.6%) said their parents/guardians were college certificate/diploma and first degree holders followed by 32.2% (67) who said their parents/guardians were postgraduate degree holders.
- About 45% (53) of the 117 male learners indicated that their parents/guardians were college certificate/diploma and first degree holders followed by 27.4% (32) who said their parents/guardians were postgraduate degree holders.

#### 4.4.6 Marital Status of Parents/Guardian

From Table 4.30, most (216 or 55%) of the learners said they were living with married parents/guardians followed by 26% (84) who indicated they were living with single or

divorced parents/guardians. As further observed from Table 4.30, regardless of grade or gender, most learners indicated they were living with married parents/guardians followed by learners living with single or divorced parents/ guardians.

Table 4.30: Marital Status of Parent/Guardian by Grade and Gender

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys		TOTAL	
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Marital status of parent/guardian</b>										
Married	108	63.5	108	68.4	139	65.9	77	65.8	216	65.9
Single/Divorced	43	25.3	41	25.9	56	26.5	28	23.9	84	25.6
Widow/Widower	7	4.1	8	5.1	10	4.7	5	4.3	15	4.6
Cohabiting	12	7.1	1	0.6	6	2.8	7	6.0	13	4.0
<b>TOTAL</b>	<b>170</b>	<b>100.0</b>	<b>158</b>	<b>100.0</b>	<b>211</b>	<b>100.0</b>	<b>117</b>	<b>100.0</b>	<b>328</b>	<b>100.0</b>

#### 4.4.7 Employment Status of Parents/Guardian

As seen from Table 4.31, 90% (293) of the learners said their parents/guardians were fully employed while the remaining 10% (33) said they were living unemployed parents/guardians.

Table 4.31: Employment Status of Parent/Guardian by Grade and Gender

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys		TOTAL	
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Does parent/guardian work?</b>										
Yes	135	46.1	158	53.9	191	65.2	102	34.8	293	89.9
No	33	100.0	.	.	18	54.5	15	45.5	33	10.1
<b>TOTAL</b>	<b>168</b>	<b>51.5</b>	<b>158</b>	<b>48.5</b>	<b>209</b>	<b>64.1</b>	<b>117</b>	<b>35.9</b>	<b>326</b>	<b>100.0</b>

- While all 158 Grade 9 learners indicated their parents/ guardians were fully employed, a third (33%) of the 168 Grade 8 learners said they were living with unemployed parents/guardians.
- A slightly bigger percentage of male learners (12.8%) than female learners (8.6%) indicated that they were living with unemployed parents/guardians.

#### 4.4.8 Wealth Quintile of Learners' Household

The distributions of household wealth quintiles are reported in Table 4.32. Nearly 60% (194) of the learners described their households as middle. About 23% of the learners described their households as low income while just fewer than 18% also described their households as high income.

Table 4.32: Household Wealth Quintile by Grade and Gender

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Household wealth quintile</b>										
Low income	71	42.0	4	2.5	43	20.4	32	27.6	75	22.9
Middle income	79	46.7	115	72.8	135	64.0	59	50.9	194	59.3
High income	19	11.2	39	24.7	33	15.6	25	21.6	58	17.7
<b>TOTAL</b>	<b>169</b>	<b>100.0</b>	<b>158</b>	<b>100.0</b>	<b>211</b>	<b>100.0</b>	<b>116</b>	<b>100.0</b>	<b>327</b>	<b>100.0</b>

- 46.7% of Grade 8 learners compared with 72.8% of Grade 9 learners described their households as middle income while 42.0% of Grade 8 learners compared with 2.5% of Grade 9 learners described their households as low income.
- Fewer Grade 8 learners (11.2%) than Grade 9 learners (24.7%) described their households as high income.

- Relatively more female learners (64.0) than male learners (50.9%) described their households as middle income.

#### 4.4.9 Household Asset Ownership

Learners were asked ten (10) questions that were related to the ownership of assets by their households. The distributions of the responses are reported in Table 4.33.

- Over 90% of the learners said their parents/guardians own television sets, refrigerators, family cars, and music/video players

A relatively greater percentage of Grade 9 learners than Grade 8 learners and greater percentage of female learners than male learners said their parents/guardians owned television sets.

- Between 74%-81% of the learners indicated they had access to multiple television channels (i.e. satellite dishes), washing machines, and telephone.

A relatively greater percentage of Grade 8 learners than Grade 9 learners and greater percentage of female learners than male learners said they had access to multiple channels.

- 92% or more of the learners indicated their households had access to tap water, water-closet, and electricity.

Table 4.33: Household Asset Ownership by Grade and Gender

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Household asset ownership: TV</b>										
Yes	151	88.8	155	99.4	197	94.3	109	93.2	306	93.9
No	19	11.2	1	0.6	12	5.7	8	6.8	20	6.1
<b>Household asset ownership: Fridge</b>										
Yes	162	95.3	156	100.0	204	97.6	114	97.4	318	97.5
No	8	4.7			5	2.4	3	2.6	8	2.5
<b>Household asset ownership: Car</b>										
Yes	156	91.8	139	89.1	189	90.4	106	90.6	295	90.5
No	14	8.2	17	10.9	20	9.6	11	9.4	31	9.5
<b>Household asset ownership: Music/Video Player/Radio</b>										
Yes	152	89.4	152	97.4	195	93.3	109	93.2	304	93.5
No	18	10.6	4	2.6	14	6.7	8	6.8	22	6.7
<b>Household asset ownership: Satellite Dish</b>										
Yes	132	77.6	111	71.2	158	75.6	85	72.6	243	74.5
No	38	22.4	45	28.8	51	24.4	32	27.4	83	25.5
<b>Household ownership: Washing machine</b>										
Yes	132	77.6	131	84.0	179	85.6	84	71.8	263	80.7
No	38	22.4	25	16.0	30	14.4	33	28.2	63	19.3
<b>Household asset ownership: Telephone</b>										
Yes	143	84.1	106	67.9	156	74.6	93	79.5	249	76.4
No	27	15.9	50	32.1	53	25.4	24	20.5	77	23.6
<b>Household asset ownership: Tap water</b>										
Yes	157	92.4	153	98.1	199	95.2	111	94.9	310	95.1
No	13	7.6	3	1.9	10	4.8	6	5.1	16	4.9
<b>Household asset ownership: Water closet</b>										
Yes	157	92.4	143	91.7	194	92.8	106	90.6	300	92.0
No	13	7.6	13	8.3	15	7.2	11	9.4	26	8.0
<b>Household asset ownership: Electricity</b>										
Yes	156	91.8	156	100.0	198	94.7	114	97.4	312	95.7
No	14	8.2			11	5.3	3	2.6	14	4.3

NWU LIBRARY

#### 4.5 Exploring Learner Opinions about Learning Practices and Norms

To assess the practices and norms contributing to learner success in geometry, nine questions were asked with responses ranging from ‘almost never’ to ‘almost always’. Table 4.34 presents the breakdown of responses to the nine items.

- About 67% of the learners said their geometry homework/tests were ‘often’/‘almost always’ examined on what is done in class.

Table 4.34: Practices Leading to Learner Success in Geometry

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys		Size	Percent
	Size	Percent	Size	Percent	Size	Percent	Size	Percent		
<b>Geometry tests examine what is done in class</b>										
Almost never	42	24.7	4	2.5	31	14.7	15	12.8	46	14.0
Sometimes	24	14.1	38	24.1	41	19.4	21	17.9	62	18.9
Often	48	28.2	65	41.1	71	33.6	42	35.9	113	34.5
Almost always	56	32.9	51	32.3	68	32.2	39	33.3	107	32.6
<b>Geometry assessment similar to what is taught in class</b>										
Almost never	16	9.4	4	2.5	13	6.2	7	6.0	20	6.1
Sometimes	34	20.0	49	31.0	55	26.1	28	23.9	83	25.3
Often	54	31.8	61	38.6	75	35.5	40	34.2	115	35.1
Almost always	66	38.8	44	27.8	68	32.2	42	35.9	110	33.5
<b>Aware of how geometry assessment is marked</b>										
Almost never	11	6.5	12	7.6	18	8.5	5	4.3	23	7.0
Sometimes	38	22.4	63	39.9	69	32.7	32	27.4	101	30.8
Often	53	31.2	51	32.3	65	30.8	39	33.3	104	31.7
Almost always	68	40.0	32	20.3	59	28.0	41	35.0	100	30.5
<b>Geometry educator explains how assessment is used</b>										
Almost never	6	3.5	1	0.6	4	1.9	3	2.6	7	2.1
Sometimes	47	27.6	34	21.5	56	26.5	25	21.4	81	24.7
Often	40	23.5	66	41.8	67	31.8	39	33.3	106	32.3
Almost always	77	45.3	57	36.1	84	39.8	50	42.7	134	40.9

Table 4.34 continued: Practices Leading to Learner Success in Geometry

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Understand what is needed in geometry assessment tasks</b>										
Almost never	6	3.5	2	1.3	4	1.9	4	3.4	8	2.4
Sometimes	45	26.5	67	42.4	78	37.0	34	29.1	112	34.1
Often	47	27.6	63	39.9	76	36.0	34	29.1	110	33.5
Almost always	72	42.4	26	16.5	53	25.1	45	38.5	98	29.9
<b>Geometry educator tells in advance WHEN going to be assessed</b>										
Almost never	7	4.1	2	1.3	5	2.4	4	3.4	9	2.7
Sometimes	31	18.2	27	17.1	38	18.0	20	17.1	58	17.7
Often	49	28.8	35	22.2	56	26.5	28	23.9	84	25.6
Almost always	83	48.8	94	59.5	112	53.1	65	55.6	177	54.0
<b>Geometry educator tells in advance WHAT going to be assessed</b>										
Almost never	4	2.4	6	3.8	4	1.9	6	5.1	10	3.0
Sometimes	37	21.8	28	17.7	40	19.0	25	21.4	65	19.8
Often	59	34.7	54	34.2	75	35.5	38	32.5	113	34.5
Almost always	70	41.2	70	44.3	92	43.6	48	41.0	140	42.7
<b>Clear about what geometry educator wants in assessment tasks</b>										
Almost never	9	5.3	6	3.8	13	6.2	2	1.7	15	4.6
Sometimes	46	27.1	54	34.2	74	35.1	26	22.2	100	30.5
Often	48	28.2	69	43.7	71	33.6	46	39.3	117	35.7
Almost always	67	39.4	29	18.4	53	25.1	43	36.8	96	29.3

- Nearly 69% of the learners said their assessments/tests in geometry were ‘often’/‘almost always’ similar to what the subject educator teaches in class.
- About 62% of the learners said they were ‘often’/‘almost always’ aware of how their geometry assessment/tests would be marked.
- Nearly three-quarters (73%) of the learners said their geometry educator often’/ ‘almost always’ explains to them how assessments were used.

- About 63% of the learners indicated that they ‘often’/‘almost always’ understood what is needed in geometry assessment tasks.
- Almost 80% of the learners said their geometry educator ‘often’/‘almost always’ told them in advance when they were going to be assessed.
- About 77% of the learners indicated that their geometry educator ‘often’/‘almost always’ told them in advance what they were going to be assessed on.
- 65% of the learners said they were ‘often’/‘almost always’ clear about what the subject educator wanted in their assessment tasks.
- 67% of the learners indicated that when they were confused about how to complete a geometry task in class, subject educator ‘often’/‘almost always’ allowed them to use other ways to answer them.

#### **4.6 Exploring Learner Opinions about the Environment for Learning Geometry**

To evaluate the acceptability of classroom environment for a successful learning of geometry, ten questions were asked with responses ranging from ‘disagree’ to ‘strongly agree’. Table 4.35 presents the distribution of responses to the ten items.

- About 82% (269) of the learners ‘strongly agreed’/‘agreed’ that they were friendly to mates in geometry class. Only 8 ‘disagreed’.
- Nearly 75% (242) of the learners indicated that they worked well with other classmates in geometry class (that is, ‘strongly agreed’/‘agreed’) with only 3% ‘disagreeing’.
- 63% (208) of the learners also ‘strongly agreed’/‘agreed’ to the statement that other learners in their geometry class liked them with about 6% ‘disagreeing’.

Table 4.35: Class Environment for Successful Learning of Geometry

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>I am friendly to geometry classmates</b>										
Disagree	5	3.0	3	1.9	5	2.4	3	2.6	8	2.4
Fairly agree	31	18.3	19	12.0	31	14.8	19	16.2	50	15.3
Agree	62	36.7	76	48.1	85	40.5	53	45.3	138	42.2
Strongly agree	71	42.0	60	38.0	89	42.4	42	35.9	131	40.1
<b>I work well with other geometry classmates</b>										
Disagree	6	3.6	4	2.5	7	3.3	3	2.6	10	3.1
Fairly agree	41	24.3	34	21.5	47	22.4	28	23.9	75	22.9
Agree	59	34.9	70	44.3	81	38.6	48	41.0	129	39.4
Strongly agree	63	37.3	50	31.6	75	35.7	38	32.5	113	34.6
<b>Learners in my geometry class like me</b>										
Disagree	12	7.1	7	4.4	12	5.7	7	6.0	19	5.8
Fairly agree	43	25.4	59	37.3	77	36.7	25	21.4	102	31.2
Agree	52	30.8	71	44.9	74	35.2	49	41.9	123	37.6
Strongly agree	62	36.7	21	13.3	47	22.4	36	30.8	83	25.4
<b>My geometry educator goes all out to assist me</b>										
Disagree	12	7.1	8	5.1	14	6.7	6	5.1	20	6.1
Fairly agree	42	24.9	33	20.9	51	24.3	24	20.5	75	22.9
Agree	49	29.0	51	32.3	67	31.9	33	28.2	100	30.6
Strongly agree	66	39.1	66	41.8	78	37.1	54	46.2	132	40.4
<b>My geometry educator has interest in my geometry-related problems</b>										
Disagree	14	8.3	8	5.1	15	7.1	7	6.0	22	6.7
Fairly agree	37	21.9	36	22.8	51	24.3	22	18.8	73	22.3
Agree	53	31.4	51	32.3	71	33.8	33	28.2	104	31.8
Strongly agree	65	38.5	63	39.9	73	34.8	55	47.0	128	39.1
<b>We discuss ideas in geometry class</b>										
Disagree	23	13.6	10	6.3	20	9.5	13	11.1	33	10.1
Fairly agree	45	26.6	29	18.4	49	23.3	25	21.4	74	22.6
Agree	42	24.9	54	34.2	61	29.0	35	29.9	96	29.4
Strongly agree	59	34.9	65	41.1	80	38.1	44	37.6	124	37.9

Table 4.35 continued: Class Environment for Successful Learning of Geometry

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>I freely give my opinions during geometry class</b>										
Disagree	32	18.9	23	14.6	33	15.7	22	18.8	55	16.8
Fairly agree	43	25.4	73	46.2	80	38.1	36	30.8	116	35.5
Agree	43	25.4	37	23.4	51	24.3	29	24.8	80	24.5
Strongly agree	51	30.2	25	15.8	46	21.9	30	25.6	76	23.2
<b>I ask my geometry educator questions in class</b>										
Disagree	20	11.8	31	19.6	36	17.1	15	12.8	51	15.6
Fairly agree	46	27.2	72	45.6	77	36.7	41	35.0	118	36.1
Agree	45	26.6	29	18.4	47	22.4	27	23.1	74	22.6
Strongly agree	58	34.3	26	16.5	50	23.8	34	29.1	84	25.7
<b>I pay attention during geometry class</b>										
Disagree	11	6.5	3	1.9	10	4.8	4	3.4	14	4.3
Fairly agree	29	17.2	34	21.5	46	21.9	17	14.5	63	19.3
Agree	52	30.8	54	34.2	62	29.5	44	37.6	106	32.4
Strongly agree	77	45.6	67	42.4	92	43.8	52	44.4	144	44.0
<b>I always try to understand the work in geometry class</b>										
Disagree	11	6.5	4	2.5	9	4.3	6	5.1	15	4.6
Fairly agree	37	21.9	12	7.6	36	17.1	13	11.1	49	15.0
Agree	46	27.2	65	41.1	80	38.1	31	26.5	111	33.9
Strongly agree	75	44.4	77	48.7	85	40.5	67	57.3	152	46.5

- 71% (232) of the learners ‘strongly agreed’/‘agreed’ to the statement that their geometry educators went all out to assist them with about 6% ‘disagreeing’.

About 71% (232) of the learners ‘strongly agreed’/‘agreed’ to the statement that their geometry educators had interest in their geometry-related problems. About 7% ‘disagreed’.

- About 67% (220) of the learners ‘strongly agreed’/‘agreed’ that they had the opportunity to discuss ideas during geometry lessons. A substantial fraction (10%) of the learners ‘disagreed’.
- Less than half of the learners ‘strongly agreed’/‘agreed’ when asked whether they were allowed to freely give their opinions during geometry lessons with about 17% ‘disagreeing’ that they are freely allowed to give opinions.
- Again, less than half (48%) of the learners ‘strongly agreed’/‘agreed’ to the statement that they asked their geometry educators questions during lessons. About 16% ‘disagreed’.
- Nearly 74% of the learners ‘strongly agreed’/‘agreed’ that they always paid attention during geometry lessons while 4% ‘disagreed’.
- Over 86% of the learners ‘strongly agreed’/ ‘agreed’ to the statement that they always tried to understand the work in geometry lessons with 5% ‘disagreeing’.

#### 4.7 Exploring Learner Attitudes toward Geometry

Seven questions were posed to learners with the aim of assessing their attitudes toward geometry with responses ranging from ‘disagree’ to ‘strongly agree’. The distribution of responses is summarized descriptively in Table 4.36.

Table 4.36: Learner Attitude toward Geometry

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>I always look forward to geometry class</b>										
Almost never	11	6.5	19	12.0	22	10.4	8	6.9	30	9.2
Sometimes	51	30.2	62	39.2	77	36.5	36	31.0	113	34.6
Often	51	30.2	58	36.7	72	34.1	37	31.9	109	33.3
Almost always	56	33.1	19	12.0	40	19.0	35	30.2	75	22.9

Table 4.36 continued: Learner Attitude toward Geometry

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>Geometry lessons are fun</b>										
Almost never	11	6.5	23	14.6	25	11.8	9	7.8	34	10.4
Sometimes	52	30.8	69	43.7	78	37.0	43	37.1	121	37.0
Often	46	27.2	36	22.8	58	27.5	24	20.7	82	25.1
Almost always	60	35.5	30	19.0	50	23.7	40	34.5	90	27.5
<b>I enjoy the activities we do during geometry class</b>										
Almost never	8	4.7	13	8.2	15	7.1	6	5.2	21	6.4
Sometimes	51	30.2	66	41.8	77	36.5	40	34.5	117	35.8
Often	54	32.0	52	32.9	71	33.6	35	30.2	106	32.4
Almost always	56	33.1	27	17.1	48	22.7	35	30.2	83	25.4
<b>I feel pleased with what I learn in geometry</b>										
Almost never	11	6.5	13	8.2	17	8.1	7	6.0	24	7.3
Sometimes	36	21.3	41	25.9	52	24.6	25	21.6	77	23.5
Often	51	30.2	62	39.2	72	34.1	41	35.3	113	34.6
Almost always	71	42.0	42	26.6	70	33.2	43	37.1	113	34.6
<b>I can do even the hardest work in geometry if I try</b>										
Almost never	10	5.9	18	11.4	20	9.5	8	6.9	28	8.6
Sometimes	44	26.0	72	45.6	79	37.4	37	31.9	116	35.5
Often	59	34.9	36	22.8	58	27.5	37	31.9	95	29.1
Almost always	56	33.1	32	20.3	54	25.6	34	29.3	88	26.9
<b>Even if geometry is hard, I can learn it</b>										
Almost never	9	5.3	6	3.8	13	6.2	2	1.7	15	4.6
Sometimes	35	20.7	37	23.4	55	26.1	17	14.7	72	22.0
Often	45	26.6	53	33.5	57	27.0	41	35.3	98	30.0
Almost always	80	47.3	62	39.2	86	40.8	56	48.3	142	43.4
<b>I am certain I can figure out how to do the difficult geometry tasks</b>										
Almost never	9	5.3	20	12.7	25	11.8	4	3.4	29	8.9
Sometimes	42	24.9	57	36.1	65	30.8	34	29.3	99	30.3
Often	59	34.9	48	30.4	70	33.2	37	31.9	107	32.7
Almost always	59	34.9	33	20.9	51	24.2	41	35.3	92	28.1

- Only about 56% of the learners ‘strongly agreed’/‘agreed’ that they always looked forward to geometry lessons with 9% responding in the negative (‘disagree’).
- Just over half (52.6%) of the learners ‘strongly agreed’/‘agreed’ geometry lessons were fun while a sizeable fraction (10%) ‘disagreed’ with the statement.

About 58% of the learners said (‘strongly agreed’/‘agreed’) the statement that they enjoyed the activities during geometry lessons. Only 6.4% (21) ‘disagreed’.

- The majority (about 70%) of the learners indicated (‘strongly agreed’/‘agreed’) that they always felt pleased with what they learned in geometry while 7% had a contrary view.
- 56% of the learners believed (‘strongly agreed’/‘agreed’) that they could do the hardest task if they tried. Only about 9% did not believe (‘disagreed’) they could do it if they tried.
- Nearly three-quarters (73.4%) of the learners had the belief (‘strongly agreed’/‘agreed’) that even if geometry was hard, they could still learn it. Only about 5% did not have that belief (‘disagreed’).
- About 61% of the learners indicated (‘strongly agreed’/‘agreed’) that they were certain they could figure out how to do the difficult tasks in geometry with about 9% indicating they were uncertain how to do that.

#### **4.8 Exploring Learner Views about Geometry Educators**

To evaluate learner views about their geometry educator, three questions were asked with responses ranging from ‘disagree’ to ‘strongly agree’. Table 4.37 presents the distribution of responses provided by learners. There appears to be a consistent upward trend in the responses provided by learners.

Table 4.37: Assessing Learner Views about Geometry Educators

	Grade				Gender				TOTAL	
	Grade 8		Grade 9		Girls		Boys			
	Size	Percent	Size	Percent	Size	Percent	Size	Percent	Size	Percent
<b>My current geometry educator knows and teaches the subject extremely well</b>										
Almost never	6	3.6	4	2.5	9	4.3	1	0.9	10	3.1
Sometimes	25	15.1	18	11.4	31	14.8	12	10.4	43	13.3
Often	52	31.3	33	20.9	53	25.4	32	27.8	85	26.2
Almost always	83	50.0	103	65.2	116	55.5	70	60.9	186	57.4
<b>My success in geometry depends on the subject educator</b>										
Almost never	8	4.8	11	7.0	16	7.7	3	2.6	19	5.9
Sometimes	23	13.9	45	28.5	44	21.1	24	20.9	68	21.0
Often	54	32.5	59	37.3	74	35.4	39	33.9	113	34.9
Almost always	81	48.8	43	27.2	75	35.9	49	42.6	124	38.3
<b>My confidence in my geometry ability increases when I have a subject educator who teaches the subject well</b>										
Almost never	3	1.8	1	0.6	3	1.4	1	0.9	4	1.2
Sometimes	21	12.7	18	11.4	30	14.4	9	7.8	39	12.0
Often	52	31.3	42	26.6	57	27.3	37	32.2	94	29.0
Almost always	90	54.2	97	61.4	119	56.9	68	59.1	187	57.7

- About 57% of the participants ‘strongly agreed’ that their current geometry educator knew and taught the subject extremely well and that they were confident their ability in geometry increased when they have an educator who taught the subject very well.

Only 10 learners ‘disagreed’ in the case of the former and 4 learners, in the case of the latter.

- About three-quarters (73.2%) of the learners ‘strongly agreed’/‘agreed’ their successes in geometry depended on the subject educator. Nearly 6% were of the negative opinion (‘disagreed’).

#### 4.9 Exploring Learner Scores for Written Geometry Test

The Written Geometry Test (WGT) served as a tool to assess learner understanding of geometry taught in Grade 8 and Grade 9. As stated in Chapter 1, at these two grades, the five core areas of geometry a learner was supposed to be familiar with are:

- Angle at a point;
- Adjacent angles in a straight line;
- Right and vertical opposite angles;
- Correspondence, alternate, and co-interior angles; and
- Angle properties of triangle and quadrilateral angles.

Table 4.38 presents the descriptive statistics of the scores obtained by learners at both grades. The minimum and maximum test scores recorded by learners were 0% and 100%, respectively. The average test score was 50.1% while the coefficient of variation was 47.8.

- On average, Grade 9 learners (average=51.6%) performed much better than Grade 8 learners (average=48.8%).
- On average, female learners (average=50.3%) performed comparatively better than male learners (average=49.8%).
- On average, 13-year olds (average=58.9%) performed much better than the 14-year olds (average=49.5%), 15-year olds (average=52.9%), 16-year olds (average=28.8%), and 17-year olds (average=15.0%).
- On average, White learners (average=71.3%) performed much better followed by learners of Indian descent (average=54.5%), and learners of African descent (average=50.1%). Coloured learners had the worst average score (average=39.4%).

- In both grades and genders, a zero score was recorded. While no zero score was recorded among the 13-year old learners and 17-year old learners, the same cannot be said about 14-year olds, 15-year olds, and 16-year olds.
- A zero score was recorded among learners of African descent but not among learners of other descent.
- In both grades some learners managed to obtain a 100% score. At least one female learner managed to obtain a 100% score, but the same cannot be said of the male learners. The maximum test score managed by a male learner was 95%.

Table 4.38: Descriptive Statistics for Test Scores

	Geometry baseline assessment score							
	COUNT	MEAN	MIN	MAX	MEDIAN	STD	VAR	CV
<b>Grade</b>								
Grade 8	166	48.8	0.0	100.0	50.0	22.6	509.1	46.3
Grade 9	158	51.6	0.0	100.0	55.0	25.3	642.5	49.1
<b>Gender</b>								
Girls	210	50.3	0.0	100.0	52.5	24.4	594.9	48.4
Boys	114	49.8	0.0	95.0	52.5	23.3	541.4	46.7
<b>Age</b>								
13 years old	29	58.9	17.5	100.0	65.0	19.8	390.4	33.6
14 years old	169	49.5	0.0	95.0	50.0	23.1	532.0	46.6
15 years old	106	52.9	0.0	100.0	55.0	24.9	621.2	47.1
16 years old	19	28.8	0.0	72.5	27.5	19.7	389.8	68.5
17 years old	1	15.0	15.0	15.0	15.0			
<b>Ethnicity</b>								
Black/African	292	50.1	0.0	100.0	52.5	23.8	566.5	47.5
Coloured	13	39.4	12.5	90.0	32.5	23.9	570.0	60.6
White	4	71.3	45.0	92.5	73.8	19.8	393.8	27.9
Indian	10	54.5	5.0	82.5	66.3	30.3	920.6	55.7
Other	5	55.0	35.0	70.0	57.5	14.0	196.9	25.5
<b>TOTAL</b>	<b>324</b>	<b>50.1</b>	<b>0.0</b>	<b>100.0</b>	<b>52.5</b>	<b>24.0</b>	<b>574.4</b>	<b>47.8</b>

STD=Standard Deviation, VAR=Variance, MIN=Minimum, MAX=Maximum, CV=Coefficient of Variation

- While at least one 13-year old learner and one 15-year old learner managed to obtain a 100% score, the same cannot be said about 14-year learners, 16-year old learners, and 17-year old learners.
- At least one learner of African descent managed to obtain a 100% score, the same cannot be said about learners of other descents.

In order to fully address the research questions, it was important to assign learners to test grades according to a learner’s achievement in the geometry test. The five geometry test grades of consideration are:

- Poor : Less than 25%
- Fairly Poor : 25% - 44%
- Average : 45% - 54%
- Good : 55% - 74%
- Very Good : 75% - 100%.

Based on these five levels, the distribution of the scores is presented descriptively in Table 4.39. Most of the learners can then be said to have obtained a ‘good’ (28.1%) mark followed by those who performed ‘fairly poorly’ (23.5%). Only about 13% obtained the ‘average’ mark.

Table 4.39: Descriptive Statistics for Test Scores by Level

Geometry test grade	Geometry baseline assessment score								
	COUNT	PERCENT	MEAN	MIN	MAX	MEDIAN	STD	VAR	CV
Poor	55	16.8	13.6	0.0	22.5	15.0	6.3	39.5	46.3
Fairly poor	77	23.5	33.5	25.0	42.5	32.5	5.5	30.6	16.5
Average	42	12.8	49.3	45.0	52.5	50.0	2.9	8.3	5.9
Good	92	28.1	64.4	55.0	72.5	65.0	5.7	32.9	8.9
Very good	61	18.7	82.3	75.0	100.0	82.5	6.4	40.5	7.7
TOTAL	327	100.0	50.0	0.0	100.0	52.5	23.9	572.8	47.9

STD=Standard Deviation, VAR=Variance, MIN=Minimum, MAX=Maximum, CV=Coefficient of Variation

#### 4.10 Examining Significant Relationships

##### 4.10.1 Research Question 1

- Are there any significant relationship between learner background characteristics and learner achievement in geometry?

Table 4.40 reports the summary Pearson Product-Moment Correlation analysis results which provide evidence of significant correlation at the 5% (0.05) level between achievements in geometry and age. The relatively small variability of age (2.59%) further suggests that age relates strongly to learner achievement in geometry. The relatively small variability is indicative of a significant relationship between learner achievement in geometry and age.

Table 4.40: Correlation between Learner Background Characteristics and Geometry Test Grade

N = 314			
	Pearson Correlation Coefficients	Prob >  r  under H0: Rho=0	Variability %
A1 Grade	0.06024	0.2873	0.37
A2 Gender	-0.01362	0.8100	0.02
A3 Age	-0.16081	0.0043	2.59
A4 Ethnicity	0.07440	0.1886	0.55
B1 Place of Residence	-0.03563	0.5293	0.13
B2 Mode of transport to school	0.03880	0.4934	0.15
B3 Type of house live in	0.05946	0.2935	0.35
B4 Caretaker at home	-0.09146	0.1057	0.84
B5 Highest education level of parent/guardian	0.03899	0.4912	0.15
B6 Marital status of parent/guardian	-0.07495	0.1853	0.56
B7 Does parent/guardian work?	-0.05031	0.3743	0.25

##### 4.10.2 Research Question 2

- Are there any significant relationship between learner socioeconomic and socio-demographic characteristics and learner achievement in geometry?

The summary of Pearson Product-Moment Correlation analysis results in Table 4.41 reveals evidence of significant correlation at the 5% (0.05) level between achievements in geometry and household wealth quintile and ownership of a telephone. The prob-values for the correlation coefficients of household ownership of TV (0.0868), household ownership of refrigerator (0.0611), and household access to tap water (0.0585) do not differ much from the 0.05 level of significance, suggesting that these factors relate only slightly to learner achievement in geometry. The relatively small variabilities further suggests that these five factors relate strongly to learner achievement in geometry, the largest being 1.51%. In general, the relatively small variability values are indicative of significant relationships between learner achievement in geometry and those five factors.

Table 4.41: Correlation between Learner Background Characteristics and Geometry Test Grade

N = 314			
	Pearson Correlation Coefficients	Prob >  r  under H0: Rho=0	Variability
B8 Household wealth quintile	0.12308	0.0292	1.51
B9Q1 Household asset ownership: TV	-0.09679	0.0868	0.94
B9Q2 Household asset ownership: Fridge	-0.10581	0.0611	1.12
B9Q3 Household asset ownership: Car	-0.01966	0.7285	0.04
B9Q4 Household asset ownership: Music/Video Player/Radio	0.02546	0.6532	0.06
B9Q5 Household asset ownership: Satellite Dish	-0.00269	0.9622	0.00
B9Q6 Household asset ownership: Washing machine	-0.02947	0.6029	0.09
B9Q7 Household asset ownership: Telephone	-0.11094	0.0495	1.23
B9Q8 Household asset ownership: Tap water	-0.10687	0.0585	1.14
B9Q9 Household asset ownership: Water closet	-0.04151	0.4636	0.17
B9Q10 Household asset ownership: Electricity	0.01740	0.7587	0.03

### 4.10.3 Research Question 3

- Are there any significant relationships between learning practices and norms and learner achievement in geometry?

From the summary of Pearson Product-Moment Correlation analysis results in Table 4.42, there is evidence of significant correlation at the 5% (0.05) level between achievements in geometry and all the eight learning practices and norms judging from the fact that the prob-values for the correlation coefficients of all the eight practices and norms are less than the 0.05 level of significance, suggesting that these factors relate to learner achievement in geometry.

Table 4.42: Correlation between Learning Practices and Norms and Geometry Test Grade

N = 327			
	Pearson Correlation Coefficient	Prob >  r  under H0: Rho=0	Variability %
C1 Geometry tests examine what is done in class	0.35150	<.0001	12.35523
C2 Geometry assessment similar to what is taught in class	0.33149	<.0001	10.98856
C3 Aware of how geometry assessment is marked	0.18154	0.0010	3.295677
C4 Geometry educator explains how assessment is used	0.17481	0.0015	3.055854
C5 Understand what is needed in geometry assessment tasks	0.31270	<.0001	9.778129
C6 Geometry educator tells in advance WHEN going to be assessed	0.21807	<.0001	4.755452
C7 Geometry educator tells in advance WHAT going to be assessed	0.14164	0.0103	2.006189
C8 Clear about what geometry educator wants in assessment tasks	0.26850	<.0001	7.209225



#### 4.10.4 Research Question 4

- Are there any significant relationships between constructs of learning environment and learner achievement in geometry?

The Pearson Product-Moment Correlation analysis results in Table 4.43 show that, except for the level of friendliness among classmates, there is evidence of significant correlation at the 5% (0.05) level between achievements in geometry and the remaining statements since the prob-values for their correlation coefficients are less than the 0.05 level of significance. This means that the remaining factors relate to learner achievement in geometry.

Table 4.43: Correlation between Learning Environment and Geometry Test Grade

N = 326		
	Pearson Correlation Coefficients	Prob >  r  under H <sub>0</sub> : Rho=0
D1 I am friendly to geometry classmates	0.03035	0.5850
D2 I work well with other geometry classmates	0.19513	0.0004
D3 Learners in my geometry class like me	0.17304	0.0017
D4 My geometry educator goes all out to assist me	0.21116	0.0001
D5 My geometry educator has interest in my geometry-related problems	0.20484	0.0002
D6 We discuss ideas in geometry class	0.19875	0.0003
D7 I freely give my opinions during geometry class	0.18779	0.0007
D8 I ask my geometry educator questions in class	0.20719	0.0002
D9 I pay attention during geometry class	0.20225	0.0002
D10 I always try to understand the work in geometry class	0.19192	0.0005

#### 4.10.5 Research Question 5

- Is there any significant relationship between attitudes towards geometry and learner achievement in geometry?

The summary Pearson Product-Moment Correlation analysis results in Table 4.44 reveals correlations between achievements in geometry were all positive and significant at the 5% (0.05) level, based on the results that the probability (prob) values are all less than 0.05.

The variability values further suggests that the attitude of ‘always looking forward to geometry lessons’ has a strong impact on learner achievement in geometry (that is, the variability of 5.1% is the least among the seven variability values. In general, the relatively small variability values are indicative of significant relationships between learner achievement in geometry and those seven attitudes.

Table 4.44: Correlation between Learners' Attitudes toward Geometry and Geometry Test Grade

	Pearson Correlation Coefficients	Prob >  r  under H <sub>0</sub> : Rho=0	Variability %
E1 I always look forward to geometry class	0.22444	<.0001	5.0
E2 Geometry lessons are fun	0.24637	<.0001	6.1
E3 I enjoy the activities we do during geometry class	0.30076	<.0001	9.0
E4 I feel pleased with what I learn in geometry	0.32514	<.0001	10.6
E5 I can do even the hardest work in geometry if I try	0.32008	<.0001	10.2
E6 Even if geometry is hard, I can learn it	0.35849	<.0001	12.9
E7 I am certain I can figure out how to do the difficult geometry tasks	0.27019	<.0001	7.3

#### 4.10.6 Research Question 6

- Are there any significant relationships between constructs of learner views about subject educator and learner achievement in geometry?

Table 4.45: Correlation between Perception about Subject Educator and Geometry Test Grade

N = 323		
	Pearson Correlation Coefficients	Prob >  r  under H <sub>0</sub> : Rho=0
F1 My current geometry educator knows and teaches the subject extremely well	0.18224	0.0010
F2 My success in geometry depends on the subject educator	0.08509	0.1270
F3 My confidence in my geometry ability increases when I have a subject educator who teaches the subject well	0.23059	<.0001

The summary of Pearson Product-Moment Correlation analysis results in Table 4.45 suggest that, except for the view that success in geometry depends on the subject educator, there is evidence of significant correlation at the 5% (0.05) level between achievements in geometry and the two remaining statements since the prob-values for their correlation coefficients are less than the 0.05 level of significance. This means that the two remaining factors relate to learner achievement in geometry.

#### 4.11 Examining Differences in Geometry Test Scores

##### 4.11.1 Research Question 7

- Are there any differences in the geometry achievements in relation to learner background, socioeconomic and sociodemographic characteristics?

Table 4.46: ANOVA Tests of Differences between Geometry Achievements by Virtue of Learner Background and Household Socioeconomic Status

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
A1 Gender	1	2.19109572	2.19109572	1.23	0.2687
A2 Grade	1	0.11200326	0.11200326	0.06	0.8023
A3 Age	4	38.22425288	9.55606322	5.36	0.0004
A4 Ethnicity	4	15.10801813	3.77700453	2.12	0.0789
B1 Place of Residence	2	2.70958883	1.35479442	0.76	0.4689
B2 Mode of transport to school	4	3.15521286	0.78880322	0.44	0.7780
B3 Type of house lived in	3	2.83865898	0.94621966	0.53	0.6617
B4 Caretaker at home	5	11.22612034	2.24522407	1.26	0.2821
B5 Highest education level of parent/guardian	4	2.42365899	0.60591475	0.34	0.8510
B6 Marital status of parent/guardian	3	5.39880209	1.79960070	1.01	0.3892
B7 Does parent/guardian work?	1	1.52824527	1.52824527	0.86	0.3555
B8 Household wealth quintile	2	10.03230362	5.01615181	2.81	0.0618
B9Q1 Household owns TV	1	5.65764548	5.65764548	3.17	0.0760
B9Q2 Household owns refrigerator	1	6.76139695	6.76139695	3.79	0.0526
B9Q3 Household owns car	1	0.23349144	0.23349144	0.13	0.7178
B9Q4 Household owns music/video/radio player	1	0.39131895	0.39131895	0.22	0.6399
B9Q5 Household owns satellite dish	1	0.00435924	0.00435924	0.00	0.9606
B9Q6 Household owns washing machine	1	0.52442918	0.52442918	0.29	0.5881
B9Q7 Household owns telephone	1	7.43277883	7.43277883	4.17	0.0422
B9Q8 Household has access to tap water	1	6.89737337	6.89737337	3.87	0.0503
B9Q9 Household has access to water closet	1	1.04034651	1.04034651	0.58	0.4457
B9Q10 Household has access to electricity	1	0.18285936	0.18285936	0.10	0.7491

The summary of the one-way Analysis of Variance (ANOVA) results is reported in Table 4.46, which reveals that there is a significant difference at the 10% (0.10) level in geometry achievements by virtue of age (prob=0.0004<0.10), ethnicity (prob=0.079

8<0.10), household wealth quintile (prob=0.0618<0.10), household ownership of TV (prob=0.0760 <0.10), household ownership of refrigerator (prob=0.0526<0.10), access to telephone (prob= 0.0422< 0.10), and household access to tap water (prob=0.0503<0.10). These findings suggest relatively significant differences in geometry achievements on the basis of these factors.

#### 4.11.2 Research Question 8

- Are there any differences in the geometry achievements in relation to learning practices and norms?

Table 4.47: ANOVA Tests of Differences between Geometry Achievements by Virtue of Learning Practices and Norms

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
C1 Geometry tests examine what is done in class	3	86.75696964	28.91898988	38.26	<.0001
C2 Geometry assessment similar to what is taught in class	3	69.88805705	23.29601902	30.82	<.0001
C3 Aware of how geometry assessment is marked	3	27.97682034	9.32560678	12.34	<.0001
C4 Geometry educator explains how assessment is used	3	19.73446857	6.57815619	8.70	<.0001
C5 Understand what is needed in geometry assessment tasks	3	87.25272655	29.08424218	38.48	<.0001
C6 Geometry educator tells in advance WHEN going to be assessed	3	46.32750081	15.44250027	20.43	<.0001
C7 Geometry educator tells in advance WHAT going to be assessed	3	15.15721801	5.05240600	6.68	0.0002
C8 Clear about what geometry educator wants in assessment tasks	3	49.40414198	16.46804733	21.79	<.0001

The one-way Analysis of Variance (ANOVA) results is reported in Table 4.47 show that there is a significant difference at the 0.05 level in geometry achievements by virtue of all the eight learning practices and norms – that is, the prob-values are all less than 0.05.

These findings suggest significant differences in geometry achievements on the basis of these factors.

#### 4.11.3 Research Question 9

- Are there any differences in the geometry achievements in relation to classroom environment?

The one-way Analysis of Variance (ANOVA) results presented in Table 4.48 reveal that there is a significant difference at the 0.05 level in geometry achievements by virtue of all the ten statements on learning environment – that is, the prob-values are all less than 0.05. These findings suggest significant differences in geometry achievements depending on the learning environment.

Table 4.48: ANOVA Tests of Differences between Geometry Achievements by Virtue of Environment

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
D1 I am friendly to geometry classmates	3	13.70956113	4.56985371	3.69	0.0123
D2 I work well with other geometry classmates	3	35.06659078	11.68886359	9.45	<.0001
D3 Learners in my geometry class like me	3	22.49523435	7.49841145	6.06	0.0005
D4 My geometry educator goes all out to assist me	3	29.55132986	9.85044329	7.96	<.0001
D5 My geometry educator has interest in my geometry-related problems	3	27.01307459	9.00435820	7.28	0.0001
D6 We discuss ideas in geometry class	3	25.19484035	8.39828012	6.79	0.0002
D7 I freely give my opinions during geometry class	3	24.73160764	8.24386921	6.66	0.0002
D8 I ask my geometry educator questions in class	3	30.76181334	10.25393778	8.29	<.0001
D9 I pay attention during geometry class	3	27.47744461	9.15914820	7.40	<.0001
D10 I always try to understand the work in geometry class	3	28.86444285	9.62148095	7.77	<.0001

#### 4.11.4 Research Question 10

- Are there any differences in the geometry achievements in relation to learner attitude towards geometry?

At the 0.05 level, there is a significant difference in geometry achievements by virtue of learner attitudes toward geometry (Table 4.49). That is, the prob-values are all less than 0.05. These findings suggest significant differences in geometry achievements on the learning environment.

Table 4.49: ANOVA Tests of Differences between Geometry Achievements by Virtue of Learner Attitudes toward Geometry

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
E1 I always look forward to geometry class	3	48.30109009	16.10036336	22.78	<.0001
E2 Geometry lessons are fun	3	41.38576895	13.79525632	19.52	<.0001
E3 I enjoy the activities we do during geometry class	3	58.76478659	19.58826220	27.71	<.0001
E4 I feel pleased with what I learn in geometry	3	70.42334496	23.47444832	33.21	<.0001
E5 I can do even the hardest work in geometry if I try	3	64.65128719	21.55042906	30.49	<.0001
E6 Even if geometry is hard, I can learn it	3	82.80826157	27.60275386	39.05	<.0001
E7 I am certain I can figure out how to do the difficult geometry tasks	3	48.85854957	16.28618319	23.04	<.0001

#### 4.11.5 Research Question 11

- Are there any differences in the geometry achievements in relation to learner views about the geometry educator?

At the 0.05 level, there is a significant difference in geometry achievements by virtue of learner views about their geometry educator, except the proposed view that success in geometry depends on the subject educator (Table 4.50). That is, the prob-values of the F-values of the two statements - *my current geometry educator knows and teaches the subject extremely well* (F1) and *my confidence in my geometry ability increases when I have a subject educator who teaches the subject well* (F3) - are less than 0.05. These findings suggest significant differences in geometry achievements on the basis of these two statements regarding learner views about their geometry educator.

Table 4.50: ANOVA Tests of Differences between Geometry Achievements by Virtue of Learner Views about Geometry Educator

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
F1 My current geometry educator knows and teaches the subject extremely well	3	22.23496798	7.41165599	4.11	0.0071
F2 My success in geometry depends on the subject educator	3	5.06211352	1.68737117	0.93	0.4242
F3 My confidence in my geometry ability increases when I have a subject educator who teaches the subject well	3	33.84324714	11.28108238	6.25	0.0004

## 4.12 Predicting Learner Achievement in Geometry

### 4.12.1 Prediction and Effects from Background-Socioeconomic Construct

#### Research Question 12

- Are there any significant relationships between learner background characteristics and learner achievement in geometry?

A multinomial logistic regression analysis was conducted to determine which factor or combination of factors was the best predictor of learner achievement in geometry. Appendix 2A displays the initial Maximum Likelihood Analysis of Variance results from the multinomial regression analysis. From the results, it appears that only A1 (gender), A3 (age), B7 (employment status of parents/guardian), and B9Q7 (household access to telephone) have general effects on learner achievement in geometry at the significance level of 0.05.

The model was re-estimated using the four significant factors A1, A3, B7, and B9Q7, and a summary of results reported in Table 4.51 (see Appendix 2B for complete results). From Table 4.51, the four factors included in the model are all significant at the 0.05 level, except for B7, whose probability value of 0.0679, does not differ much from 0.05.

Table 4.51: Final Multinomial Logistic Regression Results using Background Construct

Maximum Likelihood Analysis of Variance					
Source		DF	Chi-Square	Pr > ChiSq	
Intercept		4	24.62	<.0001	
A1 Gender		4	17.05	0.0019	
A3 Age		4	22.75	0.0001	
B7 Does parent/guardian work?		4	8.74	0.0679	
B9Q7 Household owns telephone		4	11.69	0.0198	
Likelihood Ratio		56	55.91	0.4781	
Analysis of Maximum Likelihood Estimates					
Parameter		Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	Average	-8.7839	5.1098	2.95	0.0856
	Fairly poor	-11.3957	4.4495	6.56	0.0104
	Good	3.8082	4.1565	0.84	0.3596
	Poor	-15.6539	4.7517	10.85	0.0010
A1 Gender	Average	-0.9168	0.5713	2.58	0.1085
	Fairly poor	-1.6661	0.4939	11.38	0.0007
	Good	-0.1089	0.4359	0.06	0.8027
	Poor	-1.2709	0.5300	5.75	0.0165
A3 Age	Average	0.5499	0.3719	2.19	0.1392
	Fairly poor	0.8389	0.3244	6.68	0.0097
	Good	-0.2298	0.3014	0.58	0.4458
	Poor	1.1275	0.3449	10.69	0.0011
B7 Does parent/guardian work?	Average	1.6485	0.7433	4.92	0.0266
	Fairly poor	0.5920	0.7325	0.65	0.4190
	Good	0.0874	0.7578	0.01	0.9082
	Poor	0.4342	0.8359	0.27	0.6034
B9Q7 Household owns telephone	Average	0.0162	0.5452	0.00	0.9763
	Fairly poor	1.0979	0.4270	6.61	0.0101
	Good	-0.0337	0.4283	0.01	0.9373
	Poor	0.5675	0.4695	1.46	0.2268

The Analysis of Maximum Likelihood Estimates reveals evidence of non-proportional effects of the factors that predict learners' achievement in geometry.

- The coefficients of A1 in the two significant models are all negative. Gender, therefore, appears to decrease the odds of achieving a 'fairly poor' or 'poor' grade in geometry compared to achieving a 'very good' grade.
- The coefficients of A3 in the two significant models are all positive, suggesting that age increases the odds of achieving a 'fairly poor' or 'poor' grade in geometry comparing to achieving a 'very good' grade.
- The coefficient of B7 in the only significant model is positive, suggesting that the 'employee status of parents/guardian' increases the odds of a learner achieving an 'average' grade in geometry compared to achieving a 'very good' grade.
- The coefficient of B9Q7 in the only significant model is positive. This suggests that 'household ownership of telephone' increases the odds of a learner achieving a 'fairly poor' grade in geometry compared to achieving a 'very poor' grade.

#### **4.12.2 Prediction and Effects from Views on Learning Practices and Norms Construct**

##### **Research Question 13**

- Learner achievement in geometry can be predicted from the construct of learning practices and norms as well as predicting the effects of such factors on learner geometry achievement grade.

The initial Maximum Likelihood Analysis of Variance results from the multinomial regression analysis reported in Appendix 3A suggest only C1 (views about geometry tests being done on what is taught in class) has significant effect on learner achievement in geometry at the significance level of 0.05. The prob-values for C2 and C5 also do not

differ much from the 0.05 level suggesting that C2 (whether geometry assessments are similar to what is taught in class) and C5 (learner level of understanding in what is needed in geometry assessment tasks) also have significant effects on learner achievement.

By re-estimating the model using the three significant factors C1, C2, and C5, a summary of results reported in Table 4.52 (Appendix 3B contains the complete results).

Table 4.52: Final Multinomial Logistic Regression Results using Learning Practices and Norms Construct

Maximum Likelihood Analysis of Variance					
Source		DF	Chi-Square	Pr > ChiSq	
Intercept		4	51.66	<.0001	
C1 Geometry tests examine what is done in class		4	16.39	0.0025	
C2 Geometry assessment similar to what is taught in class		4	13.67	0.0084	
C5 Understand what is needed in geometry assessment tasks		4	17.06	0.0019	
Likelihood Ratio		184	208.71	0.1022	
Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	Average	4.8513	1.1583	17.54	<.0001
	Fairly poor	6.3490	1.0645	35.57	<.0001
	Good	2.5480	1.0312	6.11	0.0135
	Poor	6.8567	1.1229	37.29	<.0001
C1 Geometry tests examine what is done in class	Average	-0.6419	0.2412	7.08	0.0078
	Fairly poor	-0.7521	0.2175	11.95	0.0005
	Good	-0.3331	0.2077	2.57	0.1088
	Poor	-0.7751	0.2357	10.81	0.0010
C2 Geometry assessment similar to what is taught in class	Average	-0.5923	0.2661	4.95	0.0260
	Fairly poor	-0.6505	0.2389	7.42	0.0065
	Good	-0.0756	0.2280	0.11	0.7400
	Poor	-0.6021	0.2587	5.41	0.0200
C5 Understand what is needed in geometry assessment tasks	Average	-0.4673	0.2612	3.20	0.0737
	Fairly poor	-0.6292	0.2337	7.25	0.0071
	Good	-0.2502	0.2171	1.33	0.2491
	Poor	-0.9802	0.2581	14.43	0.0001

The Maximum Likelihood Analysis of Variance results in Table 4.52, the three factors included in the model are all significant at the 0.05. The Analysis of Maximum Likelihood Estimates reveals evidence of non-proportional effects of the factors that predict learners' achievement in geometry.

- The coefficients of C1 in the three significant models are all negative. Views about geometry tests being done based on what is taught in class, therefore, appears to decrease the odds of achieving an 'average', 'fairly poor' or 'poor' grade in geometry compared to achieving a 'very good' grade.
- The coefficients of C2 in the two significant models are all negative, suggesting that C2 decreases the odds of achieving an 'average' or 'fairly poor' grade in geometry comparing to achieving a 'very good' grade.
- The coefficients of C5 in the three significant models are all negative, suggesting that the C5 decreases the odds of a learner achieving an 'average', 'fairly poor', and 'poor' grade in geometry compared to achieving a 'very good' grade.

#### **4.12.3 Prediction and Effects from Learning Environment Construct**

##### **Research Question 14**

- Can learner achievement in geometry be predicted from the construct of classroom environment as well as predicting the effects of such factors on learner geometry achievement grade?

The preliminary results in Appendix 4A suggest D2 (views on whether a learner works well with other geometry classmates) and D6 (views on whether learners discuss ideas in geometry class) have significant effects on learner achievement in geometry at the significance level of 0.05. However the prob-values for D4 (views on whether a learner's



geometry educator goes all out to assist him/her) does not differ much from the 0.05 level suggesting that D4 also has a significant effect on learner achievement.

The summary of re-estimating the model using the three significant factors D2, D4, and D6, presented in Table 4.53 confirms that the three factors included in the model are all significant at the 0.05 level (Appendix 4B contains the complete results).

Table 4.53: Final Multinomial Logistic Regression Results using Learning Environment Construct

Maximum Likelihood Analysis of Variance					
Source		DF	Chi-Square	Pr > ChiSq	
Intercept		4	20.81	0.0003	
D2 I work well with other geometry classmates		4	14.62	0.0056	
D4 My geometry educator goes all out to assist me		4	14.36	0.0062	
D6 We discuss ideas in geometry class		4	12.33	0.0151	
Likelihood Ratio		188	181.58	0.6180	
Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	Average	2.7426	1.0786	6.47	0.0110
	Fairly poor	3.4106	0.9457	13.01	0.0003
	Good	1.3366	0.9516	1.97	0.1601
	Poor	3.8259	0.9946	14.80	0.0001
D2 I work well with other geometry classmates	Average	0.0743	0.2783	0.07	0.7895
	Fairly poor	-0.2047	0.2342	0.76	0.3821
	Good	-0.3960	0.2249	3.10	0.0782
	Poor	-0.7827	0.2495	9.84	0.0017
D4 My geometry educator goes all out to assist me	Average	-0.7332	0.2396	9.37	0.0022
	Fairly poor	-0.4480	0.2104	4.53	0.0332
	Good	-0.0547	0.2101	0.07	0.7945
	Poor	-0.4176	0.2253	3.44	0.0638
D6 We discuss ideas in geometry class	Average	-0.3910	0.2244	3.04	0.0814
	Fairly poor	-0.3850	0.1945	3.92	0.0478
	Good	0.1580	0.1973	0.64	0.4233
	Poor	-0.0890	0.2134	0.17	0.6767

The Analysis of Maximum Likelihood Estimates show non-proportional effects of the factors that predict learners' achievement in geometry.

- The coefficients of D2 in the two significant models are all negative, suggesting that learner views about whether they work well with other geometry classmates appears to decrease the odds of achieving a 'good' or 'poor' grade in geometry compared to achieving a 'very good' grade.
- The coefficients of D4 in the two significant models are all negative, suggesting that the views on whether geometry educator goes all out to assist learners decreases the odds of achieving an 'average' or 'fairly poor' grade in geometry comparing to achieving a 'very good' grade.
- The coefficients of D6 in the only significant model is negative, suggesting that learners view on whether they discuss ideas in geometry class decreases the odds of a learner achieving a 'fairly poor' grade in geometry compared to achieving a 'very good' grade.

#### **4.12.4 Prediction and Effects from Attitude toward Geometry Construct**

##### **Research Question 15**

- Can learner achievement in geometry be predicted from the construct of learner attitude towards geometry as well as predicting the effects of such factors on learner geometry achievement grade?

The preliminary results in Appendix 5A show that only E6 (views learners hold that even if geometry is hard, they can learn it) has a significant effect on learner achievement in geometry at the significance level of 0.05. However the prob-value for E4 (views on whether a learner feels pleased with what he/she learns in geometry) does not differ much from the 0.05 level suggesting that E4 also has a significant effect on learner

achievement. The summary of re-estimating the model using the four significant factors E4 and E6, reported in Table 4.54 (Appendix 5B contains the complete results) confirms that the two factors included in the model are all significant at the 0.05. The Analysis of Maximum Likelihood Estimates shows that:

Table 4.54: Final Multinomial Logistic Regression Results using Attitude towards Geometry Construct

Maximum Likelihood Analysis of Variance					
Source	DF	Chi-Square	Pr > ChiSq		
Intercept	4	40.97	<.0001		
E4 I feel pleased with what I learn in geometry	4	15.58	0.0036		
E6 Even if geometry is hard, I can learn it	4	18.22	0.0011		
Likelihood Ratio	52	65.01	0.1062		
Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	Average	3.2262	1.0398	9.63	0.0019
	Fairly poor	5.2223	0.9406	30.83	<.0001
	Good	2.7454	0.9529	8.30	0.0040
	Poor	5.0750	0.9728	27.22	<.0001
E4 I feel pleased with what I learn in geometry	Average	-0.8653	0.2864	9.13	0.0025
	Fairly poor	-0.9993	0.2593	14.85	0.0001
	Good	-0.7206	0.2499	8.31	0.0039
	Poor	-0.8291	0.2752	9.08	0.0026
E6 Even if geometry is hard, I can learn it	Average	-0.2378	0.2910	0.67	0.4139
	Fairly poor	-0.5806	0.2565	5.12	0.0236
	Good	0.0177	0.2556	0.00	0.9449
	Poor	-0.8143	0.2711	9.02	0.0027

- Learners' level of agreement to the statement that they are pleased with what they learn in geometry (E4) appears to decrease the odds of achieving an 'average', 'fairly poor', 'good' or 'poor' grade in geometry compared to achieving a 'very good' grade.

- Learners' level of perception that even if geometry was hard, they can still learn it (E6) decreases the odds of achieving a 'fairly poor' or 'poor' grade in geometry comparing to achieving a 'very good' grade.

#### 4.12.5 Prediction and Effects from Perception about Subject Educator Construct

##### Research Question 16

- Can learner achievement in geometry be predicted from learner views about geometry educators as well as predicting the effects of such factors on learner geometry achievement grade?

The preliminary results in Appendix 6A reveal that two factors could have significant effects on learner achievement in geometry at the significance level of 0.05 – F1 (level of agreement with the statement that learners current geometry educators know and teach the subject extremely well) and F3 (learners level of agreement with the statement that their confidence in their geometry ability increases when they have subject educators who teach the subject well). The summary of the re-estimating the model using the four significant factors E4 and E6, reported in Table 4.55 confirms that the two factors included in the model are all significant at the 0.05 level (Appendix 6B contains the complete results). The Analysis of Maximum Likelihood Estimates shows that:

- Learners' level of agreement to the statement that their current geometry educators know and teach the subject extremely well (F3) appears to decrease the odds of achieving a 'fairly poor' grade in geometry compared to achieving a 'very good' grade.
- Learners' level of agreement to the statement that their confidence in their geometry ability increases when they have a subject educator who teaches the

subject well (F3) decreases the odds of achieving a ‘fairly poor’, ‘good’ or ‘poor’ grade in geometry comparing to achieving a ‘very good’ grade.

Table 4.55: Final Multinomial Logistic Regression Results using Perception about Subject Educator Construct

Maximum Likelihood Analysis of Variance					
Source		DF	Chi-Square	Pr > ChiSq	
Intercept		4	25.52	<.0001	
F1 My current geometry educator knows and teaches the subject extremely well		4	9.45	0.0509	
F3 My confidence in my geometry ability increases when I have a subject educator who teaches the subject well		4	14.25	0.0065	
Likelihood Ratio		44	41.89	0.5624	
Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	Average	2.9011	1.5016	3.73	0.0534
	Fairly poor	6.0142	1.2964	21.52	<.0001
	Good	3.7843	1.3074	8.38	0.0038
	Poor	5.0387	1.3518	13.89	0.0002
F1 My current geometry educator knows and teaches the subject extremely well	Average	-0.3621	0.2864	1.60	0.2061
	Fairly poor	-0.6662	0.2456	7.36	0.0067
	Good	-0.2143	0.2485	0.74	0.3886
	Poor	-0.3947	0.2655	2.21	0.1372
F3 My confidence in my geometry ability increases when I have a subject educator who teaches the subject well	Average	-0.5563	0.3507	2.52	0.1127
	Fairly poor	-0.9889	0.3017	10.74	0.0010
	Good	-0.7193	0.2988	5.80	0.0161
	Poor	-1.0608	0.3134	11.45	0.0007

### 4.13 Concluding Remarks

This chapter has presented and discussed, in detail, findings from the data. Particular attention was paid to ensure that the research questions set out Chapter 1 were thoroughly addressed. In Chapter Five, summary of the findings from the study, conclusions and recommendations will be presented.

## CHAPTER FIVE

### DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Introduction

The primary objective of this study has been to explore the antecedents of Grade 8 and Grade 9 learners' geometry achievement at Sol Plaatje Secondary School in Mmabatho, South Africa, as well as predicting learner achievements on the basis of five constructs – learner background characteristics, learner socioeconomic and sociodemographic characteristics, learner opinions about learning practices and norms, learner opinions about the environment for learning geometry, learner attitudes toward geometry, and learner views about geometry educators.

#### 5.2 Validity and Reliability of the Constructs

The data were first analyzed to determine the validity and reliability of the constructs, in terms of its factor structure, internal consistency, reliability, and ability to differentiate between grades.

- The task of assessing the sufficiency of a construct was based on the application of the Kaiser Measure of Sampling Adequacy (MSA) with a cut-off value of 0.5 (50%). By applying the Kaiser MSA, all five constructs were found to be statistically sufficient.
- In assessing the adequacy of a construct, confirmatory factor analyses were carried out. A cut-off value of 0.35 was used to select items from a construct. By applying this technique, all five constructs were found to be statistically adequate.

- In assessing the internal consistency of a construct, Cronbach alpha coefficient analysis was used with a threshold of 0.70. Using this technique, all five constructs were statistically found to be consistent.
- To assess the validity of a construct, the Statistical Discriminant Analysis (SDA) was appealed to. Here, the ability to predict the grade in which observations fall was used as a yardstick. The use of the SDA revealed that all five constructs were statistically valid.

### **5.3 Learner Background, Socioeconomic and Sociodemographic Characteristics**

- In all 328 learners were involved in the study - 170 Grade 8 learners and 158 Grade 9 learners.
- The ages of participating learners ranged between 13 years and 17 years. Most of the learners were 14-year olds (170) and 15-year olds (106).
- The majority (90%) of the 328 learners were of African origin followed distantly by Coloureds (4%).
- Most of the participating learners (269 or 82%) were Tswana-speaking followed by English-speaking learners (31 or 10%).
- Most (76%) of the learners indicated they lived in Mafikeng/Mmabatho.
- The majority (48%) indicated that they used public transport while 34% also indicated that family cars were used as a form of transportation to and from school.
- When learners were asked to indicate the type of house they live in, the majority (47%) said they lived in 3-bedroom houses.

- Nearly 75% of the participating learners said they were been taken care of by their mothers/fathers.
- The highest level of education of most (40%) of the participating learners' parents/guardian was certificate/diploma/first degree.
- 90% of the learners said their parents/guardians were fully employed while the remaining 10% said they lived with unemployed parents/ guardians.
- Most (65%) of the participating learners said they lived with married parents/guardians followed by 26% who indicated they lived with single or divorced parents/guardians.
- Nearly 60% of the learners described their households as middle income while 23% of the learners described their households as low income.

#### 5.4 Relationship between Learner Achievement in Geometry and the Constructs

Pearson correlation analyses were used to determine whether relationships existed between learner achievements in geometry and each of the five constructs.

- The results of the Pearson correlation analysis of the 'Learner Background Characteristics' provided evidence of significant correlation achievements in geometry and *age*.
- The Pearson correlation analysis of the 'Learner Socioeconomic and Sociodemographic Characteristics' revealed evidence of significant correlation between geometry achievements and each of the following – *household wealth quintile, ownership of telephone, household ownership of TV, household ownership of refrigerator, and household access to tap water*.
- The Pearson correlation analysis of the 'Learner Opinions about Learning Practices and Norms' suggested significant correlation between geometry

achievements and each of the eight items - *geometry tests examine what is done in class; geometry assessment similar to what is taught in class; I am aware of how geometry assessment is marked; geometry educator explains how assessment is used; I understand what is needed in geometry assessment tasks; geometry educator tells in advance WHEN learners would be assessed; geometry educator tells in advance WHAT learners would be assessed; and I am clear about what geometry educator wants in assessment tasks.*

- The Pearson correlation analysis of the 'Learner Opinions about the Environment for Learning Geometry' showed significant correlation between geometry achievements and each of the nine of the ten items - *I work well with other geometry classmates; Learners in my geometry class like me; My geometry educator goes all out to assist me; My geometry educator has interest in my geometry-related problems; We discuss ideas in geometry class; I freely give my opinions during geometry class; I ask my geometry educator questions in class; I pay attention during geometry class; and I always try to understand the work in geometry class.*
- The Pearson correlation analysis of the 'Learner Attitudes toward Geometry' revealed significant correlation between geometry achievements and all the seven items - *I always look forward to geometry class; Geometry lessons are fun; I enjoy the activities we do during geometry class; I feel pleased with what I learn in geometry; I can do even the hardest work in geometry if I try; Even if geometry is hard, I can learn it; and I am certain I can figure out how to do the difficult geometry tasks.*
- The Pearson correlation analysis of the 'Learner Views about Geometry Educators' suggested significant correlation between geometry achievements and two of the three items under this construct – *My current geometry educator knows and teaches the subject extremely well and My confidence in my geometry ability increases when I have a subject educator who teaches the subject well.*

## 5.5 Differences in Learner Achievement in Geometry and the Constructs

Since the dependent variable – learner achievement in geometry – was ordinal, one-way Analysis of Variance (ANOVA) was used to determine whether differences exist between learner achievements in geometry and each of the five constructs.

- The ANOVA test of learner achievement in geometry and the ‘Learner Background, Socioeconomic and Sociodemographic Characteristics’ construct revealed significant differences in the geometry achievement grades and *age, ethnicity, household wealth quintile, household ownership of TV, household ownership of refrigerator, household access to telephone, and household access to tap water.*
- The ANOVA test of learner achievement in geometry and the ‘Learner Opinions about Learning Practices and Norms’ construct revealed significant differences in the geometry achievement grades and all eight items under this construct – *geometry tests examine what is done in class; geometry assessment similar to what is taught in class; I am aware of how geometry assessment is marked; geometry educator explains how assessment is used; I understand what is needed in geometry assessment tasks; geometry educator tells in advance WHEN going to be assessed; geometry educator tells in advance WHAT going to be assessed; and I am clear about what geometry educator wants in assessment tasks.*
- The ANOVA test of learner achievement in geometry and the ‘Learner Opinions about the Environment for Learning Geometry’ construct established significant differences in the geometry achievement grades and all the ten items under this construct – *I am friendly to geometry classmates, I work well with other geometry classmates; Learners in my geometry class like me; My geometry educator goes all out to assist me; My geometry educator has interest in my geometry-related problems; We discuss ideas in geometry class; I freely give my opinions during*

*geometry class; I ask my geometry educator questions in class; I pay attention during geometry class; and I always try to understand the work in geometry class*

- The ANOVA test of learner achievement in geometry and the ‘Learner Attitudes toward Geometry’ construct found significant differences in the geometry achievement grades and all the seven items under this construct - *I always look forward to geometry class; Geometry lessons are fun; I enjoy the activities we do during geometry class; I feel pleased with what I learn in geometry; I can do even the hardest work in geometry if I try; Even if geometry is hard, I can learn it; and I am certain I can figure out how to do the difficult geometry tasks.*
- The ANOVA test of learner achievement in geometry and the ‘Learner Views about Geometry Educators’ construct established significant differences in the geometry achievement grades and all the two of the three items under this construct - *My current geometry educator knows and teaches the subject extremely well and My confidence in my geometry ability increases when I have a subject educator who teaches the subject well.*

## **5.6 Predicting Learner Achievement in Geometry**

Multinomial logistic regression analyses were conducted to determine which factor or combination of factors from a construct was the best predictors of learner achievement in geometry.

- Predicting from the ‘Learner Background, Socioeconomic and Sociodemographic Characteristics’ construct produced the following findings:
  - Gender was found to decrease the odds of achieving a ‘fairly poor’ or ‘poor’ grade in geometry compared to achieving a ‘very good’ grade.

- Age increases the odds of achieving a 'fairly poor' or 'poor' grade in geometry comparing to achieving a 'very good' grade.
  - Employee status of parents/guardian' increases the odds of a learner achieving an 'average' grade in geometry compared to achieving a 'very good' grade.
  - Household ownership of telephone increases the odds of a learner achieving a 'fairly poor' grade in geometry compared to achieving a 'very poor' grade.
- Predicting from the 'Views on Learning Practices and Norms' construct gave the following findings:
    - Learner views about geometry tests being done based on what is taught in class decrease the odds of achieving an 'average', 'fairly poor' or 'poor' grade in geometry compared to achieving a 'very good' grade.
    - Learner views on the statement that geometry assessments are similar to what is taught in class decreases the odds of achieving an 'average' or 'fairly poor' grade in geometry comparing to achieving a 'very good' grade.
    - Learner level of agreement with the statement that they understand what is needed in geometry assessment tasks decreases the odds of a learner achieving an 'average', 'fairly poor', and 'poor' grade in geometry compared to achieving a 'very good' grade.
  - Predicting from the 'Learner Opinions about the Environment for Learning Geometry' construct revealed the following findings:

- Learner views about whether they work well with other geometry classmates decrease the odds of achieving an ‘good’ or ‘poor’ grade in geometry compared to achieving a ‘very good’ grade.
  - Learner views on whether geometry educator goes all out to assist learners decreases the odds of achieving an ‘average’ or ‘fairly poor’ grade in geometry comparing to achieving a ‘very good’ grade.
  - Learner views on whether they discuss ideas in geometry class decreases the odds of a learner achieving a ‘fairly poor’ grade in geometry compared to achieving a ‘very good’ grade.
- Predicting from the ‘Learner Opinions Attitude toward Geometry’ construct revealed the following findings:
    - Learners’ level of agreement to the statement that they are pleased with what they learn in geometry decreases the odds of achieving an ‘average’, ‘fairly poor’, ‘good’ or ‘poor’ grade in geometry compared to achieving a ‘very good’ grade.
    - Learners’ level of perception that even if geometry was hard, they can still learn it decreases the odds of achieving a ‘fairly poor’ or ‘poor’ grade in geometry comparing to achieving a ‘very good’ grade.
  - Predicting from the ‘Learner Opinions Attitude toward Geometry’ construct revealed the following findings:
    - Learners’ level of agreement to the statement that their current geometry educators know and teach the subject extremely well decreases the odds of achieving a ‘fairly poor’ grade in geometry compared to achieving a ‘very good’ grade.

- Learners' level of agreement to the statement that their confidence in their geometry ability increases when they have a subject educator who teaches the subject well decreases the odds of achieving a 'fairly poor', 'good' or 'poor' grade in geometry comparing to achieving a 'very good' grade.

### **5.7 Recommendations and Suggestions for Future Research**

It is the hope of the researcher that this research study will indeed contribute towards better educational and geometry teaching and learning environments. Concrete findings do not mean that there is no space for further research. Suggestions being put forward by the researcher include the following:

- That, despite this significant contribution of this study to the field of learning in high schools, especially in the area of mathematics, an improvement of the instrumentation would be desirable to cover other relevant issues that may be necessary.
- That a larger and more diverse sample would provide further evidence to support the reliability and validity of the findings from this study.
- That the present study was restricted to investigating learner achievement in geometry. It would be desirable for future research to include the perceptions of mathematics educators across a variety of high schools.
- That the results of the present study have investigated learner achievements only in one area of mathematics, that is, geometry. It would be meaningful for future studies to include achievement outcomes in other areas of mathematics including algebra, calculus, probability, and simple statistical analysis.

## 5.8 Concluding Remarks

This research study was designed to investigate the antecedents of high school geometry achievements, choosing specifically Grade 8 and Grade 9 learners from Sol Plaatje Secondary School in Mmabatho, South Africa. Findings from the study revealed a number of problem areas as well as factors that contribute to the learner achievement in geometry. As established from the study, the understanding of geometry at the two grades appeared to be assimilated, connected and grasped by many of the learners, even though it was also evident that some learners were unable to understand the geometry concepts, as they lack the prerequisite knowledge. Several other learners had misunderstandings which can be modified.

One of the main accomplishments of this study was the establishment of factors that contribute to the learner achievement in geometry. Also, the common difficulties in the learners' understanding of geometry were discovered. Possible directions for future research were identified. Finally, we hope that the study will indeed contribute towards more educational and geometry environments.

## REFERENCES

- Best, J. W., and Khan, J. V. (1993). *Researcher in Education*. London: Allyn and Bacon
- Biggs, J.B. (1987). *Student Approaches to Learning and Studying*. Melbourne: Australian Council for Educational Research
- Biggs, J.B. (1993). 'What do Inventories of Students' Learning Processes Really Measure? A Theoretical Review and Clarification'. *British Journal of Educational Psychology*, vol. 63, pp 3–19
- Bishop A.J. (1986). 'What are Some Obstacles to Learning Geometry?' in *Studies in Mathematics Education 10: U.N.E.S.C.O, Morris, R., (Ed)*, pp 141-159
- Bransford, J.D., Brown, A.L., and Cocking, (Ed). (1999). *How People Learn; Brain, Mind, Experience and School*. Washington, DC: National Press
- Brodie, K.W., Carpenter, L.A., Earnshaw, R.A., Gallop J.R., Hubbard R.J., Mumford, A.M., Osland, C.D., and Quarendon P. (1992). *Scientific visualization*. Berlin, Germany: Springer-Verlag
- Burger, W.F., and Shanghnessy, J.M. (1986). 'Characterizing the Van Hiele Levels of Development in Geometry'. *Journal for Research in Mathematics Education*, vol. 17 (1), pp 31-48
- Carmines, J. E. and Zeller F.L. (1979). *Methods of Meta-Analysis: Correcting Errors and Bias in Research Findings*. Newbury Park, CA: Sage
- Chinnappan, M. (1992). *Generative Activity in the Problem Space: A Comparative Analysis of Geometry Problem Solving Behaviour among High School Student*. Ph. D. Thesis, Flinders University, South Australia
- Clements, D. (2001). 'Teaching and Learning Geometry', in *Research Companion to the NCTM Standards for Mathematics*. Kilpatrick, J. (Ed.), Reston, VA: NCTM
- Czarnocha, B., Dubinsky. , Prabhu, V., and Vidakovic, D. (1999). 'One Theoretical Perspective in Undergraduate Mathematics Education Research', in *Proceeding of the 23rd. conference of the international group for Psychology of mathematics education*, Zaslavsky, O. (Ed.), vol. 1, pp 95-110

De Villiers, M. (1999). *Rethinking Proof with the Geometry Sketchpad*, Emeryville, CA: Key Curriculum Press

Department of Education, (2002). *Revised National Curriculum Statement Policy (School) Grade R-7: Mathematics*. Pretoria: Department of Education

Dubinsky, E. (1991). 'Reflective Abstraction in Advanced Thinking', in *Advanced Mathematics Thinking*, Tall, D. (Ed.), pp 95-123, Dordrecht, The Netherlands: Kluwer

'Education'. (1982). In 'The World Book Dictionary', p 670. Chicago, U.S.A: World Book Inc

Entwistle, N., Tait, H., and Mccune, V. (2000). 'Patterns of Response to Approaches to Studying Inventory across Contrasting Groups and Contexts'. *European Journal of Psychology of Education*, vol. 15, pp 33-48

Ernest, P. (1989). 'The Knowledge, Belief and Attitudes of Mathematics Teacher: A Model'. *Journal of Education for Teaching*, vol. 15, pp 13-33

Ferguson, P.D., and Fraser J. (1999). 'Changes in Learning Environment During the Transition from Primary to Secondary School'. *Learning Environment Research*, vol. 1, pp 369-383

Fey, J., Atchison, W.F., Good, R.A., Heid, M.K., Johnson, J., Kantowski, M.G., and Rosen, L.P. (1994). *Computing and Mathematics: The Impact on Secondary School Curricula*. College Park, MD: University of Maryland

Fishbein, E. (1993). 'The Theory of Figural Concept'. *Educational Studies in Mathematics*, vol. 24, pp 139-162

Fraser, B.J. (2000). 'Twenty Thousand Hours: Editor's introduction'. *Learning Environment Research*, vol. 4, pp 1-5

Fraser, B.J. (1998). 'Classroom Environment Instrument: Development, Validity and Application. *Learning Environment Research*, vol 1(1), pp 7-33

Fraser, B.J., and Tobin, K.G., (Eds). (1998). *Qualitative and Quantitative Landscape of Classroom Learning Environments*. UK: Kluwer Academic Publishers

Freudenthal, H. (1973). *Mathematics as an Education Task*. Dordrecht, The Netherlands: D. Reidel

Fuys, D., Geddes, D., and Tischler, R. (1988). *The Van Hiele Model of Thinking in Geometry among Adolescent*. Reston, VA: The National Council of Teachers of Mathematics

Goh, S.C., and Fraser, B.J. (1998). 'Teacher Interpersonal Behaviour, Classroom Environment and Student Outcomes in Primary Mathematics in Singapore'. *Learning Environment Research*, vol. 1, pp 199-229

Greaves, M. (2002). *The Philosophical Status of Diagrams*. Stanford, CA: CSLI

Grouws, D.A., (Ed). (1995). *Mathematics Learning and Knowing: A Cognitive Process Journal of Education*, vol. 177 (1)

Henderson, D.G., Fisher, D.L., Fraser, B.J. (1998). 'Learning Environment, Student's Attitudes and Other Effects of Student Sex and Other Science Study in Environmental Science Class'. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA

Hilbert, D. (1971). *Foundation of Geometry*, 2nd Ed. La Salle, IL: Open Court

Hoffer, A. (1981). 'Geometry is More Than Proof'. *Mathematics Teacher*, vol. 74, pp 11-18

Hoffer, A. (1983). 'Van Hiele-Based Research', in *Acquisition of Mathematics Concept and Processes*, Lesch, R., and Landan, M. (Eds.). New York: Academic Press

Jaworski, B., and Wood, T.L. (1999). 'Themes and Issues in Service Programmes', In *Mathematics Teachers Education: Critical International Perspective*, Jaworski, J., Wood, T.L., and Dowson, S. (Eds). London; Falmer press.

Koehler, M.S., and Grouws, D.A. (1992). 'Mathematics Teaching Practice and Their Effects', in *Handbook of Research on Mathematics Teaching and Learning: A Project of the National Council of Teachers of Mathematics*, Grouws, D.A. (Ed.). New York: Macmillan.

Kong, S., and Kwok, L. (1999). 'An Intensive Teaching and Learning Environment for Graph Sketching'. *Computers and Education*, vol. 32, pp 1-17

Lawrie, C. (1998). *An Investigation into Assessment of Student's Van Hiele levels of Understanding in Geometry*. Doctorial dissertation, University of New England, Australia

- Marlino, M.R. (1997). 'Science Education, Scientific Literacy and Technology: Issues and Promises'. Paper presented at the ASCILITE 1997, Perth, Australia
- Mitchelmore M.C. (1983). 'Geometry and spatial learning some lessons from a Jamaican experience. *For the Learning of Mathematics*, vol. 3(3), pp 2-7
- Mitchelmore, M.C. (2002). 'The Role of Obstraction and Generalization in Development of Mathematical Knowledge'. EARCOME (2002) Proceedings, vol. 1, pp 157-167
- Mvore, R.C. (1994). 'Making the Transition to Formal Proof'. *Educational Studies in Mathematics*, vol. 27(3), pp 249-266
- Nachlieli, T. (1998). 'Concepts and Figures in Geometrical Reasoning'. *International Journal of Science Education*, vol. 20(10), pp 1193-1211
- National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards*. Reston, VA: Author
- Nunnally, J. C. (1978). *Psychometric (2<sup>nd</sup> Ed)*. New York: McGraw-Hill
- Pegg, J. and Davey, G. (1991). 'Levels of Geometrical Understanding'. *Australian Mathematics Teacher*, vol. 47, pp 10-13
- Phillips, R.B. (1973). 'Teacher Attitude as Related to Students Attitude and Achievement in Elementary School Mathematics'. *School Science and Mathematics*, vol. 73, pp 501-507
- Polya, G. (1973b). *Mathematics and Plausible Reasoning*. Princeton, NJ: Princeton University Press
- Principles and Standards for School Mathematics. (2000). Reston, VA: National Council of Teachers of Mathematics.
- Prosser, M., and Trigwell, K. (1999). *Understanding Teaching and Learning*. Buckingham: Open University Press
- Ramsden, P. (Ed). (1988). *Improving Learning: New perspectives*, London: Kogan Page

Relich, J., Way, J., and Martin, A. (1994). 'Attitudes to Teaching Mathematics: Further Development of a Measuring Instrument'. *Mathematics Education Research Journal*, vol. 6(1), pp 56-69

Rosier, M. J. (1980). *Changes in Secondary School Mathematics in Australia, 1964-1978*. Hawthorn, Victoria: Australian Council for Educational Research

Joint Mathematics Council. (2001). *Teaching and Learning Geometry*. London: Joint Mathematical Council

Sadler-Smith, E. (1996). 'Approaches to Studying: Age, Gender and Academic Performance'. *Educational Studies*, vol. 22, pp 367-380

Schnister, S. (1971). 'Geometry: A Potpourri'. *Ridel Publication Dordrecht*, vol. (4), pp 76-86

Sfard, A. (1991). 'On the Dual Nature of Mathematics Conception: Reflection on Processes and Object as Different Sides of the Same Coin'. *Educational Studies in Mathematics*, vol. 22, pp 1-36

Shulman, L.S. (1986). 'Those Who Understand'. *Knowledge Growth in Teaching*, vol.5, pp 4- 14

Spear, W.R. (1998). 'Ideas', *Arithmetic Teacher*, vol. 40, pp 397-404

Speering, W., and Rennie, L. (1996). 'Students Perception about Science: The Impact of Transition from Primary to Secondary School'. *Research in science Education*, vol. 26(3), pp 283-298

Suydam, M.N., and Weaver, J.F. (1975). Research on Mathematics Education (K12) Reported in 1974. *Journal for Research in Mathematics Education*, vol 8, pp 253-282

Tall, D. (1999). 'Reflection on APOS Theory in Elementary and Advanced Mathematical Thinking', in *Proceeding of the 23<sup>rd</sup> Conference of the International Group of Psychology of Mathematics Education*, Zaslavsky, O., (Ed.), vol.1, pp 111-118

Teppo, A. (1991). 'Van Hiele Levels of Geometric Thought Revisited'. *Mathematics Teacher*, vol. 84, pp 210-221

Van Hiele, P.M. (1986). *Structure and Insight: A Theory of Mathematics Education*. Orlando, FL.: Academic Press

Van Hiele, P.M., and Van G .D. (1958). *A Method of Initiation into Geometry at Secondary Schools*. In H. Freudenthal (Ed), Groningen. The Netherlands pp 67-80

Vermetten, Y.J., Vermunt, J.D., and Lodewijks, H. G. (1999). 'A Longitudinal Perspective on Learning Strategies in Higher Education: Different Viewpoints towards Development'. *British Journal of Educational Psychology*, vol. 69, pp 221-242

Waldrup, B.G., and Fisher, D.L. (2003). 'Identifying Exemplary Science Teachers Through Their Classroom Interaction with Students'. *Learning Environment Research*, vol. 6, pp 157-174

Webb, P. (1998). *The Nature and Impact of Accredited In-Service Education on Under-specified Science and Mathematics Teachers: Which Factors Generate Best Practices in the Classroom?* Johannesburg, Joint Education Trust

Wertheimer, M. (1986). *Productive Thinking*. John Dickens and Co.

Whitely, W. (1999). 'The Decline and Rise of Geometry in 20<sup>th</sup> Century North America', in *Proceeding of the 1999 Conference of the Mathematics Education Study Group of Canada*

Willson, W.W. (1977). *The Mathematics Curriculum: Geometry*. Glasgow Blackie/School Council

Winslaw, C. (2000). 'Between Platonism and Constructivism: Is there a Mathematical Acquisition Device?' *For the Learning of Mathematics*, vol. 20(3), pp 12-22

Wood, D. (1999). *Assessing Progress and Process in Computer Based-Tutoring and Learning*. Edited Transcription of ACNTA Seminar. St. John College: Cambridge

Wubbles, T. (1993). *Teacher-Student Relationship in Science and Mathematics Classes*. Perth: Curtin University of Technology

Zachos, I. (1994). *Problem Solving in Euclidean Geometry in Greek Schools*. Leeds University

Zeitler, H. (1991). 'Axiomatics of Geometry in School and in Science'. *For the Learning of Geometry*, vol. 10(2), pp 17-24

## APPENDIX 2A

Data Summary			
Response	Achievement	Response Levels	5
Weight Variable	None	Populations	308
Data Set	MY_TK	Total Frequency	314
Frequency Missing	14	Observations	314

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	29.17	<.0001
A1	4	13.04	0.0111
A2	4	1.29	0.8626
A3	4	23.56	<.0001
A4	4	1.97	0.7415
B1	4	3.22	0.5216
B2	4	1.71	0.7882
B3	4	0.81	0.9364
B4	4	6.08	0.1932
B5	4	4.93	0.2942
B6	4	1.01	0.9084
B7	4	10.38	0.0345
B8	4	8.56	0.0730
B9Q1	4	8.54	0.0738
B9Q2	3*		
B9Q3	4	1.74	0.7842
B9Q4	4	8.22	0.0840
B9Q5	4	1.70	0.7915
B9Q6	4	1.97	0.7409
B9Q7	4	10.14	0.0382
B9Q8	4	6.87	0.1428
B9Q9	4	3.23	0.5204
B9Q10	4	3.15	0.5336
Likelihood Ratio	1E3	862.89	1.0000

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	-18.1269	6.7029	7.31	0.0068
	2	-21.5183	5.9435	13.11	0.0003
	3	-0.8239	5.3369	0.02	0.8773
	4	-26.9123	6.4523	17.40	<.0001
A1	1	-0.1319	0.6769	0.04	0.8455
	2	-1.3905	0.5548	6.28	0.0122
	3	0.3105	0.4862	0.41	0.5231
	4	-1.0422	0.6021	3.00	0.0834
A2	1	-0.1314	0.4805	0.07	0.7844
	2	-0.4494	0.4152	1.17	0.2790
	3	-0.1358	0.3691	0.14	0.7130
	4	-0.2515	0.4399	0.33	0.5675
A3	1	0.5594	0.4015	1.94	0.1636
	2	0.9390	0.3515	7.14	0.0075
	3	-0.2711	0.3200	0.72	0.3969
	4	1.2299	0.3772	10.63	0.0011
A4	1	0.0735	0.3338	0.05	0.8258
	2	-0.1676	0.3001	0.31	0.5765
	3	0.1802	0.2239	0.65	0.4210
	4	-0.0305	0.3046	0.01	0.9203
B1	1	0.5697	0.4653	1.50	0.2208
	2	0.3506	0.4113	0.73	0.3939
	3	-0.1099	0.3911	0.08	0.7788
	4	0.1842	0.4486	0.17	0.6814
	4	0.0995	0.3045	0.11	0.7437
B2	1	-0.2737	0.3009	0.83	0.3630
	2	-0.2136	0.2477	0.74	0.3886
	3	-0.1719	0.2126	0.65	0.4190
	4	-0.3211	0.2685	1.43	0.2318
B3	1	0.2871	0.3300	0.76	0.3844
	2	0.0793	0.2804	0.08	0.7774
	3	0.0976	0.2649	0.14	0.7127
	4	0.0995	0.3045	0.11	0.7437

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
B4	1	-0.2369	0.3161	0.56	0.4536
	2	0.0902	0.2547	0.13	0.7232
	3	-0.0466	0.2391	0.04	0.8455
	4	0.4141	0.2606	2.53	0.1120
B5	1	0.2436	0.2573	0.90	0.3439
	2	0.2793	0.2243	1.55	0.2130
	3	-0.0974	0.2067	0.22	0.6375
	4	-0.0400	0.2382	0.03	0.8665
B6	1	0.1392	0.3544	0.15	0.6945
	2	0.1082	0.3159	0.12	0.7320
	3	0.2817	0.2972	0.90	0.3433
	4	0.1526	0.3343	0.21	0.6480
B7	1	2.1098	1.0134	4.33	0.0374
	2	1.2053	0.9426	1.63	0.2010
	3	-0.4255	0.9398	0.21	0.6507
	4	-0.1135	1.0752	0.01	0.9159
B8	1	-1.2736	0.5001	6.48	0.0109
	2	-0.8669	0.4063	4.55	0.0329
	3	-0.5983	0.3683	2.64	0.1043
	4	-0.2793	0.4341	0.41	0.5200
B9Q1	1	2.3161	1.3479	2.95	0.0857
	2	1.5529	1.3200	1.38	0.2394
	3	-0.7121	1.3847	0.26	0.6071
	4	1.1262	1.3787	0.67	0.4140
B9Q2	1	6.6134	1.6389	16.28	<.0001
	2	7.9747	1.2613	39.98	<.0001
	3	5.9925#			
	4	7.9423	1.3521	34.51	<.0001
B9Q3	1	-1.1581	0.9670	1.43	0.2311
	2	-0.0462	0.6271	0.01	0.9412
	3	-0.2895	0.6205	0.22	0.6408
	4	-0.0591	0.6771	0.01	0.9305

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
B9Q4	1	-1.5139	1.0860	1.94	0.1633
	2	-1.9844	1.0469	3.59	0.0580
	3	0.4057	0.8213	0.24	0.6213
	4	-0.7883	1.0284	0.59	0.4434
B9Q5	1	-0.6059	0.5900	1.05	0.3045
	2	0.0715	0.4534	0.02	0.8746
	3	0.0428	0.4186	0.01	0.9185
	4	0.0630	0.4861	0.02	0.8969
B9Q6	1	0.4938	0.6176	0.64	0.4239
	2	-0.1236	0.5401	0.05	0.8190
	3	0.3686	0.4982	0.55	0.4594
	4	-0.0182	0.5684	0.00	0.9745
B9Q1	1	2.3161	1.3479	2.95	0.0857
	2	1.5529	1.3200	1.38	0.2394
	3	-0.7121	1.3847	0.26	0.6071
	4	1.1262	1.3787	0.67	0.4140
B9Q2	1	6.6134	1.6389	16.28	<.0001
	2	7.9747	1.2613	39.98	<.0001
	3	5.9925#			
	4	7.9423	1.3521	34.51	<.0001
B9Q3	1	-1.1581	0.9670	1.43	0.2311
	2	-0.0462	0.6271	0.01	0.9412
	3	-0.2895	0.6205	0.22	0.6408
	4	-0.0591	0.6771	0.01	0.9305
B9Q4	1	-1.5139	1.0860	1.94	0.1633
	2	-1.9844	1.0469	3.59	0.0580
	3	0.4057	0.8213	0.24	0.6213
	4	-0.7883	1.0284	0.59	0.4434
B9Q5	1	-0.6059	0.5900	1.05	0.3045
	2	0.0715	0.4534	0.02	0.8746
	3	0.0428	0.4186	0.01	0.9185
	4	0.0630	0.4861	0.02	0.8969

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
B9Q6	1	0.4938	0.6176	0.64	0.4239
	2	-0.1236	0.5401	0.05	0.8190
	3	0.3686	0.4982	0.55	0.4594
	4	-0.0182	0.5684	0.00	0.9745
B9Q7	1	-0.2138	0.5902	0.13	0.7172
	2	0.8926	0.4587	3.79	0.0516
	3	-0.3068	0.4579	0.45	0.5028
	4	0.5338	0.5035	1.12	0.2891
B9Q8	1	1.6779	1.4409	1.36	0.2442
	2	2.3018	1.2818	3.22	0.0725
	3	-0.1501	1.3655	0.01	0.9124
	4	1.7671	1.3354	1.75	0.1857
B9Q9	1	1.3531	0.9601	1.99	0.1587
	2	0.4335	0.9356	0.21	0.6431
	3	1.1257	0.8636	1.70	0.1924
	4	0.9586	0.9311	1.06	0.3032
B9Q10	1	-0.5669	1.2225	0.22	0.6428
	2	-1.5683	1.1804	1.77	0.1840
	3	-0.0140	1.0229	0.00	0.9891
	4	-1.1110	1.2499	0.79	0.3740

## APPENDIX 2B

Data Summary			
Response	Achievement	Response Levels	5
Weight Variable	None	Populations	19
Data Set	MY_TK	Total Frequency	322
Frequency Missing	6	Observations	322

Response Profiles	
Response	Greater
1	Average
2	Fairly poor
3	Good
4	Poor
5	Very good

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	24.62	<.0001
A1	4	17.05	0.0019
A2	4	22.75	0.0001
B7	4	8.74	0.0679
B9Q7	4	11.69	0.0198
Likelihood Ratio	56	55.91	0.4781

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	-8.7839	5.1098	2.95	0.0856
	2	-11.3957	4.4495	6.56	0.0104
	3	3.8082	4.1565	0.84	0.3596
	4	-15.6539	4.7517	10.85	0.0010
A1	1	-0.9168	0.5713	2.58	0.1085
	2	-1.6661	0.4939	11.38	0.0007
	3	-0.1089	0.4359	0.06	0.8027
	4	-1.2709	0.5300	5.75	0.0165
A3	1	0.5499	0.3719	2.19	0.1392
	2	0.8389	0.3244	6.68	0.0097
	3	-0.2298	0.3014	0.58	0.4458
	4	1.1275	0.3449	10.69	0.0011
B7	1	1.6485	0.7433	4.92	0.0266
	2	0.5920	0.7325	0.65	0.4190
	3	0.0874	0.7578	0.01	0.9082
	4	0.4342	0.8359	0.27	0.6034
B9Q7	1	0.0162	0.5452	0.00	0.9763
	2	1.0979	0.4270	6.61	0.0101
	3	-0.0337	0.4283	0.01	0.9373
	4	0.5675	0.4695	1.46	0.2268

NWU  
LIBRARY

### APPENDIX 3A

Data Summary			
Response	Achievement	Response Levels	5
Weight Variable	None	Populations	301
Data Set	MY_TK	Total Frequency	327
Frequency Missing	1	Observations	327

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	45.84	<.0001
C1	4	14.14	0.0069
C2	4	9.20	0.0562
C3	4	4.00	0.4059
C4	4	3.24	0.5187
C5	4	8.91	0.0634
C6	4	1.87	0.7600
C7	4	1.27	0.8660
C8	4	6.60	0.1587
Likelihood Ratio	1E3	884.04	1.0000

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	6.0186	1.4948	16.21	<.0001
	2	7.2956	1.3565	28.93	<.0001
	3	2.1187	1.2886	2.70	0.1001
	4	7.9779	1.4464	30.42	<.0001
C1	1	-0.6181	0.2500	6.11	0.0134
	2	-0.7053	0.2229	10.01	0.0016
	3	-0.3214	0.2095	2.35	0.1251
	4	-0.7680	0.2437	9.93	0.0016
C2	1	-0.5321	0.2811	3.58	0.0584
	2	-0.6044	0.2506	5.82	0.0159
	3	-0.1028	0.2373	0.19	0.6648
	4	-0.4749	0.2722	3.04	0.0811

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
C3	1	0.0628	0.2555	0.06	0.8059
	2	0.1436	0.2285	0.39	0.5299
	3	0.0440	0.2110	0.04	0.8349
	4	-0.2604	0.2466	1.11	0.2910
C4	1	-0.2877	0.2686	1.15	0.2840
	2	-0.2697	0.2406	1.26	0.2623
	3	0.00781	0.2274	0.00	0.9726
	4	-0.0249	0.2614	0.01	0.9241
C5	1	-0.2301	0.2855	0.65	0.4202
	2	-0.4625	0.2554	3.28	0.0702
	3	-0.2365	0.2402	0.97	0.3248
	4	-0.7831	0.2838	7.62	0.0058
C6	1	0.0127	0.3025	0.00	0.9665
	2	-0.0961	0.2685	0.13	0.7202
	3	-0.0929	0.2580	0.13	0.7189
	4	-0.3115	0.2853	1.19	0.2750
C7	1	0.0757	0.2902	0.07	0.7941
	2	0.1095	0.2584	0.18	0.6719
	3	0.2441	0.2422	1.02	0.3135
	4	0.2038	0.2807	0.53	0.4679
C8	1	-0.5863	0.2873	4.17	0.0412
	2	-0.4506	0.2571	3.07	0.0797
	3	-0.0639	0.2405	0.07	0.7904
	4	-0.3156	0.2801	1.27	0.2599

## APPENDIX 3B

Data Summary			
Response	Level	Response Levels	5
Weight Variable	None	Populations	50
Data Set	MY_TK	Total Frequency	327
Frequency Missing	1	Observations	327

Response Profiles	
Response	Achievement
1	Average
2	Fairly poor
3	Good
4	Poor
5	Very good

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	51.66	<.0001
C1	4	16.39	0.0025
C2	4	13.67	0.0084
C3	4	17.06	0.0019
Likelihood Ratio	184	208.71	0.1022

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	4.8513	1.1583	17.54	<.0001
	2	6.3490	1.0645	35.57	<.0001
	3	2.5480	1.0312	6.11	0.0135
	4	6.8567	1.1229	37.29	<.0001
C1	1	-0.6419	0.2412	7.08	0.0078
	2	-0.7521	0.2175	11.95	0.0005
	3	-0.3331	0.2077	2.57	0.1088
	4	-0.7751	0.2357	10.81	0.0010
C2	1	-0.5923	0.2661	4.95	0.0260
	2	-0.6505	0.2389	7.42	0.0065
	3	-0.0756	0.2280	0.11	0.7400
	4	-0.6021	0.2587	5.41	0.0200
C5	1	-0.4673	0.2612	3.20	0.0737
	2	-0.6292	0.2337	7.25	0.0071
	3	-0.2502	0.2171	1.33	0.2491
	4	-0.9802	0.2581	14.43	0.0001

## APPENDIX 4A

Data Summary			
Response	Achievement	Response Levels	5
Weight Variable	None	Populations	315
Data Set	MY_TK	Total Frequency	326
Frequency Missing	2	Observations	326

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	21.31	0.0003
D1	4	6.14	0.1891
D2	4	10.78	0.0291
D3	4	4.38	0.3565
D4	4	8.00	0.0917
D5	4	5.80	0.2147
D6	4	12.23	0.0157
D7	4	1.29	0.8631
D8	4	3.83	0.4299
D9	4	6.91	0.1410
D10	4	3.10	0.5405
Likelihood Ratio	1E3	915.48	1.0000

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	3.9882	1.4440	7.63	0.0057
	2	4.7992	1.2604	14.50	0.0001
	3	2.5668	1.2235	4.40	0.0359
	4	5.4829	1.3297	17.00	<.0001
D1	1	-0.0791	0.3169	0.06	0.8028
	2	0.5234	0.2887	3.29	0.0698
	3	0.0555	0.2657	0.04	0.8344
	4	0.3410	0.3015	1.28	0.2581
D2	1	0.1866	0.3036	0.38	0.5388
	2	-0.0891	0.2670	0.11	0.7385
	3	-0.3145	0.2554	1.52	0.2181
	4	-0.6729	0.2836	5.63	0.0177

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
D3	1	0.0943	0.2677	0.12	0.7246
	2	-0.0886	0.2346	0.14	0.7056
	3	0.3199	0.2247	2.03	0.1544
	4	-0.0309	0.2549	0.01	0.9035
D4	1	-0.4517	0.2925	2.38	0.1226
	2	-0.1543	0.2601	0.35	0.5529
	3	0.2673	0.2568	1.08	0.2980
	4	-0.0624	0.2740	0.05	0.8198
D5	1	-0.4126	0.3097	1.77	0.1828
	2	-0.1299	0.2759	0.22	0.6376
	3	-0.5436	0.2652	4.20	0.0404
	4	-0.3725	0.2892	1.66	0.1978
D6	1	-0.2710	0.2566	1.12	0.2909
	2	-0.2678	0.2295	1.36	0.2433
	3	0.3855	0.2275	2.87	0.0901
	4	0.0829	0.2491	0.11	0.7394
D7	1	-0.0645	0.2715	0.06	0.8123
	2	-0.1699	0.2363	0.52	0.4721
	3	-0.2442	0.2314	1.11	0.2913
	4	-0.1528	0.2606	0.34	0.5576
D8	1	-0.3762	0.2504	2.26	0.1330
	2	-0.3105	0.2180	2.03	0.1544
	3	-0.2190	0.2127	1.06	0.3032
	4	-0.4274	0.2428	3.10	0.0783
D9	1	0.0932	0.3044	0.09	0.7594
	2	-0.5014	0.2576	3.79	0.0516
	3	-0.1080	0.2543	0.18	0.6712
	4	-0.1202	0.2817	0.18	0.6695
D10	1	-0.1966	0.2960	0.44	0.5065
	2	-0.3523	0.2607	1.83	0.1766
	3	-0.2911	0.2551	1.30	0.2538
	4	-0.4637	0.2793	2.76	0.0969

## APPENDIX 4B

Data Summary			
Response	Achievement	Response Levels	5
Weight Variable	None	Populations	51
Data Set	MY_TK	Total Frequency	326
Frequency Missing	2	Observations	326

Response Profiles	
Response	Achievement
1	Average
2	Fairly poor
3	Good
4	Poor
5	Very good

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	20.81	0.0003
D2	4	14.62	0.0056
D4	4	14.36	0.0062
D5	4	12.33	0.0151
Likelihood Ratio	188	181.58	0.6180

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	2.7426	1.0786	6.47	0.0110
	2	3.4106	0.9457	13.01	0.0003
	3	1.3366	0.9516	1.97	0.1601
	4	3.8259	0.9946	14.80	0.0001
D2	1	0.0743	0.2783	0.07	0.7895
	2	-0.2047	0.2342	0.76	0.3821
	3	-0.3960	0.2249	3.10	0.0782
	4	-0.7827	0.2495	9.84	0.0017
D4	1	-0.7332	0.2396	9.37	0.0022
	2	-0.4480	0.2104	4.53	0.0332
	3	-0.0547	0.2101	0.07	0.7945
	4	-0.4176	0.2253	3.44	0.0638
D6	1	-0.3910	0.2244	3.04	0.0814
	2	-0.3850	0.1945	3.92	0.0478
	3	0.1580	0.1973	0.64	0.4233
	4	-0.0890	0.2134	0.17	0.6767

## APPENDIX 5A

Data Summary			
Response	Achievement	Response Levels	5
Weight Variable	None	Populations	272
Data Set	MY_TK	Total Frequency	327
Frequency Missing	1	Observations	327

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	44.25	<.0001
E1	4	2.59	0.6294
E2	4	2.40	0.6617
E3	4	8.25	0.0829
E4	4	8.36	0.0793
E5	4	7.03	0.1342
E6	4	10.08	0.0390
E7	4	6.05	0.1953
Likelihood Ratio	1E3	810.49	1.0000

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	3.9180	1.1625	11.36	0.0008
	2	5.8180	1.0474	30.85	<.0001
	3	3.0811	1.0526	8.57	0.0034
	4	6.2171	1.0868	32.73	<.0001
E1	1	0.3173	0.3302	0.92	0.3367
	2	0.3660	0.2914	1.58	0.2092
	3	0.1619	0.2672	0.37	0.5446
	4	0.0268	0.3134	0.01	0.9319
E2	1	0.2912	0.3329	0.77	0.3817
	2	0.2432	0.2999	0.66	0.4174
	3	0.0693	0.2757	0.06	0.8016
	4	-0.1230	0.3283	0.14	0.7079

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
E3	1	-0.8803	0.3586	6.03	0.0141
	2	-0.8399	0.3251	6.67	0.0098
	3	-0.6832	0.3059	4.99	0.0255
	4	-0.5463	0.3549	2.37	0.1237
E4	1	-0.6385	0.3284	3.78	0.0519
	2	-0.8320	0.2979	7.80	0.0052
	3	-0.6215	0.2826	4.83	0.0279
	4	-0.4707	0.3176	2.20	0.1384
E5	1	-0.6898	0.2951	5.47	0.0194
	2	-0.3335	0.2671	1.56	0.2117
	3	-0.1704	0.2462	0.48	0.4888
	4	-0.4787	0.2889	2.75	0.0975
E6	1	-0.2468	0.3156	0.61	0.4342
	2	-0.5714	0.2748	4.32	0.0376
	3	-0.0307	0.2709	0.01	0.9097
	4	-0.6304	0.2926	4.64	0.0312
E7	1	0.4985	0.2873	3.01	0.0827
	2	0.2027	0.2559	0.63	0.4282
	3	0.4795	0.2401	3.99	0.0458
	4	0.1268	0.2738	0.21	0.6432

## APPENDIX 5B

Data Summary			
Response	Achievement	Response Levels	5
Weight Variable	None	Populations	16
Data Set	MY_TK	Total Frequency	327
Frequency Missing	1	Observations	327

Response Profiles	
Response	Achievement
1	Average
2	Fairly poor
3	Good
4	Poor
5	Very good

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	40.97	<.0001
E4	4	15.58	0.0036
E6	4	18.22	0.0011
Likelihood Ratio	52	65.01	0.1062

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	3.2262	1.0398	9.63	0.0019
	2	5.2223	0.9406	30.83	<.0001
	3	2.7454	0.9529	8.30	0.0040
	4	5.0750	0.9728	27.22	<.0001
E4	1	-0.8653	0.2864	9.13	0.0025
	2	-0.9993	0.2593	14.85	0.0001
	3	-0.7206	0.2499	8.31	0.0039
	4	-0.8291	0.2752	9.08	0.0026
E6	1	-0.2378	0.2910	0.67	0.4139
	2	-0.5806	0.2565	5.12	0.0236
	3	0.0177	0.2556	0.00	0.9449
	4	-0.8143	0.2711	9.02	0.0027

## APPENDIX 6A

Data Summary			
Response	Achievement	Response Levels	5
Weight Variable	None	Populations	42
Data Set	MY_TK	Total Frequency	323
Frequency Missing	5	Observations	323

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	24.68	<.0001
F1	4	9.26	0.0549
F2	4	2.04	0.7276
F3	4	13.19	0.0104
Likelihood Ratio	152	162.54	0.2647

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	3.1838	1.5735	4.09	0.0430
	2	6.3447	1.3618	21.71	<.0001
	3	4.3072	1.3663	9.94	0.0016
	4	5.3636	1.4204	14.26	0.0002
F1	1	-0.3466	0.2879	1.45	0.2285
	2	-0.6481	0.2470	6.88	0.0087
	3	-0.1794	0.2503	0.51	0.4734
	4	-0.3771	0.2673	1.99	0.1583
F2	1	-0.1462	0.2445	0.36	0.5498
	2	-0.1707	0.2133	0.64	0.4235
	3	-0.2837	0.2005	2.00	0.1571
	4	-0.1683	0.2272	0.55	0.4590
F3	1	-0.5206	0.3544	2.16	0.1418
	2	-0.9479	0.3046	9.68	0.0019
	3	-0.6515	0.3016	4.67	0.0307
	4	-1.0198	0.3164	10.39	0.0013

## APPENDIX 6B

Data Summary			
Response	Achievement	Response Levels	5
Weight Variable	None	Populations	14
Data Set	MY_TK	Total Frequency	323
Frequency Missing	5	Observations	323

Response Profiles	
Response	Achievement
1	Average
2	Fairly poor
3	Good
4	Poor
5	Very good

Maximum Likelihood Analysis of Variance			
Source	DF	Chi-Square	Pr > ChiSq
Intercept	4	25.52	<.0001
F1	4	9.45	0.0509
F3	4	14.25	0.0065
Likelihood Ratio	44	41.89	0.5624

Analysis of Maximum Likelihood Estimates					
Parameter	Function Number	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	2.9011	1.5016	3.73	0.0534
	2	6.0142	1.2964	21.52	<.0001
	3	3.7843	1.3074	8.38	0.0038
	4	5.0387	1.3518	13.89	0.0002
F1	1	-0.3621	0.2864	1.60	0.2061
	2	-0.6662	0.2456	7.36	0.0067
	3	-0.2143	0.2485	0.74	0.3886
	4	-0.3947	0.2655	2.21	0.1372
F3	1	-0.5563	0.3507	2.52	0.1127
	2	-0.9889	0.3017	10.74	0.0010
	3	-0.7193	0.2988	5.80	0.0161
	4	-1.0608	0.3134	11.45	0.0007

**PART A: BACKGROUND FACTORS**

A1. What grade are you?

1	Grade 8	
2	Grade 9	

A2. Please indicate your gender:

1	Female	
2	Male	

A3. Please indicate your age in years: ..... Years

A4. Which of the following ethnic grouping do you associate yourself?

1	Black/African	
2	Coloured	
3	White	
4	Indian	
5	Other, please specify: .....	

A5. What language do you speak at home?

1	Tswana	
2	Afrikaans	
3	English	
4	Other, please specify: .....	

**PART B: SOCIOECONOMIC FACTORS**

B1. Which of the following best describes where you reside?

1	Mafikeng/Mmabatho resident	
2	Reside in a village around Mafikeng/Mmabatho	
3	Reside in informal settlement around Mafikeng/Mmabatho	

B2. Please indicate your mode of transport to and from school.

1	Family car	
2	Public transport	
3	By foot	
4	On bicycle	
5	Other, please specify: .....	

B3. What type of house do you live in?

1	1-bedroom house	
2	2-bedroom house	
3	3-bedroom house	
4	Other, please specify: .....	

B4. Who takes care of you at home?

1	Nobody	
2	Mother/Father	
3	Grandmother/Grandfather	
4	Brother/Sister	
5	Aunt/Uncle	
6	Other, please specify: .....	

B5. What is the highest level of schooling your parent(s)/guardian has completed?

1	None/Some primary	
2	Primary	
3	Secondary/Some tertiary	
4	Certificate/Diploma/First Degree	
5	Postgraduate degree	

B6. Please describe the marital status of your parent/guardian.

1	Married	
2	Single/Divorced	
3	Widow/Widower	
4	Cohabiting	

B7. Does any of your parents/guardian work?

1	Yes	
2	No	

B8. Please describe your household wealth quintile.

1	Low income	
2	Middle income	
3	High income	

B9. Does your household have the following assets and access to the following amenities?

	Yes	No
	1	2
Television		
Fridge		
Car		
Music/Video Player and Radio		
Satellite Dish		
Washing Machine		
Telephone (Land-line/Mobile)		
Tap Water		
Water closet		
Electricity		

### PART C: LEARNER PERCEPTION ABOUT GEOMETRY

Please indicate your level of agreement with the following questions on your perceptions about geometry assessment in class.

	Almost never	Sometimes	Often	Almost always
	1	2	3	4
My geometry homework/tests examine what I have done in class				
My assessment in geometry is similar to what the educator has taught me				
I am aware of how my assessment will be marked				
My subject educator explains to me how each type of assessment is to be used.				
I understand what is needed in all my geometry assessment tasks.				
My subject educator tells me in advance WHEN I am going to be assessed				
My subject educator tells me in advance WHAT I am going to be assessed				
I am clear about what my subject educator wants in my geometry assessment tasks				
When I am confused about how to complete a geometry assessment task, my subject educator allows another way to answer it				

**PART D: LEARNER OPINION ABOUT GEOMETRY**

Please indicate your level of agreement with the following questions on your opinions about your geometry class.

	Almost never	Sometimes	Often	Almost always
	1	2	3	4
I am friendly to my geometry classmates				
I work well with other geometry classmates				
Learners in my geometry class like me				
My subject educator in geometry goes all out to assist me				
My subject educator has interest in my geometry-related problems				
We discuss ideas in geometry class				
I freely give my opinions during geometry class				
I ask my geometry educator questions in class				
I pay attention during geometry class				
I always try to understand the work in the geometry class				

**PART E: LEARNER ATTITUDE ABOUT GEOMETRY**

Please indicate your level of agreement with the following questions on your opinions about your geometry class.

	Almost never	Sometimes	Often	Almost always
	1	2	3	4
I always look forward to geometry lessons				
Geometry lessons are fun				
I enjoy the activities we do during geometry lessons				
I feel pleased with myself with what I learn in geometry				
I can do even the hardest work in geometry if I try				
Even if geometry is hard, I can learn it				
I am certain I can figure out how to do the difficult geometry tasks				

**PART F: LEARNER PERCEPTION ABOUT GEOMETRY EDUCATOR**

Please indicate your level of agreement with the following questions on your perceptions about your geometry educator.

	Almost never	Sometimes	Often	Almost always
	1	2	3	4
My current geometry educator knows and teaches the subject extremely well				
My success in geometry depends on the subject educator				
My confidence in my geometry ability increases when I have a subject educator who teaches the subject well				

**PART G: BASELINE LEARNER ASSESSMENT IN GEOMETRY**

This section presents a short list of baseline assessment questions in geometry which seeks assess learners' ability in geometry. Please answer the following questions.

G1. From Figure 1, AB and CD are two straight lines such that the two are parallel.

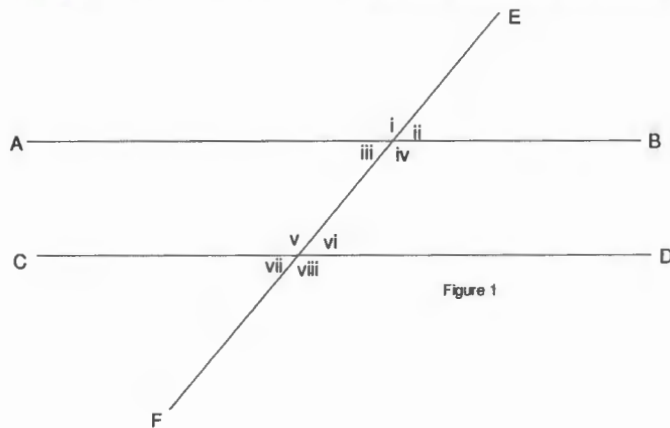


Figure 1

Identify the following from the diagram below, with reasons:

- a. Alternate angles
- b. Corresponding angles
- c. Vertical opposite angles
- d. Supplementary angles
- e. Co-interior angles

G2. From Figure 2, AB, CD, and EF are three straight lines such that the two are parallel. Find the values of g, k, p, w, x, y, and z.

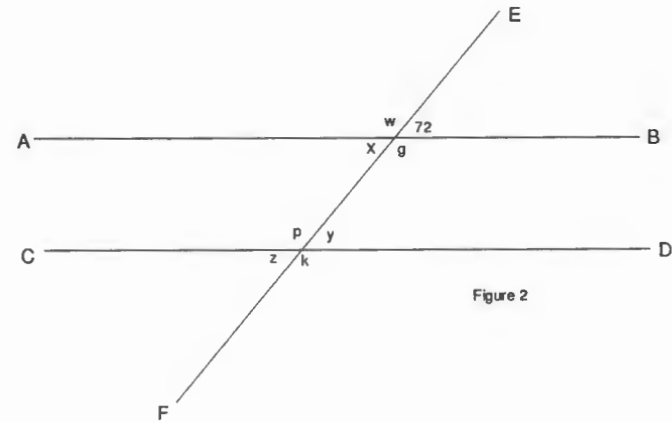


Figure 2

G3. From Figure 3, find the value of x.

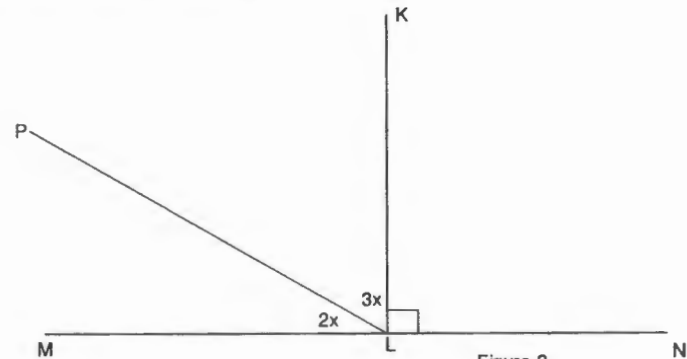


Figure 3

G4. From Figure 4, AB and CD are two straight lines. Find the value of  $x$  and  $m$ .

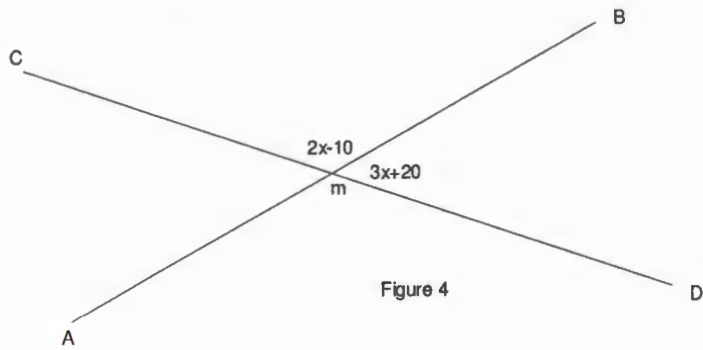


Figure 4

G5. From Figure 5, AB is a straight line. Determine the value of  $x$ .

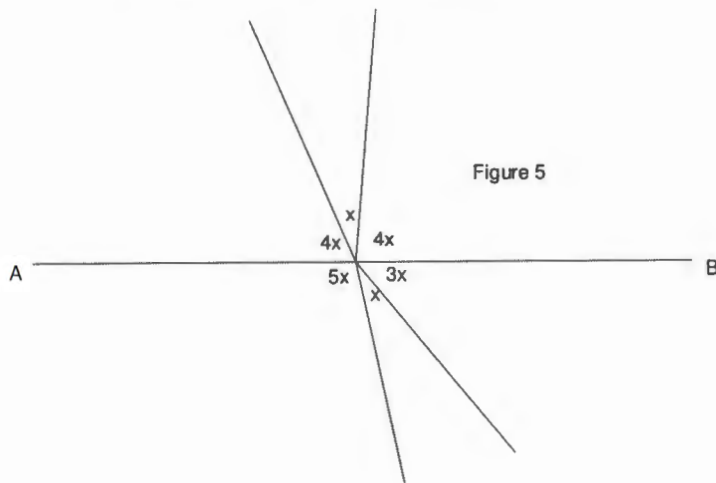


Figure 5

G7. From Figure 7, determine the value of  $x$  from triangle ABC.

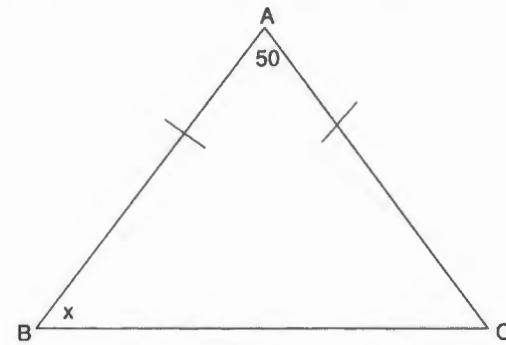


Figure 7

G8. From Figure 8, determine the value of  $x$  from triangle ABC.

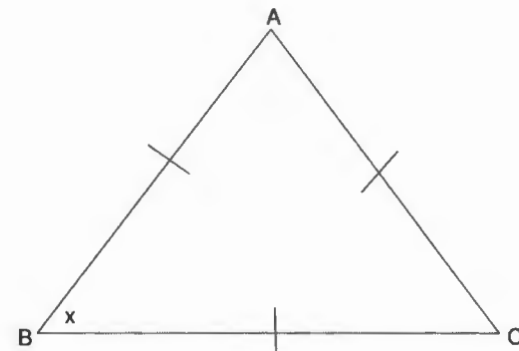
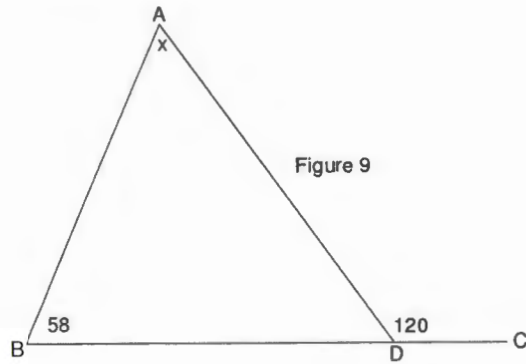
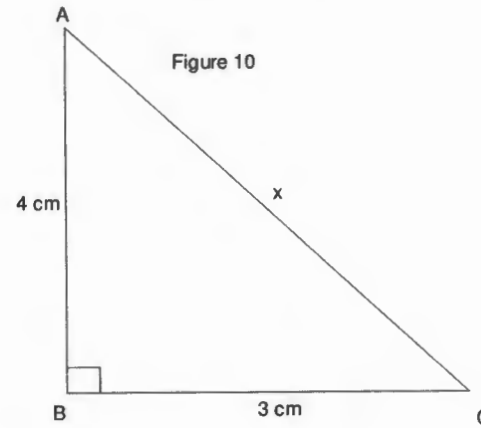


Figure 8

G9. From Figure 9, determine the value of  $x$ .



G10. From Figure 10, determine the length of the straight line  $AC$ .



Thank you for participating in this study!!!