CHAPTER   ONE

BACKGROUND AND OVERVIEW OF THE STUDY

1.1   INTRODUCTION AND PROBLEM STATEMENT

Algebra is a branch of mathematics, which studies the properties and relationships of quantities by the use of signs and symbols such as letters of the alphabet (Harber & Payton, 1979:25). Linear algebra is a branch of algebra, which is introduced in the school system from grades 6-10. The algebraic graphs are also taught within these grade levels (see section 2.2). At grade 9, the students have started learning how to draw a graph from a table of values, and to interpret the graph. But in the teaching and learning of linear algebra the learner must learn and understand how to choose a scale from a table of values so that he/she can understand the graph. Consequently, scaling is one of the skills necessary for constructing graphs. The inability of learners to use a scale properly in drawing graphs gives rise to some issues with the understanding of algebraic graphs.

In addition to the above, a test was designed to determine the pre-knowledge of grade 9 learners about scaling in algebraic linear graphs. The results from Task 1 in this study show that about 65% of the students could not draw the graph from a table of values neither could they interpret a graph showing that they have understood the algebraic graph. Although about 50% of the students were able to show that they know how to construct a table of values, their inability to choose or know how the scale of a given graph

drawn from a table of values is used, makes it difficult for them to understand the algebraic graph. Consequently, they were unable to:

(i)   Draw the graph by:
    (a) Plotting the correct points
    (b) Joining the points to make a straight line
    (c) Selecting appropriate axes
(ii)   Locate points on a graph
(iii)   Interpolate and extrapolate from the graph
(iv)   Interpret (describe the relationship between the variables), and interrelate the data display on the graphs
(v)   Predict from the graph

The mastery of the above highlighted points, based on a proper or correct choice of scale from a table of value, would indicate a substantial understanding of linear graphs (McKenzie 1986:573).

The study therefore seeks answers to the question:

- What is the influence of scaling in the understanding of algebraic graphs in grade 9?

1.2 AIMS OF THE RESEARCH

The primary aim of this research is to investigate the effects, which an appropriate choice of scale based on a table of values, has on the understanding of algebraic graphs for grade 9 learners. The objective of the study is to establish whether or not scaling has some influence in the understanding of algebraic graphs amongst grade 9 learners.

1.3 RESEARCH HYPOTHESIS

Null hypothesis:

To achieve the aim stated in paragraph 1.2, the following hypothesis is set: 'Using a scale to draw an algebraic linear graph can have an effect in the understanding of algebraic graphs at grade 9'.

1.4 RESEARCH DESIGN, STRATEGIES AND METHODOLOGY

The research design will consist of a literature study and an empirical investigation.

1.4.1 Review of the literature

A DIALOG search was performed with the following key words: Grade 9 learners, linear algebraic graph, scaling, table of values, construction, interpretation, prediction, teaching, learning, graphs, problem in understanding of algebraic graphs.

An intensive and comprehensive review of the relevant primary and secondary sources and electronic media was undertaken in order to identify the effects of scaling in the understanding of algebraic graphs for grade 9 learners.

Chapter 2 will investigate all these in a theoretical perspective.

1.4.2 Empirical investigation

The research was done in two grade 9 mathematics classes for mathematics, with twenty students randomly selected from each of the classes. The first twenty students formed the experimental group and the second twenty students from the other class formed the control group. They are referred to as Forms B1 and B2 respectively.

Ten questions were designed on scaling in linear algebraic graphs for grade 9 and administered to the forty students. This was the first task (Task 1). A 12-item questionnaire was designed and administered to the experimental group immediately after a teaching series of four weeks in two sessions on scaling. This was followed by interview 1 for four students in the experimental group. The second task (Task 2), comprising 15 questions, was administered to the two groups as well as a second interview (Interview 2) for the four students selected from the experimental group.

The aim of Task 1 was to identify the pre-knowledge of the students in scaling in linear algebraic graphs.

A teaching course on scaling in linear mapping and linear algebraic graphs was given to the experimental group and lasted for four weeks with two sessions per week. A questionnaire and interview were conducted for the experimental group as indicated above.

To collect and interpret the data, the following was adhered to:

All the physical materials such as the written calculations, records of interviews, drawings, worksheets and the responses made by the students to questionnaires were collected and categorized.

All the worksheets and other written data arising from the interview were either interpreted quantitatively or qualitatively depending on the nature of the data.

1.5 RESEARCH LAYOUTS AND PROCEDURE

 The aim of the research is to investigate the influence of scaling in the understanding of algebraic graphs for grade 9 learners. The objective of the research is to establish the fact that scaling has influence in the understanding of algebraic graphs at grade 9. In chapter one the theme of the research is introduced. Chapter 2 focuses on a literature review using primary, secondary and electronic media sources in a theoretical perspective. The method of research is discussed in chapter 3 while the results of the statistical analyses of the data and the interpretation of results are discussed in chapter 4. In chapter 5, the summary of findings are discussed and

conclusions drawn are presented. The review of the literature is summarized and the limitations and recommendations of the study are discussed.

CHAPTER TWO

THE IMPORTANCE OF SCALING IN THE LEARNING AND UNDERSTANDING OF ALGEBRAIC GRAPHS FOR GRADE 9 LEARNERS

2.1 INTRODUCTION

To understand graphs requires that learners must be able to construct, interpret, and use graphs to make predictions. Construction involves going from the raw data (or abstract function) through the process of selection of axes, scaling, identification of units, interpolation, extrapolation and plotting (Leinhardt, Zaslavsky, & Stein 1990:1-64). Construction could be local, such as plotting a number of points, or global, such as completing a number of graphs given some points. The local construction is associated with quantitative construction in which two points could be given to satisfy the equation $y = mx + c$. The global construction is associated with the qualitative construction where a graph of a given situation could be sketched (see section 2.3.1.1.).

The interpretation of a graph refers to the action by which students make sense of or deduce meaning from a graph or portion of a graph. It requires looking at the entire graph or part of it and deducing meaning from the relationship between the two variables and in particular the pattern of the covariations. By covariation, we mean the differences that exist between the two variables.

Prediction refers to the action of conjecturing from a given part of a given graph when other points (explicitly given or plotted) of the graph should be allocated, or what other parts of the graph should look like (Leinhardt et al 1990:13).

In terms of understanding graphs, scaling falls under their construction. Therefore in this chapter we shall discuss the grade 9 learners and the content of algebraic graphs in this grade (see section 2.2.). This will be followed by an analysis of scaling in section 2.3. This section 2.3 has been divided into three subsections 2.3.1, 2.3.2 and 2.3.3 which deals with, scaling in the context of algebraic linear graphs, how scale is used in algebraic linear graphs and choosing a scale for a table of values respectively. The factors involved which affect the learners' understanding of algebraic linear graphs, will be discussed in section 2.4 and the analysis of the problems in the understanding of algebraic graphs in section 2.5.

In order for the learner to learn and understand how to use scaling to construct algebraic linear graphs, there is the need to identify which teaching

methods can facilitate the learning of linear graphs. This will be discussed in section 2.6. The conclusion to this chapter will be discussed in section 2.7

2.2 THE GRADE 9 (FORM B) LEARNERS AND THE CONTENT OF ALGEBRAIC GRAPHS FOR GRADE 9 LEARNERS.

In Lesotho, the grade 9 learners are the students in form B, who have completed their first year (Form A) in a secondary school.

The school system is divided into secondary and high school phases. The secondary school phase lasts for three years. The pupils who have completed standard 5 or grade 7 in primary school start their secondary education in grade 8, or form A. This is the stage at which algebra is being introduced to the students (Narainsamy 1998). Therefore, grade 9 is the second year in secondary education.

The contents of the topic of the algebraic graph for grade 9 learners are:

- Solution of linear equations and inequalities
- Graphical solutions of linear equations and two linear mapping, parallel to the axes (Form B Mathematics syllabus of Lesotho 2000)

The assessment objectives state that candidates should at the end of the lessons have the ability to:

1. Recognise the appropriate mathematical procedures for a given situation;

2. Perform calculations using suitable methods; with or without calculations aids;

3. Use the common system of units;

4. Estimate, approximate and use an appropriate degree of accuracy;

5. Interpret, use and present information in written, graphical, diagrammatic and tabular form;

6. Use geometrical instruments;

7. Recognise and apply spatial relationships in two or three dimentsions;

8. Recognase patterns and structures in a variety of situations in ordered form and justify generalisations;

9. Understand and use mathematical language and symbols to present mathematical arguments in a logical and clear fashion;

10. Apply and interpret mathematics in a variety of situations, including daily life;

11. Formulate problems into mathematical terms.

The Assessment objectives that are relevant to this research study are numbers 1, 2, 3, 4, 5, 8 and 10. In other words the learning of algebraic graphs by scaling requires students to recognise the appropriate mathematical procedures necessary for constructing the graph of a given situation, perform calculations using suitable methods with or without calculating aids, use the common system of units, estimate and aproximate using an appropriate degree of accuracy, and interpret, use and present information in written, graphical, diagrammatical and tabular forms. In the event sound teaching and learning have taken place, the learners should be able to apply what they have learnt in everyday life.

2.3 ANALYSIS OF SCALING IN TERMS OF GRAPHING IN ALGEBRA

In this aspect of the study, not much research has been carried out. Most of the literature consulted has concentrated on the construction, interpretation and predictions of graphing. In the construction of graphs Leinhardt, Zaslavsky and Stein (1990) identified four tasks necessary for the construction of graphs so that one can understand, interpret and make predictions from the graph: They are the scaling, classification, translation and prediction.

The *scaling task* is one of the tasks, which; if perform properly, could help one to appropriately construct a graph as well as interpret it, and make predictions from it. The scaling task could either be interpretational or constructional and it involves decisions regarding choosing a scale and unit that are characteristic in a particular domain of graphing (Leinhardt et al 1990:4). Therefore the scaling issued arises, as one wants to construct and give meaning to a graph with a view to facilitate understanding.

The *prediction task* is the action of conjecturing from a given part of the graph where other points (not explicitly given or plotted) of the graph should be located (Leinhardt et al 1990:13). Prediction can be mentally or physically carried out. Prediction task relies on construction, estimation and sometimes on measurement skills as well as on pattern detection. For example, calculating the average age of some students from a graph requires interpolation if the pattern of lines on the graph does not provide enough

10

quantitative information to determine exactly the average age of the students. This requires prediction from the graph. Furthermore, if the coordinates of the targeted points cannot be read off from the graph, this requires prediction so that one can be able to estimate by interpolation and obtain the required information.

The *classification task* refers to the action by which we (a) decide whether a particular relation is a function; (b) identifying a function among other relations; (c) identify a special kind of function among other function (Leinhardt et al 1990:15). In an algebraic graph, series of graphs of linear functions may be constructed either from one relation or from different By *translation,* we mean (a) the act of recognizing the same function or graphing different forms of representations; and/or (b) identifying a specific transformation of a function in one representation and its corresponding transformation in another representation (Kaput 1987:187-207); and/or (c) constructing one representation of a function, given another one. Thus the translation task can rely primarily either on interpretation or on construction. For example, the graph of a straight line, which passes through the origin, has a zero intercept. And if the coefficient of an equation of a line is negative, it translates the line into a decreasing straight line with negative slope. The translation task is fundamental to the concept of function, which has both strong graphical and nongraphical aspects, since the graphical representation can be translated into algebraic coefficients or vice versa (Leinhardt et al 1990:16).

Leinhardt et al (1990) refers to scale as the assignment of values to intervals

between the lines on the Cartesian system. In two-dimensional graphs, there are two decisions, one for the horizontal or X-axis and the other for the vertical or Y-axis. The unit notion is also connected to scale. It refers to a thing that is counted or measured. Unit is an issue in a situated context and its nature influences the interpretation and plausibility of results and the type of variables used (Leinhardt et al 1990:4). By situation, I am referring to the context of the graph and the setting in which the graph is being used, e.g. the science laboratory, mathematics class etc.

The variables are the objects of the functions and graphs; they are the data, both concrete and abstract. In a two-dimensional graph, the variables may be in the same form or in different forms. By form I am referring to the property of the unit, whether it is categorical, ordinal, an interval or ratio (Leinhardt et al 1990). The variables may be continuous or discrete but for this study we are concerned with the discrete variable. The categorical, ordinal and interval forms are associated with the discrete variable

Hornby (2000:1048) defined scale as a range of values forming a system of measurement or grading to represent the value of the item being measured. He further stressed that in terms of graphing, scale is a series of marks at regular intervals, e.g. the ruler and axes on Cartesian graphs, for the purpose of measurement in order to be able to represent the situations under consideration. The situations being represented or measured may be of different units and with scaling they can be appropriately represented on the graph, e.g. one centimetre represents three maloti on the x-axis. The scale chosen will enable us to construct, modify, interpret and make

predictionfrom the graphs. This could lead to a better understanding of the meaning of the graph with regards to the situation it represents.

Hornby further reported that scaling could also be seen as a relation between the actual size of an object and a map or diagram, e.g. one centimetre represents 10 kilometres. In this respect, scales permit one to choose axes, plot the points and give the opportunity for one to discover more solutions so that one could interpret and understand the graph.

Bertin (1983:296), regarding an investigation on dimensional identification in the representation of lines, points and areas, reported that: a situational identification, by relating the map to a region whose size is familiar, can lead to an approximate evaluation of the dimensions of the space being represented. And the most precise and rapid evaluation is provided by scale. According to him 'scale' expresses ' the relationship between the linear dimensions of the sheet of paper and the dimensions of the space being represented (Bertin 1983:296). There are different types of scale used in general construction, such as the graphic scale, fractional scale, the grid, known shape, distance, etc. But for this study, we shall concern ourselves with the graphic scale.

The graphic scale utilizes an image of known length, the centimetre, the metre, the kilometre etc and can be drawn in the simplest possible way with a worksheet where space is lacking (Bertin 1983:296). The diagram below represents a scale of 2cm on the worksheet representing 10km on the table or coordinates.

0	10	20	30	40	50

This is an example of a scale, which can be used for measurement in an algebraic graph. The notion of scale acquires particular importance when a study involves several graphical constructions, and the opportunity to use the graph for problem solving can easily be realized.

2.3.1 Scaling in the context of algebraic linear graphs
2.3.1.1 Scaling and construction, interpretation and prediction

Bednarz et al (1996:289) in their research on the role of Cartesian graphs in the CARAPACE environment (Software package for solving linear equations by graphical method) reported that students lack the ability to choose and understand what scale was used to construct a graph. Because of this the students cannot find the meaning inherent in a graph, neither are they able to interpret graphs. Although their research was concerned with how to use the computer in drawing linear graphs or Cartesian graphs, they pointed out that the ability of the students to understand or choose scales for constructing a graph allows them to plot the points correctly and hence they can draw the best line of fit, and by changing the scales, most fractions within or between the numbers on the axes can be seen. Hence one can modify or change the nature and shape or size of the graphs. This will result in obtaining multiple solutions from the graph, and in so doing a better understanding of it can be achieved.

In terms of construction, Leinhardt et al (1990:1-64) researched the task, learning and teaching of functions, graphs and graphing. They reported that construction involves going from raw data (or abstract functions) through the process of selection and labelling of axes, selection of scale, and identification of unit, interpolation, extrapolation and plotting. To them, construction could be local (e.g. plot a number of points) or global (complete a number of graphs, given certain points). The construction of a graph could also be quantitative or qualitative. The quantitative construction could be an equation, $y = mx + b$, given two points that satisfy the equation (see section 2.1). The qualitative construction could be to sketch a graph of a situation (Leinhardt et al 1990: 13). Therefore, in the construction of a graph, the following tasks must be carried out so that one can understand and make predictions from the graph: the scaling, translation, prediction and classification tasks, which have already been mentioned.

Research conducted by Mevarech and Kramarsky (1997: 228-261) examined alternative conceptions in students' stability and change from verbal description to graphic representations. The study shows that students, while constructing graphs to represent a given situation, conserved the shape of an increasing line by repairing the X or Y – axis, i.e. the scale could be changed to include more values or values that were not initially represented. In the classroom context, Zemira and Brancha's report is very common among our learners. Some may even rescale the axes of non-sequential units to enable them to mark off the values on the axes so that they can adequately represent the data on the graph while constructing it. The scaling and

rescaling enable students to resolve any misconception and encourage a clear conception of the situation, which the graph represents. Hence, Leinhardt et al (1990) are supported here in their view that prediction relies on construction of a graph. A precise prediction can be made from a graph by scaling and rescaling and drawing a series of graphs to represent the situation in question, so that one can perceive the full meaning, which the

The term 'interpretation of a graph', refers to the action by which the students make sense of or gain meaning from a graph (or a portion of a graph), a functional equation or a situation (Leinhardt et al 1990:8). Just as in construction, interpretation could be local and specific or global and general. An example of global and general interpretation is: what happens to X as Y increases? An example of local and specific is: how do the bacteria hange after 5 hours? Both answers may require getting the information from a graph drawn to scale as well as from table of value

Furthermore, interpretation could be quantitative or qualitative. A quantitative interpretation is associated with a local and specific interpretation while a qualitative interpretation is associated with global and general interpretations of graphs. The qualitative interpretations require looking at the entire graph (or part of it) and gaining meaning about the relationship between the two variables and in particular, their pattern of covariations (Leinhardt et al 1990).

 The prediction made from a graph drawn by scaling, refers to the action of conjecturing from a given part of a graph where other points (not explicitly

given or plotted) of the graph should be allocated or how other parts of the graph should look (Leinhardt et al 1990:13). Predictions can occur when

construction and could be done either mentally or physically, but are much easier from a graph drawn by scaling. Other skills, which predictions rely on, are the estimation and pattern detection. At this juncture, the point reported by Leinhardt et al is necessary and important because most co-ordinates of the target points cannot be read off the graph due to the scale chosen and the units represented on the axis. Furthermore Leinhardt et al reported that prediction could be done from ordered pairs. According to them this task could be approached by numerical interpolation. But the classroom experience shows that prediction is fraught with some problems. Most students in making predictions from ordered pairs, will mistakenly represent the value of the vertical axes in place of the horizontal axis and therefore may not be able to understand the situation. Even when they are asked to interpret the ordered pairs on a graph, the same mistake will occur, as most students tend to read off the values of the vertical axis on the horizontal axis, and the horizontal axis on the vertical axis. This will render the graph meaningless and so learners may not be able to understand it. Therefore predicting from a graph drawn to scale from a table of a value will resolve this problem, provided a sound teaching and learning approach is employed.

Bednarz et al (1996), while examining the role of Cartesian graphs in the CARAPACE environment, supported the idea of making predictions from a graph by zooming-in and zooming-out, which will allow the number or unit not represented on the axis to be seen and equally change the shape or size of the graph so that one can interpret and make prediction from the graph.

The idea was also supported by Brassell (1987). According to him, replotting points after changing the scale of the axes led students to realize the elements that are invariant in the plotting of a point as well as those that depend on the scale chosen (Bednarz et al 1996: 289)

2.3.1.2 Scaling and table of values/order of pair

The research conducted by the National center for Research in mathematical sciences Education in Mathematics in context (1998:4-36) on graphing equations examines the role of ordered pairs, tables of values and scales in the representations of graphing equations. The research affirmed that situations could be represented as ordered pairs and on tables. The values on the table will enable one to choose the scale and units to be represented on the axes so that the graph can be adequately represented. In a comparative study of the wages earned by factory workers and home workers, the values obtained were gained from as much as 600 workers. This number has to be represented on a graph of 30 cm vertically and 18 cm horizontally. They therefore reported that the choice of an appropriate scale was necessary to represent this information on the graph. Bertin (1983:296) supported this view by stating that a scale expresses the relationship between the linear dimension of the sheet of paper and the value being represented. This is a strong point that should be upheld in teaching and learning. The graph will not be adequately represented if an appropriate scale is not chosen so that the data can be adequately represented and the graph understood.

A table of values is a table containing the list of values for the variables, which may be represented on a graph or chart. The ordered pair is a pair of

values representing a fixed point. The pair of values also gives the values of the units on the axes, the first value on the horizontal axis and the second value on the vertical axis. The pairs are sometimes called the co-ordinates of points. According to Wainer (1991:52-58) most graphical displays cannot give the information needed if a scale is not chosen to represent the values on the table. Therefore, it is better to scale and rescale them so that better information can be obtained from the graph and the graph can give a true picture of what it represents. He based his research on double-Y-axes to explain this situation, and reported that the scale was chosen based on the information collected (Wainer 1991: 50). This helped to represent the information on the graph. This led to a series of graphs on the same information. With scaling and rescaling, better information, inherent in the graph, can be obtained.

Wavering (1989) supported the issue of scaling and rescaling of the same data collected in order to produce a series of graphs. According to him, the results of data from table is graphing. Therefore, the table of values and ordered pairs determines which scales can be used to construct a graph so that it is meaningful and understandable. This requires a sound teaching approach in which learners are involved in the generation of tables or ordered pairs. Computer technology can also assist in making the teaching and learning of linear graphs more meaningful and understandable. Bednarz et al (1996), while investigating the role of cartesian graphs in the CARAPACE environment, reported that using computer technology to generate data and consequently draw a graph, provided the learners with a good opportunity to understand algebraic linear graphs. According to them,

scaling has some effect in the understanding of algebraic graph, especially by zooming-in and out so that all the elements in between the units can be read off the graph. The nature and shape or size of the graph will also change. This makes it easy for one to interpret and predict from the graph (Bednarz et al 1996: 270–293). But students should be given the opportunities to work their way through their own graphs, otherwise the logical development and understanding of graphing may be short-circuited (Wavering, 1989:373-379).

Furthermore, one can also choose a scale and draw a graph from ordered pairs. Wainer (1989: 121–140) noted that plotting graphs from ordered pairs is fraught with some difficulties. The student may confuse the reading of the values of the pair on the vertical axis instead of the horizontal axis or vice versa. He also revealed that this situation might lead to making some incorrect assumptions and ignoring some vital information. Therefore meaningful information cannot be obtained from the graph. The classroom experience has shown that choosing a scale with a sound teaching and learning approach can resolve such problems or difficulties. Mendoza and Mellor (1992: 150-151) supported this idea by stressing that the maximum potential is actualized when the reader is capable of interpreting and generalizing data from a table.

2.3.1.3   Scaling and the axe

According to Wavering (1989), seriation and proportional reasoning are needed for scaling data from a table on the axes. In the classroom situation,

the opinion by NSF (1998:4-36) reached the same conclusion as Wavering in his research on graphing equations of linear systems. Brassell (1987) in his research on the effect of real time laboratory graphing on learning graphic representations of distance and velocity, stressed that if they are using graphs with axes already drawn to scale from a table of values for distance and velocity, students can construct a graph from which they can make predictions. Gerber (1985: 27-33) researched the topic of designing graphs for effective learning. He stressed that a good graph provides precise communication of the message which that graph is carrying. A clear and useful graph must possess the following: title, labelling (axes, scaling, colour, drawing, units) signs and symbols, and a legend/ key (Gerber 1985: 27-29). To him, with careful labelling of the axes it should be easy to read the message conveyed by the graph.

Berg and Philips (1994: 323-344) researched the relationship between logical thinking structures and the ability to construct and interpret line graphs. According to them, learners have difficulties with graph construction and interpretation. They further reported that the students have a problem with entering the variable on the axes and determining the linearity of scale as well as with positioning the zero point on the axis (Berg & Phillips 1994: 324). They also reported that students performed significantly in ordering/tables and scaling the axes in responding to questions requiring them to draw or interpret graphs. They also recommended that more investigations should be carried out to discover why students choose to label axes the way they do.

From the above literature on scaling and axes, it is critically clear that even in the classroom context after drawing the axes, the scale has to be chosen so that one can represent the values or units on the graph. In most cases, it is possible to represent or draw a graph without choosing a scale for lower values that are within the range of the graph worksheet being used. But what happens if the values on the table of values are so large that the dimensions of the worksheet cannot accommodate the values? Therefore, the students should be taught the skill of scaling as soon as they begin to learn anything concerning graphing. At this early stage the following should be considered regarding skills development in scaling:

(a)Ordering the row and column (drawing the axes and choosing a scale to represent the units on the axes);

(b)Spacing the axis according to size (scale) so that the information or values on the table of values can be represented;

© Understanding the situation or the nature of the graph.

2.3.1.4 Scaling and plotting of points on the graphs

Wainer (1992: 14) researched the understanding of graphs and tables. In this study he reported that the ability to plot an experimental graph necessarily precedes an ability to analyze it. According to Bicknell (2000:239) what follows a table of values, drawing of axes and choosing a scale based on the values or data from the table is the plotting of the points or calculation of co-ordinates of point(s). Any bumps on the line mean an error. The points are then connected with a smooth line for linear graphs and a curve for quadratic graphs (Bicknell 2000: 239).

The research conducted by Bednarz et al (1996) examined the use of Cartesian graphs in solving problems and the role that graphical representation plays in helping grade 9 students to solve problems. The study shows that the students plot points on the axes after they have decided on an appropriate scale, which makes it easy for them to solve problems (Bednarz et al 1996: 268-270). It also became clear that choosing a scale from a table of values is necessary before plotting a graph. Hence scaling has some effect on the understanding of algebraic linear graphs.

2.3.2. How scale is used in algebraic graphs

In terms of an algebraic linear graph, a scale is used to mark off the values or units on the axis of a graph so that the values or coordinates on the table of values can be adequately represented on the graph. In practice, a scale is chosen based on the table of values and the dimensions of the graph on which the values are to be represented. In order to understand the graph, an already selected scale can be rescaled so as to change the nature and shape or size of the graph (modification). This will make for easy understanding of the graph as well as for the ability to interpret and predict from the graph (Bednarz et al 1996).

2.4 FACTORS INVOLVED IN THE CHOICES OF SCALE FOR THE UNDERSTANDING OF ALGEBRAIC GRAPHS

Berg and Phillips (1994:323-344) reported in their investigations of the relationship between logical thinking structure and ability to construct and interpret line graphs that students have difficulties in the construction and interpretation of graphs, especially those in grade 7 through 12 (Berg & Phillips 1994:323). Their study shows that there is a connection between logical thinking and graphing and therefore seriation and proportional reasoning are needed for scaling data on axes. This means that in the construction and interpretation of graphs, logical thinking ability needs to be considered. In this connection, language and the nature of the data also play an important role in helping the learner to know how to choose a scale for constructing graphs. The child could be taught scaling; beginning with numbers that are not too large so that they can decide on an appropriate scale (semiotic thinking).

Wainer (1991:50-51) also reported that the nature of the units determine which scale to be used so that we can adequately represent the graph and obtain a meaningful message from it. The study also shows that the type of information provided on the table indicates which scale is to be decided on for constructing the graph. This view was supported by Bednarz et al (1996:289) in their research on technology and the functional approach to algebra, reporting that the nature of the problems, which the graph will help students to solve, will necessitate which scale to choose to draw or represent the graph. This is why Gerber (1995) suggests that the use of scale in making a good graphic display highlights the information needed to communicate its message. One can solve a problem with a graph if one understands the message which it carries.

Furthermore, a student's prior knowledge of how to construct a graph can indicate the choice of a scale in the construction of a graph (Mevarech & Kramarsky 1997.230). In order to ensure effective learning previous knowledge about constructing a graph and in particular scaling is necessary so as to be able to cause the students to learn and understand. This is a common phenomenon in the teaching and learning activities in the school.

Another factor, which the classroom experience has shown, is the dimensions of the graph worksheet paper being used. Most of the paper used in the classroom is either twenty-two centimetres on the vertical axis and eighteen centimetres on the horizontal axis or twenty-six centimetres on the vertical axis and sixteen centimetres on the horizontal axis. Therefore, any value on the table of values above this dimension has to be represented on the graph paper by choosing an appropriate scale so that the data can adequately be represented on the graph (Bertin 1983:296).

The student's way of learning can also indicate the choice of a scale in order to construct a given graph. Could the use of scale to draw a graph at this level be too early for the grade 9 learners? At what level do we think that the learners should begin to construct a graph by choosing an appropriate scale (Berg & Phillips 1999:323-344)? This question needs to be answered while the practising teacher is designing his or her teaching instruction regarding linear graphs. This is part of the problem which this study is going to unfold.

University of South Africa etd – Ijeh, S. H.(2003)

Therefore the following could be relevant for the choice of scale in the understanding of algebra graphs for grade 9 learners:

- Construction of a graph.
- Dimensions of the graph.
- Values of variables in the table of values.
- Nature of the problem being solved.
- Student's problems in learning about the graph.
- Interpretation of the graph.
- Predicting from the graph.
- Student's prior knowledge about graphing.

2.5   PROBLEMS IN THE UNDERSTANDING OF THE ALGEBRAIC GRAPHS

The following problems have been identified through literature studies in the understanding of the algebraic graph:

(i) Ability to construct a graph.

(ii) Ability to interpret the graph.

(iii) Features of the contents and presentation of graphs.

(iv) How the graph is taught in the classroom.

(v) Logical reasoning ability of the learner and the teaching of algebraic graphs to the grade 9 learners.

(vi) Information not on the graph (Mendoza & Mellor 1992:151, Wainer 1992:14, Pegg & Davey 1994:132, Wainer 1989:121-140, Wavering

28

1985:27, Leinhardt et al 1990:1-64, McKenzie & Padilla 1986:571-573), Berg & Phillips (1994:323).

2.5.1 Ability to construct graphs

Berg & Phillips (1994:323) reported, in an investigation of the relationship between logical thinking and the ability to construct and interpret line graphs, that a major stumbling block for grades 7 to 12 in the understanding of line graphs is the inability of the students to construct and interpret graphs.

A research study conducted by Leinhardt et al (1990: 1-64) examined the construction and interpretation of graphs by learners. According to them, students have difficulties in constructing and interpreting graphs. They reported that construction involves the selection of labelling of axes, scaling, identification of units and plotting. Berg and Phillips (1994:324) added that a static conception of graphs, a view of the graph as a picture of an event, confusion between slope and height, problem of one variables, determining the linearity of the scale and positioning of the zero point or axis are also part of the problems in construction of graphs. This opinion was also supported by Mevarech and Kramarsky (1997:23).

In my own opinion and with experience from my classroom observations, I support the views of Berg and Phillips (1994:323-344); Leinhardt et al (1990: 164); Wavering (1989:323-379) and Mevarech and Kramarsky (1997:229-262), that all the above mentioned difficulties exist with learners

from grades 7 to 12, which we have classified under a broad heading as 'construction problem.' In addition, the nature of the data or table of values or ordered pairs should be included under construction because this is also another difficulty which the learner encounters in graphing.

In the construction of graphs, the classroom experience and beyond have shown that the learners should be able to understand the nature of the data or values in the table or ordered pair value in relation to the dimensions of the graph worksheet being used for graphing (Bertin 1983:296). This will determine how to choose the axes as well as the scale. This means that the learner must understand the linearity of scaling while taking into consideration the data presented on the table. This aspect of difficulty in graphing can easily be resolved if a sound teaching strategy is used and the learners are well taught. The knowledge of ratio and proportion as a prior skill for graph construction is a necessity because it helps the learners in scaling, plotting, reading, and interpreting graphs. Furthermore, the learner should be involved in the generation of the data so that the difficulties in the construction of the graph can also be resolved (Brasell 1987:385-395, Pegg & Davey 1994:109-133). The problems of one variable, static conceptions of graph, viewing the graph as a picture of an event and confusion between slope and height surfaced in construction after the graph have been plotted and these issues should be included in the interpretation of graphs.

2.5.2 Ability to interpret the graphs

By interpretation we mean the action by which the students make sense or gain meaning from a graph (or portion of graph), a functional equation or situation (Leinhardt et al 1990:8), e.g. finding the value of x, when y = 4, is an interpretation. Finding the slope is another interpretation. Another major problem in construction of linear graphs among learners is the confusion arising from plotting of the graphs. When using the values from the ordered pairs or table of values, most students tend to read the first value in the pair as the value on the y-axis and the second value on the x-axis, or to read the values on the vertical axis in place of the value on the horizontal axis and vice versa.

The slope/height confusion is manifested when students mistakenly replace the gradient with maximum or minimum values (Mevarech & Karmarsky 1997: 232). When students were presented with a distance vs time graph, consisting of two intersecting lines representing two objects, although the speed indicated by the lines was different, and when the following question was presented: 'Do objects A and B ever have the same speed?' many students incorrectly chose the intersection point as the time when speed of the two objects was equal (Mevarech & Kramarsky 1997:232).

Approaching the graph as a picture, and a static conception of a graph, is manifested when the students interpret the graph of a given situation (Mevarech & Kramarsky 1997:323). According to them, when students were presented with a distance vs time graph consisting of increasing and decreasing lines the latter said that the graph showed 'climbing a mountain, first going uphill then going downhill using their personal experience.'

The static conception of the graph is manifested when the students rescale the axes. Rescaling and plotting a series of graphs becomes confusing to students, as the graphs will assume different shape or sizes from the same data and after rescaling. Many students find it difficult to comprehend the difference between the first graph and other graphs drawn from the same table of values.

Another difficulty pointed out by Mevarech and Kramarsky (1997) is an interval/point confusion. They reported that students mistakenly focus on a single point rather than an interval in an attempt to interpret the graph. In comparative investigations of the growth of two populations (e.g.' when are girls growing faster than boys'?), students refer to a single point (usually the maximum point), rather than to an interval (Mevarech & Kramarsky 1997:232). It appears to be more difficult to think of indefinitely many points between two given points than to think of infinitely many points on the line altogether (Berg & Phillips 1994:324). All the above-mentioned problems are associated with interpretation of graphs in linear algebra.

2.5.3 Features of the contents and presentation of graphs

Mendoza and Mellor (1992:151), in a preliminary investigation of graphs, reported that another difficulty in the understanding of graphs is the particular features of the contents and presentation of the graph. If the features of the graph and the way it is being presented are wrong, student will ultimately interpret the graph wrongly and may make a wrong

prediction from it. The practising teacher should therefore identify a student's specific errors in graphing, and those factors which contribute to these errors, so that he or she will be able to plan instruction and help students to overcome their difficulties (Mendoza & Mellor 1992:151)

2.5.4 Logical reasoning ability and the teaching of algebraic graphs to grade 9 learners (Form B)

The logical reasoning ability of the learners can also result in difficulties in understanding of algebraic graphs for grade 9 learners. According to Wavering (1999: 378) there are some flaws and errors in logic committed by the learners in graphing because of their reasoning progress at this stage. To him, teachers can become familiar with these typical flaws and mistakes in logic and seek appropriate means to help the students understand their errors in graph constructions. The logical progression from simple to complex reasoning involved in graphing suggests approaches to teaching graphing through the middle and high school years. These approaches need to be concerned with using data that can be graphed using the scaling and ordering reasoning processes that students are developing. Furthermore, he suggested that data used for graphing should be generated from the student's own experiments, which generate graphable data. This opinion of Wavering (1989:373-379) is in line with the idea of Berg and Philips (1994:323-344). The suggestions indicate that sound teaching can also assist the learners in the understanding of algebraic graphs. Learners must be actively involved in the teaching and learning progress so that they can learn and understand (Biggs 1993:73-75). At this point practising teachers must be aware of the Piaget theory of cognitive development so that he/she will be able to design

effective instruction in the teaching of algebraic graphs. According to Berg and Phillips (1994:323-344) active participation (both physical and mental manipulation of objects and their relations) by learners is critical for intellectual development. The investigation carried out by Berg and Phillips (1994:326) shows that during this active participation, information received physically and mentally is assimilated to the learners' current mental structures while accommodating (reorganizing or adapting) his or her structures to the distinct characteristics of the data (Berg & Philips 1994: 326). The practising teacher must be familiar with the way his or her students reason and should reason along with them. If the learner and the teacher reason differently, learning and teaching could be a disaster.

2.5.5   **Information not on the graph**

Mendoza and Mellor's (1992: 157) research into students' concepts of linear graphs shows that students cannot solve problems with graphs in which information is not adequately represented, such as interpretation and prediction. This situation leads to misinformation and does not provide a good opportunity for the student to solve problems. For example, if students are asked to predict a child's allowance for 1990 when the allowance for 1986-89 was given, the students may find it difficult to predict this. They may even say that 1990 is not on the graph.

2.6   WHICH TEACHING METHOD CAN HELP LEARNERS IN THE UNDERSTANDING OF ALGEBRAIC GRAPHS AT GRADE 9?

Narainsamy's (1998: 33-50) research on the use of Logo in the pre-algebra stage shows that the way a subject is taught and presented in the classroom will influence the amount and type of learning that is effected amongst pupils. For many years mathematics was taught in what is referred to as the traditional way with the teacher transmitting all the knowledge and the child passively accepting it all without question (Narainsamy 1998:33). According to her, a new mathematics emerged in the 1960's where the emphasis was placed on the child's understanding of concepts. Then in the 1980's the theory of constructivism, where the learners are expected to construct their own knowledge, was advocated for learning mathematics (Narainsamy 1998: 33). Unfortunately the new mathematics could not change the drastic situation of having the learner be passive in the teaching and leaning process.

2.6.1 How graphs are taught in the traditional classroom

To think of the traditional mathematics classroom is to imagine the teacher working on the board while a full class of boys and girls gazes in amazement. The teacher in a graphing class fills the board with examples to illustrate how graphs of linear algebra are to be simplified or used in solving problems. The teaching strategy that dominated the classroom was to show and tell pupils what to do, and then check that the pupils had applied what

was shown correctly. According to Narainsamy (1998:6), knowledge was seen as the ability to regurgitate facts and to imitate rituals. The traditional classroom was seen as a silent working place where children are passive listeners and where narrow views and misconceptions are born. Pupils have virtually no part in any decision making. In such a classroom the child takes directives from the teacher, irrespective of age or, proficiency and all students are even required to use the same textbook, which has been designed sequentially to follow some careful graded progression. The lesson does not allow for experiences where the children are able to discover, invent or apply mathematics to problems that are meaningful to them (Cangelosi 1996: 7)

A good mathematics classroom where meaningful teaching and learning is taking place provides a powerful means of communication between the teacher and the student or between the students themselves but the traditional mathematics classroom is ironically a place where the children's opinions are never heard (Narainsamy 1996:34). The traditional method of teaching algebra graphs is associated with "talk, chalk, paper, pencil and chalk board". This technique has been used over the years and persists even to this day. It is born from the fact that many teachers are concerned mainly with completing the syllabus before the final examination without, in most cases, minding whether the students understand or not. The present topic the effect of scaling in the understanding of algebra graphs for grade 9 learners — is so significant because of the symbolic connections that represent potentials for increased understanding between the graphic and algebraic

worlds (Leinhardt et al 1990:1). How then is scaling taught, for the purpose of construction of algebraic graphs, to grade 9 learners?

2.6.2 How scaling is taught for the purpose of constructing algebraic linear graphs to grade 9 (Form B) learners

In using scale to solve algebraic graphs for grade 9 learners, they should first be introduced to the concept of ratio and proportion (Bicknell 2000:239).

On a number line, the students are taught how to mark off the values on the intervals so as to know the fractions between the intervals of points on the line. Equally, the students are made to divide certain values into different ratios. Some of the ratios will involve displaying a pattern of values, which decreases or increases with equal numbers of unit. For example, the students are asked to continue the pattern 2,4, 6 -------- and 3,6,9, -----. Therefore the teaching of scaling takes ratio and proportion, pattern, intervals and number line system as prior knowledge of grade 9 learners for the teaching and learning of the concept of scaling in the construction of algebraic graphs (Leinhardt et al 1990:4).

After the generation of tables of values or ordered pairs, the students are now faced with choosing a scale based on the table of values so as to be able to construct the graph. This is done by looking at the data on the table of values and the dimensions of the graph paper with which the graph is to be

37

constructed. Then the scale is chosen and plotting of the points follows. Therefore the teacher begins teaching the pupils how to choose the scale from a table of values only after being convinced that they can generate patterns of number in an increasing or decreasing manner with equal incremental units and can determine the fractions between the intervals of points on the axes. Drawing the axes, plotting the graph and drawing the best line of fit will follow this procedure (Bicknell 2000: 239, McKenzie & Padilla 1986: 572-573).

In the traditional mathematics classroom, where the teacher only shows how and what is to be done, there is little discussion; pupils are seldom given the chance to ask questions if they do not understand something. Often children, who have already built up a fear of mathematics, feel afraid of the teacher and the reaction of peers if they do not understand (Narainsamy 1998: 35). In this situation, the teacher sets an exercise and a series of routine steps are followed in doing the exercise and the evaluation of the students' work. Students are given time to complete the exercise, the teacher marks the assignment and gives the solutions to the exercises so that those who got the answers wrong can take down the corrections.

This kind of situation does not make for effective teaching and learning, even in the traditional classroom. For effective teaching and learning even in the traditional classroom the teaching strategy should involve discussion centred on incorrect answers (Narainsamy 1998:36). This will enable the teacher to analyze how the pupils are thinking and to correct any wrong procedures that the pupils have used in arriving at the incorrect answer.

According to Narainsamy (1998:36), when children want to learn, they may make some mistakes which do not occur merely through carelessness or stupidity, but which represent the outcome of their attempts to make sense of what (to them) is a nonsensical, or at least pointless situation.

At present, teaching media have improved the standard of teaching and learning. For many years, the textbook and the chalkboard were the only teaching media. But nowadays whiteboards, flipcharts and overhead transparencies are being used in our classrooms. However, the chalkboard and the textbooks remain the chief means of communication between the teachers and the students in our secondary and high schools in Lesotho.

2.6.3 Using the theory of constructivism to teach the concept of scaling.

A direct contrast to the traditional approach is the constructivist approach to mathematics education. While in the traditional approach, learning is passive and a direct acquisition of knowledge from the teacher, the latter stems from the theory of cognitive development in the philosophy of mathematics education through the work of Piaget. Constructivism is seen as a means of improving mathematics learning in the classroom. The two basic epistemological principles underlying these paradigms are:

- that knowledge is actively constructed by the learner, that is, knowledge is the result of learners' activities rather than of the passive reception of information or instruction;

- that knowledge is an adaptive function, that is gaining knowledge is a process of adapting to the world that is experienced by the

39

learner (Anderson & Piazza 1996:51).

The constructivist is concerned with the process and not the product. The way in which a child assimilates and combines ideas as he/she attempts a solution is a reflection of his/her cognitive development. Cognitive development is encouraged when the learner goes through challenging experience in different contexts. This is a process of learning in which learners can overcome obstacles to achieve their goal. This is a central aspect of conceptual development. When children make sense of new information and experiences then they show evidence of having learned and understood. This philosophy presents a good basis for children trying to understand the concept of scaling which will be necessary for them to understand algebraic graphs, since they will be expected to develop their own knowledge about constructing, interpreting and predicting from the graph they have constructed.

Narainsamy (1998: 42) is of the opinion that using constructivism as a philosophical basis for mathematics education 'can be very beneficial, especially if full advantage is taken of all the available principles of the system'. The application of constructivist theory to the teaching and learning of mathematics concepts is strongly advocated for the grade 9 learners especially regarding algebraic graphs.

In terms of learning in a constructivist setting, there is the need for concrete experiences in the transitional stage of schooling, as students at this stage are

not able to handle abstract concepts (Narainsamy 1998:42). The constructivists feel that for students to understand, they should develop concepts from appropriate activities, including appropriate tools such as sharing of materials and patterns provided by the teacher. Interaction between the learning activities and concepts that children have already learnt, will allow them to draw meaningful conclusions and deductions and develop important concepts and principles. Furthermore, Narainsamy noted that a major advantage of the constructivist approach is that it could reach children of all abilities. Consequently, teachers need to be trained to fit in with the new ideas of letting the child learn, by being involved in activities that promote algebraic thinking. They should try to foster the development of mathematical meaning in the children (Steffe 1990:167-168).

In South Wales (1998), Australia (1990), New Zealand (1992), and Lesotho (Ministry of Education and Manpower Development 2000), and later in South Africa (curriculum 2005), it was advocated that active learning processes should replace traditional passive learning (Narainsamy 1998:42-44). This is because a meaningful teaching and learning process is realized if mathematics is learnt through the active participation and productive processes of the learner. The teacher must be thoroughly organized in planning appropriate activities, providing opportunities and creating a classroom atmosphere with his/her learning objective in mind. The activities must be such that they can engage the students in constructing their knowledge based on their previous experiences and can achieve specific mathematical goals. The teacher guides the students in their activities, not as he/she would in discovery learning, but with such things as clarifying their

remarks, posing challenging questions and making his/her comments around the children's concerned (Narainsamy 1998:44).

In a constructivist classroom, children develop mathematical inquiry and engage in analytical reasoning. Ellerton and Clements (1992:5) reported that during constructivism, cognitive conflicts are resolved and children are focused on how the problem is solved, rather than on the end result or product. Therefore for a proper understanding of algebraic graphs through the use of scale and to avoid difficulties which the learner may encounter in an attempt to understand algebraic graphs, sound teaching and learning strategies must be employed. One of these is a strategy which must involve the learner in choosing a scale from a table of values and constructing a graph so that they can understand it.

2.7 CONCLUSION

This chapter focused on scaling as it affects grade 9 learners in the understanding of algebraic graphs. The subjects are the grade 9 learners: the second year students in the secondary school in Lesotho. The content of algebraic graphs in grade 9 encompasses graphical solution of linear equations, two linear mappings and parallels to axes (Form B, Mathematics Syllabus of Lesotho 2000). The meaning of scaling was fully discussed in general and in particular with algebraic graphs. In order to understand algebraic graphs using scaling, learners must be able to construct, interpret, and make predictions from the graph.   For the purpose of this research we shall focus on scaling, one of the four tasks necessary for the construction of

graphs. Scaling is the assigning of values to intervals between the lines on the Cartesian system as in two-dimensional graphs. Hornby (2000:1048) defines scale as a range of values forming a system of measurement or grading to represent the value of the item being measured. This means that a scale is a series of marks at regular intervals as in the ruler and the axes of the Cartesian graphs. Bertin (1983:296) reported that there are different types of scale. These are the graphic, fractional, the grid, known shape, distance, etc. But our concern in this research is the graphical scale which expresses the relationship between the linear dimensions of the sheet of paper and the dimensions of the space being represented. The scale, table of values/order of pairs, the axes, and the plotting of points on the axes are related. The selection of axes and plotting of points depends on the scale chosen, based on the units in the table of values.

In algebraic graphs there are some factors that will help in determining which scale will be necessary to construct a given graph. These are the construction of graphs, dimensions of the graph worksheet, values of the variables and the nature of the problem being solved. Other issues are students' problems in the learning of graphs, interpretation of graphs, prediction and students' prior knowledge about graphing.

Problems encompass the ability to construct and interpret graphs and the nature of the features of the contents and presentation of the graphs. The way graphing is taught, the logical reasoning ability of the learners and information not on the graph were other problems identified. This chapter was concluded with a suggestion about the teaching method that is necessary

for teaching scaling so that learners will be able to learn and understand algebraic graphs in grade 9 (Form B). The theory of constructivism was strongly advocated. In chapter 3, the methodology of the research will be discussed. Chapter 4 will focus on analysis and interpretation of results, while the summary, conclusion and recommendations will be presented in chapter 5.

CHAPTER 3

METHOD OF RESEARCH

3.1 INTRODUCTION

The basic aim of this study is to establish the effect which scaling has on the understanding of algebraic graphs by grade 9 learners. The problem of poor performance in mathematics especially in algebraic graphs in the Secondary and High School is experienced countrywide in Lesotho. The possible fundamental cause could be linked to the failure of the learners to understand how to choose a scale based on a table of values in order to construct a graph to represent the required information on an algebraic linear graph and possibly also to the way in which scaling is taught and learnt in the school in the case of such graphs in grade 9 mathematics.

Chapter two has probed this problem through a study of the literature. In this chapter the problem is subjected to empirical investigation. The hypothesis will be tested by means of data gathered from the sample of grade 9 learners selected from Qholaqhoe High School, Butha-Buthe.

The researcher will give a description of the research sample. This will be followed by an in-depth discussion of the research methods, questionnaire, tasks, and the interview, which are the methods of investigation used in the study. Thereafter, the procedure followed in the collection of data for the empirical investigation will be described.   The data collected will be subjected to a statistical analysis and calculations in chapter four so that the hypothesis can be tested. This will be followed by data analysis and interpretations.

3.2 AIMS OF THE RESEARCH

The aim of the current study is to investigate the effect of scaling on the understanding of algebraic graphs amongst grade 9 learners. More specifically, the objective was to ascertain what extent the effect of a scale chosen based on a table of values has on this understanding.   The students' understanding of algebraic graphs as a result of their inability to choose a correct scale for a table of values was evidenced from the formative assessments that were done during the course and at the end of the investigation.   From the qualitative and quantitative nature of the investigation employed, it was clear that the study would allow for some form of generalizations to be made about a wider population after a small selected sample was studied (Cohen & Manion 1995: 106-107).

The study was conducted with students in grade 9 who have had some exposure to algebraic graphs and it was conducted with the control group

passing through their normal classroom lesson, while the experimental group was given special training on how to choose scales for drawing algebraic linear graphs.

3.3   STUDY POPULATION AND SAMPLE

The researcher has selected Qholaqhoe high school, Butha-Buthe 400, his current place of work, to conduct the research. The sample is taken from grade 9 learners (form B), of which the researcher is the mathematics teacher. There are two grade 9 classes (B1 and B2). Twenty students each were purposefully/judgementally selected from the two classes in terms of ability and gender. In terms of ability, 7 best, 7 average and 6 from the students with lower ability constituted twenty students in each group. There were 10 boys and 10 girls in each group. This gives a total of forty students representing the population sample for the study. Four students were selected from the experimental group consisting of two boys and two girls.

Qholaqhoe high school is in Butha-Buthe district of Lesotho and the school is located in a remote area of this district. Permission had to be obtained from the students, principal and the education office for this study (see appendix).   The researcher had to provide the twenty students in the experimental group with learning facilities such as graph books, pencils and

rulers. These materials boosted morale and enthusiasm to participate in the special training course on scaling.

These students were greatly encouraged and they participated in the lessons very well. Although there were a few cases of absenteeism from the special training due to illness and family problems, the researcher was able to bridge the gap by assisting those students affected individually with the lesson they did not attend.

The principal and the education office were happy with such research, as they hoped that it would make an appreciable impact on the teaching and learning of mathematics in the school. The principal was delighted with the nature of the conduct of the research, especially seeing students using the right materials provided by the teacher. This she saw as something that was going to encourage others too. My colleagues in the school co-operated very well with me, especially in arrangements for the time of the lessons.

3.3.1 Study Population

The population for this study was derived from the grade 9 learners. In Lesotho, they are the second year students in the secondary school at Qholaqhoe high school where the research was conducted. The grade 9 is form B, which has two classes, Form B1 and Form B2. There are fifty-two students in Form B1 and forty-eight students in Form B2. This gives a total of one hundred students.

3.3.2 Sample of the Population

For the purpose of this study, twenty students each were selected from Form B1 and Form B2 respectively. This gives a total population sample of forty students. The forty students were selected using purposeful/judgement sampling technique in terms of gender and ability. In each case there were ten boys and ten girls. Hence the sample population is made up of twenty boys and twenty girls. Form B1 comprises the experimental group and Form B2 the control group.

3.3.3 Venue and Time

The selected students in Form B1 attended the classes in the school in their own class. A double period was allocated for the lesson. After special arrangements with colleagues, one period was made available on Tuesdays and Thursdays.

A second period was taken from the launch break, which is one hour twenty minutes long. Therefore the students and I agreed to use one period from it in addition to the one period that was made available by my colleagues. The special training lasted for four weeks with 2 sessions per week in the month of April, 2003.

3.4 INSTRUMENTATION

The following test, questionnaires and interview were used:

Pre-test: A pre-test consisting of ten items was designed to find out the previous knowledge of the students about scaling for constructing algebraic linear graphs and solving problems in mathematics. This was administered to the students in both the experimental and control group before a special teaching on scaling was given to the experimental group. The control group passes through normal class teaching on algebraic graphs. If the mean of the performances of both groups are the same, then this will represent a fair selection. A low performance will indicate that the students have little or no knowledge of scaling.

*Questionnaire***:** A twelve-item questionnaire was designed with emphasis on scaling and the effect of scaling in the understanding of algebraic graphs. This was given only to the experimental group after the extra tutoring (intervention) since they had a special tutoring on scaling. If the proportion of the students that answers the questions correctly is greater, then scaling has an effect in the understanding of algebraic graphs. The students exposure to the correct materials during the extra tutoring could have influenced this as a way of providing a conducive environment for the teaching and learning to take place but not a major factor to influence the understanding of algebraic linear graphs.

Interview 1: A first structured interview was given to some selected students from the experimental group on the bases of gender and ability (see 3.3). It consisted of six item questions focusing on scaling, and attitudes to solving problems in mathematics if one understands algebraic graphs through proper

understanding of how to choose a scale.   Only four students from the experimental group were interviewed.

*Post-test***:** A post-test consisting of 15 questions was designed and administered to the students in both the experimental and control group. If the mean of the performance of the experimental group is higher than the mean of the performance of the control group, then there is a significant difference, which must have been influenced by the extra tutoring on scaling (see table 4.8).

Interview 2: A nine items interview focusing on the effect of scaling and students' attitudes to problem solving in mathematics, especially in algebraic graphs, if they know how to choose a scale from a table of values, was administered to the same four students (see 3.3) from the experimental group after the post-test. Interview 2 further probed into how well the students had understood the special training on scaling. Hence the interview was extended to nine questions. If the students' responses proved that they have understood algebraic linear graphs by using scaling to construct a graph, this would mean that the extra training has influenced them to understand algebraic linear graphs and thus scaling has an influence on the understanding of algebraic linear graphs.

3.5 VARIABLES USED

The following independent and dependent variables were used in this study:

The choosing of scale from a table of values in relation to the dimension of the graph worksheet to construct a graph and the special training are the *independent variables.* The students' understanding of algebraic graphs depends on the choice of scale based on the table of values provided. To understand an algebraic graph, one must be able to:

 (1) Construct a graph.

 (2) Interpret the graph

 (3) Make predictions from the graph.

These are the *dependent variables.*

3.6 METHOD OF RESEARCH

Both qualitative and quantitative research was conducted. In doing the quantitative research, a pre-test, post-test experimental and control group design was used as subjects and were randomly assigned to groups in terms of gender and ability. The same test was administered to the two groups, followed by an interview for some selected students in the experimental group, to assess the influence of scaling on the understanding of algebraic graphs.

 The experimental group was given special training on how to choose a scale and use it to construct a graph in a problem-solving context. The control group passed through normal class teaching with no special training on scaling.

In executing the qualitative research, an interview and questionnaire were used to gather data from the selected students directly in the school.

3.7 STATISTICAL PROCEDURES AND TECHNIQUES

The data collected were processed using SPSS system software and students t-test to determine whether there was a significant difference between the experimental and control groups. A standardized students' t-distribution is used.

$$t = X - x/S.$$

Where: t = Standardized student test.

X = Random variables (scores).

x = Variables mean.

S = Standard Deviation.

The standardized variable Z is calculated as;

$$Z = P - \mu x / S.$$

Where:

P = True population of student (sample)

μx = Population mean of the sample student.

S = Standard deviation from the mean.

$$S = \sqrt{P (1 - P)/N}$$

Where;

P = True population of students (sample)

N = Sample size

Sample size = Number of students $*$Number of questions.

$\quad$ P = X/N.

Where: $\quad$ X/N is an unbiased estimator of the population P.

STATISTICAL TEST FOR PROPORTION OF QUESTIONS ANSWERED CORRECTLY IN THE QUESTIONNIARES.

A null hypothesis:

$\quad$ $H_0: \pi = 0,5$

As an alternative hypothesis, the scaling has some effect if the students are able to answer more than half of the questions correctly. This is because they have received extra tutoring on scaling, compared to the control group. Test statistic:

$$Z = P\text{-}0.50/\sqrt{0.5(0.5)}/20.$$

$$= 0.696 - 0.5/0.1118$$

$$Z = 1.752$$

Level significance: $\alpha = 0.05$

Critical value: $Z_{0.05}$ $\quad$ $=1,645$

$$P = 167/20*12.$$

$$= 167/240.$$

$$= 0.696.$$

We can reject H_o since 1,752 >1.645. Thus we can conclude that the students in the experimental group answered more than half of the questions correctly.

3.8 PROCEDURE

3.8.1 Experimental Techniques

The researcher sought permission from the principal and the education office at Butha-Buthe before beginning to conduct the research at Qholaqhoe High School, Butha-Buthe 400. The students were all informed that they were going to participate in a research project.

In April 2003, the students were given the first task (Task 1). This was followed by special teaching focusing on SCALING to the experimental group in Form B1 while Form B2 went through the normal classroom teaching experience.

The teaching lasted for four weeks with two sessions in a week, made up of a double period. After the teaching, the questionnaires were administered to the experimental group. Four students comprising two boys and two girls in the experimental group, were interviewed (INTERVIEW 1) immediately.
A second task (Task 2) was also administered to both the control and experimental group. The same four students from the experimental group were interviewed (INTERVIEW 2) at a later time.

Before the special teaching the researcher had to ensure that all the students involved possess the appropriate materials for the lessons. I had to buy twenty-five graph books and pencils for all of them. Most of them possessed their textbooks but the few that did not borrowed them from other students who were not involved in the study. In the case of assignments, the researcher had to ensure that the exercise was written on the chalkboard for them to do as a way of assisting those who did not have the textbooks.

During the special teaching, some students were absent due to family problems and illness but the researcher ensured that these students were taught what the others had done when they were absent. After the completion of the special teaching, the data were computerized for analysis.

3.8.1.1 Validity and Reliability

In this study, the validity and reliability of the instruments and data collected were considered. Validity, according to Bell (1987:1), tells us whether an item measures or describes what it is supposed to measure or describe. Reliability is the extent to which a test or procedure produces similar results under constant conditions on all occasions (Bell 1987:1,Winter 1987:3 & Hammersley 1987:73-79). If a test is unreliable, then it must also lack validity, but a reliable item is not necessarily valid. Whether the analysis of the instruments and the data collected is considered reliable or not depends on the correctness and consistency of the data in relation to what actually they are intended to measure (Bogdan & Biklen 1992:48, Winter 1987:3).

Validity, according to Patton (1980:14) and Winter (1987:7), depends on the 'skill, competence and rigor' of the person conducting the fieldwork. For this reason, the researcher have to check the validity and reliability of all the instruments and data collected in conjunction with the supervisors in relation to the grade 9 (Form B) syllabus as well as of the scaling. The type of validity used for this study is content validity. A content validity is a judgemental process and it is concerned with the representativeness or sampling adequacy of the content (e.g. topic or items) (DE Vos 2000:84). In using content validity, the instruments were scrutinized to ensure that they will help to determine the influence of scaling on the understanding of algebraic graphs for the grade 9 (Form B) learners before they were administered to the students. The data collected were stored in a disk and subsequently analyzed in order to obtain the results of the research.

3.8.1.2 Data Collection

The following method was adhered to: All the physical materials (questions/task answers) created by the students were collected and categorized.

Although the interviews were not video taped because of the lack of electricity in the school and its remoteness, the researcher was able to comprehensively record the interview responses.

- **Task 1.**

Contents: The contents of the first task were equations and inequalities; graphical solutions of linear equations, two linear mappings and parallels to the axes. This is the algebraic graph learnt in grade 9 in Lesotho. The task involves a ten-item questionnaire focusing on scaling which the students in the control and experimental group have to answer (see appendix: Task 1.).

Aims and Objectives: The aim of Task 1 was to enable the researcher to determine the pre-knowledge, and background about scaling with regards to algebraic graphs, of the students.

Expectation: It was expected that if more than half of the students had scored more than fifty percent in task 1, they had a good background knowledge about scaling, which was reflected in their performance. But if more than half of the students scored less than fifty percent, this would indicate that they had little or no knowledge about scaling in algebraic linear graphs. Therefore one could deduce that some factors were necessary for the understanding of algebraic graphs of which scaling is one.

- **A teaching programme on scaling**

Content: Following the first task (Task 1), from which the researcher was able to identify that some factors were necessary for the understanding of algebraic linear graphs, the special teaching course was given to the experimental group.

Aims and Objectives: The aims of the special teaching programme were to provide the students in the experimental group with knowledge about scaling in algebraic linear graphs. This is to enable them to develop the ability to

demonstrate and solve problems in mathematics, especially in algebraic linear graphs. At the end of the special teaching programme, the students should be able to choose a scale for a table of values generated from a problem in linear algebra in order to construct, interpret, and predict from the graph constructed.

Expectation: At the end of the special teaching course each student should be able to choose a scale for a table of values in order to construct a graph as well as to understand it.

- **Questionnaire**

Content: The questionnaire consisted of 12 questions focusing on scaling. The content is as laid down in the grade 9 syllabuses and to based on the special teaching course for the experimental group.

*Aims and Objectives***:** The aim of the questionnaire was to determine if there is any significant difference in the students' ability to construct an algebraic linear graph before and after the special teaching course using the inferential statistics. If the students answer more than half of the questions correctly, then it means that the special teaching course on scaling has had some effects which will be noticed in the results or responses to the questionnaire by the students.

Expectation: The responses to the questionnaire by the students from the experimental group should be able to demonstrate that the students can construct and understand algebraic linear graphs through scaling

•**Interview 1**

Content: The Interview 1 questions focused on the grade 9 syllabuses on linear algebraic graphs. They were administered to four selected students from the experimental group immediately after the special teaching ended.

Aims and Objectives: The aim of the interview was to find out what effect scaling has on the understanding of algebraic graphs by the grade 9 learners. Their attitude to the importance of scaling in the understanding of algebraic graphs was investigated.

Expectation: The students should be able to demonstrate that a knowledge of scaling acquired through special teaching can influence the understanding of algebraic linear graphs.

- **Task 2**

Content: The content of task 2 is as it is in paragraph 2.2. This is in line with the grade 9 (Form B) syllabus in Lesotho.

Aims and Objectives: The aim of Task 2, which was the post-test, was to determine if scaling has on effect on the understanding of algebraic linear graphs. A significant difference in the mean scores of the responses to the Task between the control and experimental group would indicate this.

Expectations: The experimental group should perform much better than the control group because of the extra tutoring they have received on scaling. That is, a significant difference must exist in the mean scores of the two groups in Task 2.

- **Interview 2**

Contents: The contents of interview 2 are the same as in interview 1, focusing on scaling with regards to paragraph 2.2. It is more elaborate than interview 1 and contains nine-item instead of the six-item question for the four students selected from the experimental group.

Aims and Objectives: To determine what effect scaling has in the understanding of algebraic graphs. The students, in terms of their abilities in and attitudes to problem solving in mathematics and algebraic linear graphs in particular, must demonstrate this. The level of understanding of the special teaching course on scaling will also be revealed in the student responses to the interview.

Expectation: The responses from the students to the interview questions should be able to demonstrate that scaling has an effect on the understanding of algebraic linear graphs. This can be judged from the responses to the interview. The interview will further provide the researcher with more information about how well the teaching and learning on scaling during the extra tutoring was. How well the students understood the aspect which were presented to them during the special training on scaling will also be demonstrated.

3.9 SUMMARY AND CONCLUSION

This chapter focused on the methods used by the researcher to conduct the research: the strategies and techniques which the researcher has designed and implemented to collect data in order to be able to accept or reject the null hypothesis.

In this chapter, the study population and sample, which include the total number of students in grade 9 (Form B) and the number of participants respectively, were discussed in section 3.3. The instrumentation which consists of the pre-test, questionnaires, the interviews, and the post-test was discussed in section 3.4. The variables used include the independent and dependent variables. They are discussed in section 3.5 and the method of research in section 3.6.

The statistical procedure and techniques used were outlined in section 3.7, and the procedure used for the study in section 3.8. In chapter 4 data will be analyzed and the results interpreted.

CHAPTER FOUR

ANALYSIS AND INTERPRETATION OF RESULTS

4.1 INTRODUCTION

The aim of the study was to investigate the effect of scaling on the understanding of algebraic graphs for grade 9 learners. In this chapter, the null hypothesis is stated followed by a summary of statistics and the testing of the hypothesis.

4.2 NULL HYPOTHESIS

Only one hypothesis was set for this study: Using a scale to draw a graph can influence the understanding of algebraic graphs in grade 9 learners (Form B).

4.3 PROCEDURE

A series of tests was carried out to determine the effect of the independent variable on the dependent variable. The tests used include the pre-test (task 1), the questionnaire, the post-test (task 2) and the interviews.

4.4 SUMMARY OF STATISTICS

The statistics for the students' performances in the questionnaire, and the pre-and post-tests of the experimental and control groups were calculated as follows:

4.4.1 The Pre-test (Task 1)

Table 4.1 Summary statistics for the pre-test of the experimental and control group.

EXPERIMENTAL GROUP			CONTROL GROUP		
S/NO	STUDENTS	MARKS (10)	S/NO	STUDENTS	MARKS (10)
1	S1	4	1	S1	3
2	S2	3	2	S2	3
3	S3	4	3	S3	2
4	S4	6	4	S4	1
5	S5	8	5	S5	7
6	S6	4	6	S6	6
7	S7	4	7	S7	4
8	S8	4	8	S8	4
9	S9	3	9	S9	5
10	S10	4	10	S10	6
11	S11	4	11	S11	4
12	S12	5	12	S12	3
13	S13	6	13	S13	4
14	S14	5	14	S14	5
15	S15	4	15	S15	6
16	S16	6	16	S16	5
17	S17	3	17	S17	3
18	S18	4	18	S18	3
19	S19	1	19	S19	4
20	S20	5	20	S20	2

Table 4.2 Summary statistics for the pre-test (task 1) of the experimental group.

Experimental group: 20 students.

Mean = 4.35 or 43.5%

Descriptive

	Statistic	Std error
Mark Mean	4.35	. 327
95% confidence interval Lower Bound	3.67	
Interval for mean Upper Bound	5.03	
5% Trimmed mean	4.33	
Median	4.00	
Variance	2.134	
Std	1.461	
Minimum	1	
Maximum	8	
Range	7	
Inter-quartile	1.00	
Skew ness	. 329	. 512
KURTOSIS	1.795	. 992

Table 4.2.1 The box and whisker plot for the pre-test (Task 1) for the experimental group.

The box and whisker plot shows that there are two outliers in   this group: student # 5 (mark of 8) and student # 19 (mark of 1)
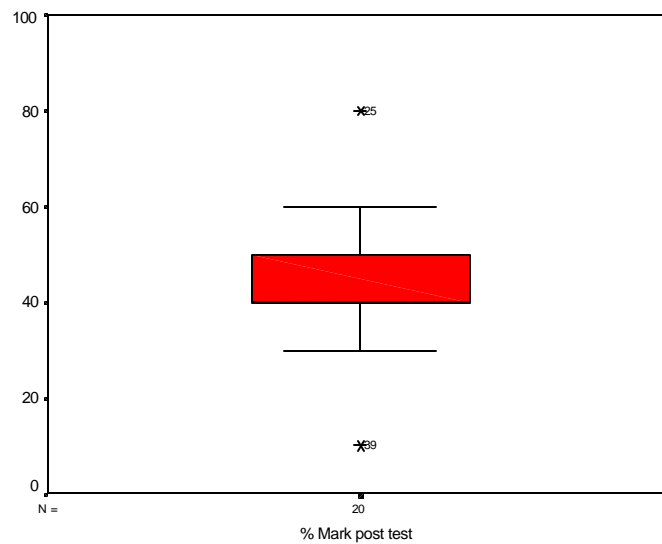
Table 4.2.1.

Table 4.3 Summary statistics for pre-test (task 1) for the control group.

Control group: 20 students

Mean: 4.0 or 40%

Descriptive

		Statistics	Standard Error
Mean Mark		4.00	.348
95% Confidence	Lower Bound	3.27	
Interval for mean	Upper Bound	4.73	
5% Trimmed mean		4.00	
Median		4.00	
Variance		2.421	
Std. Deviation		1.556	
Minimum		1	
Maximum		7	
Range		6	
Interquartile Range		2.00	
Skeweness		.093	.512
Kurtosis		- .458	.992

Table 4.3.1 The box and whisker plot for the summary of statistics (task 1) for the control group.
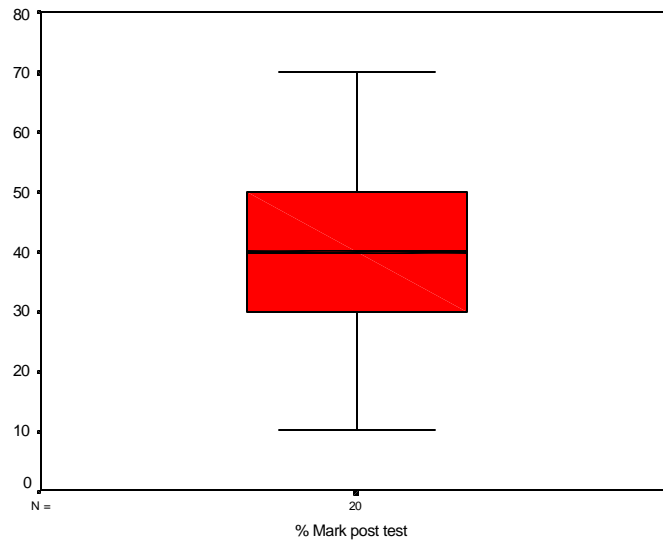
A t-test was done to compare the two mean scores of the groups.

The null hypothesis states that the means of the two groups are equal.

The alternative hypothesis is that the means of the two groups do differ.

Table 4.4 **INDEPENDENT SAMPLE TEST**

The computer results are as follows:

	MARKS	
	Equal variances assumed	Equal variance not assumed.
Levene's test for F	.225	
Equality of variances sig.	.628	
t-test for equality of t	-.733	-.733
Means df	38	37.850
Sig. (2 tailed)	.468	.468
Mean difference	-.35	-.35
Std error difference	.477	.477
95% confidence interval of difference: Lower Bound	-1.316	-1.316
Upper Bound	.616	.616

The computer results show that the means are equal. This means that there was no bias built into the selection of students for the study and that the students had little or no pre-knowledge about scaling.

4.4.2 The Questionnaire

Table 4.5 Summary statistics for questionnaire for the experimental group.

Table 4.5.1 Frequency table for the sum of marks across the 12 questions.

TOTAL

	Frequency	Percentage	Valid percent	Cumulative percent
Valid 6	3	15.0	15.0	15.0
7	3	15.0	15.0	30.0
8	5	25.0	25.0	55.0
9	5	25.0	25.0	80.0
10	2	10	10	90.0
11	1	5.0	5.0	95.0
12	1	5.0	5.0	100.0
Total	20	100.0	100.0	

Table 4.5.2 Frequency table for the (total number for correct answer)/ 12*100

TOTAL PERCENTAGE (TOTPERC1)

	Frequency	Percent	Valid percent	Cumulative percent
Valid 50	3	15.0	15.0	15.0
58.33	3	15.0	15.0	30.0
66.67	5	25.0	25.0	55.0
75.00	5	25.0	25.0	80.0
83.33	2	10.0	10.0	90.0
91.67	1	5.0	5.0	95.0
100.00	1	5.0	5.0	100.0
Total	20	100.00	100.00	

Table 4.5.3 Case processing summary.

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Question * Group	167	100.0%	0	.O%	167	100.0%

Table 4.5.4   Question * group cross tabulation.

	Group	Total
	Experimental	
Question Q1	20	20
Q2	16	16
Q3	13	13
Q4	7	7
Q5	18	18
Q6	7	7
Q7	16	16
Q8	14	14
Q9	16	16
Q10	17	17
Q11	9	9
Q12	14	14
	167	167

Table 4.5.5 A bar chart of the number of questions answered correctly per question.

Cases weighted by FREQ
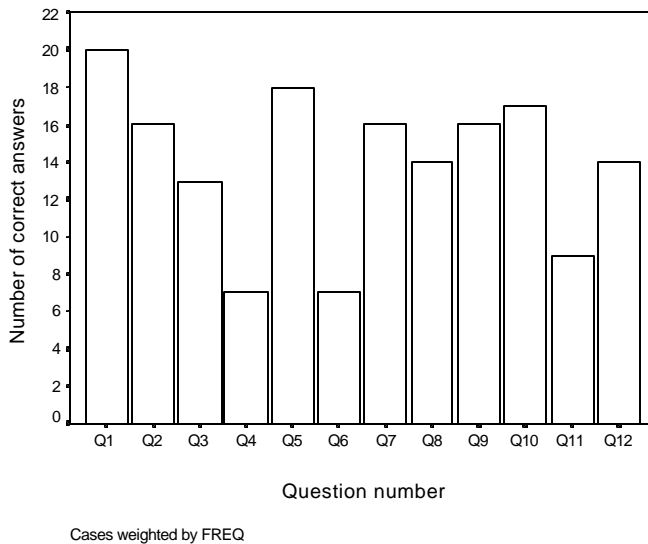
Since we have the outcomes of either 0 or 1 we can test the hypothesis about the proportion of questions answered correctly.

STATISTICAL TEST FOR QUESTIONS ANSWERED CORRECTLY.

As null hypothesis: the population mean for the experimental group is equal to the population mean for the control group.

$H_0: \pi = 0,5$

As alternative hypothesis: The students should be able to answer more than half of the questions correctly since they had extra tutoring.

$H_1: \pi > 0.5$

Test statistic: This is a t-test which is used for determining if two variables are related or not. It is usually obtained from a table at a given level of significance and compared with the t-value from the student's performance from the test. The level of significance is usually chosen depending on the nature of the data and what it is used for. The value obtained from the table is called the critical value. For this study, the level of significance is 5%.

Level of significance: $\alpha = 0.05$

Critical value: $Z_{0.05} = 1.645$

P $= 167/20*12$

 $= \underline{167}$

   240

 $= 0.6958.$

$Z = P - 0.50$

  $\sqrt{0.5(0.5)/20}$

 $= .696 - 0.5/0.1118$

 $= 1.752.$

Since 1.752 > 1.645, the students in the experimental group therefore answered more than half of the questions correctly.

4.4.3 The Post-test (Task 2)

Table 4.6 Summary statistics for post-test (task 2) for the experimental and control group.

Experimental group: Control group

S/NO	Students: Exp.	Marks (15)	S/No	Students: Control.	Marks (15)
1	S1	13	1	S1	6
2	S2	12	2	S2	6
3	S3	10	3	S3	7
4	S4	13	4	S4	5
5	S5	15	5	S5	9
6	S6	12	6	S6	8
7	S7	12	7	S7	9
8	S8	11	8	S8	10
9	S9	12	9	S9	6
10	S10	10	10	S10	9
11	S11	10	11	S11	9
12	S12	12	12	S12	7
13	S13	11	13	S13	12
14	S14	10	14	S14	8
15	S15	10	15	S15	11
16	S16	13	16	S16	11
17	S17	10	17	S17	7
18	S18	9	18	S18	6
19	S19	10	18	S19	9
20	S20	10	20	S20	7

Table 4.6.1. Summary statistics for the post-test for the experimental group.

Experimental group: N=20

Mean: 75%

Descriptive

		STATISTICS	STD ERROR
% Mark	Post-test mean	75.0000	2.26207
95% Confidence	Lower Bound	70.2654	
Interval for Mean	Upper Bound	79.7346	
5% Trimmed Mean		74.4444	
Median		73.3333	
Variance		102.339	
Std Deviation		10.11626	
Minimum		60.00	
Maximum		100.00	
Range		40.00	
Inter quartile Range		13.3333	
Skewness		.734	.512
Kurtosis		.175	.992

Table 4.6.2 The box and whisker plots for the post-test (task 2) of the experimental group.

The box and whisker plot shows that the data for this group is symmetrical and that there are no outliers.
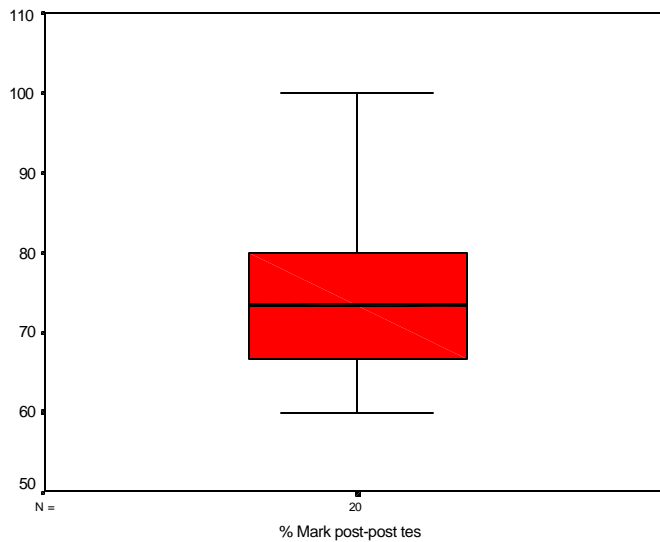
Table 4.7 summary statistics for the post-test for the control group
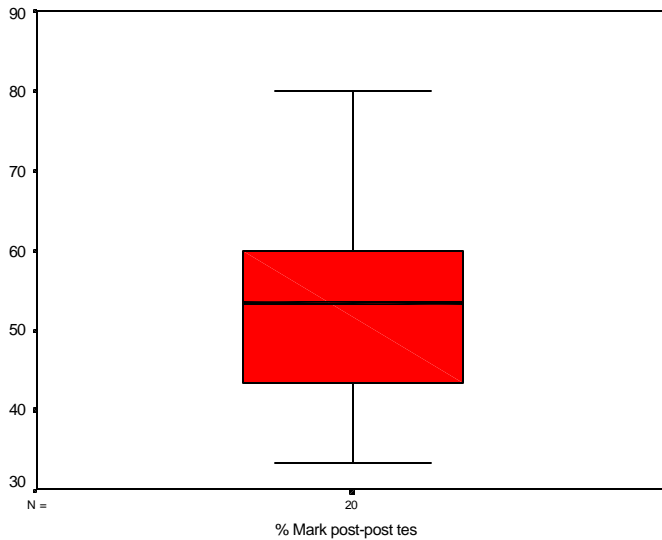
Control group: N=20

Mean: 54%

Descriptive

			Statistic	Std Error
% Mark	Post-test Mean		54.0000	2.89787
95% Confidence	Lower Bound		47.9347	
Interval for Mean	Upper Bound		60.0653	
5% Trimmed Mean			53.7037	
Median			53.3333	
Variance			167.953	
Std. Deviation			12.95968	
Minimum			33.33	
Maximum			80.00	
Range			46.67	
Interquartile Range			18.3333	
Skewness			.370	.512

Table 4.7.1 The box and whisker plot for the summary statistics for the post-test (task 2) of the control group.

The box -and whisker plot shows that the data is symmetrical and that there was no outlier in this group.

% Mark post-post tes

To see if the difference between the mean scores of the experimental and control groups for the post-test is statistically significant, a t-test was used.

As the alternative, we set the hypothesis that the post-test marks for the experimental group are higher than the post-test marks for the control group.

The results of the test of the paired variables:

Table 4.8 summary statistics of the independent sample test for paired variables.

	Equal variance assumed	Equal variance not assumed
Levene's Test for F	0.42	
Equality of Variances Sig.	.839	
t—test for Equality of Means t	4.301	
Df	38	
Sig (2-tailed)	.000	
Mean Difference	17.5000	
Std. Error	4.06867	

95% Confidence Interval of the Difference:		
Lower Bound	9.26340	
Upper Bound	25.7366	2

The test indicates that the variances are not equal. Hence we look at the columns where equal variance is not assumed. The test statistic is $t = 4.301$ and P – value $= 0.00$. This implies that we can reject the null hypothesis and conclude that the experimental group performed better than the control group in the post-test.

4.4.4 INTERVIEW 1

A summary of interview 1 is given below.

Question 1: Do you like solving problems in algebraic graphs?

Responses:

S1: Yes. I like solving problems in algebraic graphs.
S2: Yes, I like doing algebraic graph and solve problems
 with it.
S3: Yes, I like solving graph problems in algebra.
S4: Yes, I like doing graph.

Question 2: What is the first thing that you must do before you plot the points on the graphs?

Responses:

S1: Choose a scale.
S2: Make axes and choose a scale.
S3: Prepare a table of values and draw the axes with a scale.
S4: Choose a scale from a table of values or coordinates.

Question 3: If your answer in (2) is that you must choose a scale, does it mean that you cannot draw any graph without a scale?

Responses:

S1: it is possible to draw a graph without scale but if the values on the table are large, it becomes necessary to choose a scale.
S2: You must choose a scale if you want to draw a good and meaningful graph but you can draw some graphs without scale if the values are small and the graph paper is enough for drawing the graph.
S3: Yes, You cannot draw any graph without a scale.
S4: Yes.

Question 4: Would you like doing graphical problems in mathematics if you know how to choose a scale from a table of values?

Responses:

S1: Yes.
S2: Yes.
S3: Yes and always.
S4: Yes.

Question 5: Can you interpret a graph if you know the scale used in drawing the graph?
Responses:

S1: I can interpret a graph if I know the scale used and even similar graph.
S2: Same as S1.
S3: I can interpret the graph after drawing with a scale.
S4: Sometimes.

Question 6: Can you suggest how important scaling is in drawing a graph?
Responses: The four students suggested the following:

> *1. Scale helps in drawing graphs.*
> *2. Scaling helps to interpret graphs.*

3. Scaling helps in solving problems involving graphs.

4. Scaling helps to change the shape of graphs.

5. Scaling helps to make prediction from the graph.

6. It makes it easier for one to understand a graph.

7. It is easy to construct a graph using scale.

From the responses to the questions, which were also designed to determine the effect of scaling in the understanding of algebraic graphs, the students have demonstrated in terms of attitude and problem solving that scaling can influence this understanding. They also show from their responses that Scaling is important in drawing graphs through the extra tutoring they have received. The evidence was that they affirmed they would continue doing mathematics, having acquired the ability to choose a scale in order to be able to draw a graph.

4.4.5 INTERVIEW 2

Interview 2 consists of nine questions designed to investigate if the extra tutoring has made a difference in the students' ability to understand algebraic graph through scaling. The nine questions focused on scaling and attitudes to problem solving using scaling. The importance of interview 2 was to determine the extent to which the extra tutoring on scaling had influenced their understanding of algebraic graphs as was observed in the post-test for the experimental and control groups. This is why interview 2 was conducted at a later time.

Question 1: What does the scale: 2cm representing 1 unit mean?

Responses:

S1: 2cm is on the graph and 1 unit is on the table.

S2: 2cm is on the graph while 1 unit is on the table of values.

S3: 2cm on the graph and 1 unit is the number on the table of values.

S4: 2cm is on the graph and 1 unit equals the numbers on the table.

Question 2: A scale was chosen as one centimeter representing five units. On your graph sheet there were five square divisions representing one centimetre.

(i) What is the value of one square division?

(ii) How many centimetres give 3 units?

(The researcher presented the graph sheet to them)

Responses:

S1: (i) = 1cm.

    (ii) = 0.6cm.

S2 (i) = 1cm.

    (ii) = 0.6cm.

S3 (i) = 1cm.

    (ii) = 0.6cm.

S4 (i) = 1cm.

    (ii) = 0.6cm.

Question 3: A scale of 2cm representing 1 unit was chosen for a table of values to draw a graph. Which one of the following possibilities will increase the size of the graph?

    (a) 1cm representing 1 unit

    (b) 2cm representing 2 unit

    (c) 1cm representing 2 unit

    (d) 3cm representing 1 unit.

Responses:

S1: option d.

S2: option d.

S3: option d.

78

S4: option d.

Question 4   From 3 which one of the scale will reduce the sizes of the graph?

Responses:

S1: option a and c.
S2: option c.
S3: option c.
S4: option a and c.

Question 5: Consider the following scales:

        (i)   1cm representing 2 units.

        (ii)   2cm representing 1 unit.

Which of the scales will provide a better graph for solving problems?

Responses:

S1: option (ii).
S2: option (ii).
S3: option (ii).
S4: option (ii).

Question 6: On the axis of a linear graph, starting from the origin, at 1cm mark = 1990; 2cm mark = 1992; 3cm mark = 1994, which year will the 7cm mark represent?

Responses:

S1: 2002.
S2: 2002.
S3: 2002.
S4: 2002.

Question 7: From question 6, what will be the cm mark for the year 1995?

Responses:

S1 = 3½ cm.

S2 = 3.5 cm.

S3 = 3½ cm.

S4 = 3.5 cm.

Question 8: You are given the following values on a table.

X	1	2	4	7	8
Y	10	20	40	70	80

But the dimensions of your graph are 18cm horizontally and 22cm vertically. What do you do so that you can adequately represent the information on the graph?

Responses:

S1: Choose a scale.

S2: You have to choose a scale that can represent the values on the table on the graph sheet provided.

S3: You have to choose a scale that can help you to draw the graph.

S4: You have to choose a scale so that you can plot all the values on the graph sheet.

Question 9: Would you like solving graphical problems in mathematics if you knew how to choose scales in order to construct a graph? Why?

Responses:

S1: Yes, because it is easy to draw a graph with scale.

S2: Yes, because using scale to draw a graph make it easy to understand the graph.

S3: Yes, it is easy to draw graph with scale.

S4: Yes, because it is simple to draw a graph with scale.

From the responses of the students, the extra tutoring on scaling has influenced their understanding of algebraic graphs. The responses of the students show that they have acquired the ability to choose scale in order to

be able to draw a graph. The evidence that they can construct, interpret and predict from a graph drawn to scale was well demonstrated from their responses. The ability to interpolate and extrapolate from a linear algebraic graph was also noticed.

4.5   CONCLUSION

The aim of this chapter was to investigate whether scaling has an influence on the understanding of algebraic graphs for grade 9 learners (Form B). The computer results from the pre-test show that there was no bias built into the selection of the students for the study. Their little or no pre-knowledge of scaling was also evidenced in the results provided.

The questionnaire was only administered to the experimental group. The computer result also shows that the extra tutoring has influenced the understanding of algebraic graphs as nearly all the students answered more than half of the questions correctly.

The post-test for the experimental and control groups also indicated that scaling has influenced understanding. The scores for the post-test for the experimental group were higher than the scores for the post-test of the control group.

The interview 1 responses indicated that the extra tutoring produced a positive change in the students' attitudes to understanding of algebraic linear graph and problem solving by using scales to construct the graph. The

interview 2 responses shows the same indication as in interview 1, since the extent to which the extra tutoring on how to choose a scale from a table of values can help in the understanding of algebraic graph was demonstrated. There was also an indication that a sound teaching method was employed in the teaching of the experimental group on how to choose scales and use them to draw a graph, since the post-test was administered at a later time and the effect was still noticeable.

CHAPTER 5

SUMMERY, RECOMMENDATION AND CONCLUSION

5.1   INTRODUCTION

This chapter summarizes the research. A statement of the problem is given in section 5.2. The review of the literature is summarized in section 5.3, followed by the method of the research in section 5.4, the procedure of the research in section 5.5, and the result and conclusion in section 5.8, and finally some recommendations are made in section 6.9. The concluding remarks are discussed in section 5.10.

5.2   STATEMENT OF THE PROBLEM

The difficulties in the understanding of algebraic linear graphs have been the focus of numerous research studies. These difficulties have been traced to learners;

1) Inability to construct linear graphs when presented with values either on a table or co-ordinates form.
2) Inability to interpret graphs of given situations or linear equations.

3) Inability to use the graph to make predictions.

4) In ability to use the graph to solve problems in mathematics

In the construction of graphs, four tasks were identified as being necessary for the construction of graphs: scaling, translation, prediction and classification (Leinhardt et al 1990:4). The inability of learners to understand algebraic linear graphs without scale was evidenced in much of the consulted literature.

5.3   REVIEW OF THE LITERATURE

The literature review focused on: the grade 9 learners and the content of algebraic graphs for such learners, an analysis of scaling in terms of graphing in algebra, factors involved in the choice of scales for the understanding of algebraic graphs, the problems in the understanding of algebraic graphs and which teaching methods could help learners to understand scaling in algebraic graphs.

The grade 9 learners and the content of algebraic graphs for such learners were as it is in section 2.2. Many literatures were consulted with regards to analysis of scaling in terms of graphing in algebraic. According to Bertin (1983), a scale expresses the relationship between the linear dimension of the sheet of paper and the dimension of the space being represented. This is the case of the graphic scale which I am concern about in this study.

Several factors have been identified in numerous pieces of research that necessitate the choice of scale. They are; construction of graphs, logical

thinking of the learners, nature of the data, dimension of the graph sheet, pre-knowledge about learning graphs, students problems with learning of algebraic graphs, interpretation of the graphs and predicting from the graphs (Leinhandt 1990:1-64; berg et al 1994: 323; Doerr & Zbger 2000: 142-163). The ability to construct, interpret and make prediction from the graph were some of the problems identifies to exist with learners at grade 9 (Mendoza & Meller 1992: 151; Wainer 1992: 14, Mckemzie & Paditla 1986: 571-573). Other problems were features of the contents and presentations of the graphs; how graphs are taught in the classrooms, logical reasoning of the learners and information not on the graph.

In order to make the learner to learn and understand the concept of scaling in algebra; the constructivist approach is highly recommended for teaching scaling. This method of teaching will help resolve some of the difficulties which the learners have with regards to understanding algebraic linear graphs.

5.4 METHOD OF RESEARCH

The great 9 (Form B) students of Qholaqhoe High Schools constituted the subjects for the research study populations. A total of forty students were selected using the purposeful/judgment sampling technique from the two classes of the form B (Form B1 and Form B2) on the basis of gender and ability.

The following research instruments were used: Pre-test, (task1); Post-test (task 2) questionnaire, interview 1 and interview 2 (see sections 3.4).

5.5 PROCEDURE

The procedure was as in section 3.8. While the quantitative research in this study uses interview and questionnaire to gather data directly from the students, the quantitative research uses the pre-test, post-test as well as the questionnaire. They were process by using the SPSS system software for Windows Release 6.12. The tests were used to determine whether the differences between the performance in the experimental and control groups were of statistical significance.

5.6 RESULTS

With reference to table 4.4, there was a fair selection of subjects for the study and the students had little or no knowledge about scaling (see test for equality of means and difference in this table 4.4). With regard to table 4.5.3, 4.5.4 and 4.5.5 there was a positive influence of scaling in the understanding of algebraic graphs, as the students in the experimental group who receive extra tutoring on scaling answered more than half of the questions correctly. The null hypothesis was rejected and alternative hypothesis was accepted since at 0.05 level of significance, the Z-value (1.752) was greater than the critical value (1.645).

In table 4.8, the test statistic t = 4.301 and P-value = 0.00. This implies that we can reject the null hypothesis and conclude that the experimental group perform better than the control group in the post-test (Task 2). This also

indicated that the scaling has an influence on the understanding of algebraic graphs for the grade 9 (Form B) learners. This evidence cannot be unconnected with the fact that the experimental group had received extra tutoring and exposed to good material on scaling.

Furthermore, the student's responses to interview 1 and interview 2 clearly justify the fact that scaling has an influence on the understanding of algebraic linear graph in grade 9 (Form B). The students demonstrated in their responses that with scaling they could:

1) Construct graphs.
2) Interpret graphs
3) Predict from the graphs
4) Solve problems with graphs
5) Continually solve problems in algebraic graph since they have acquired the ability to choose scale in order to construct a graph and understand it.

5.7   CONCLUSIONS

The hypothesis that using a scale to draw algebraic linear graphs can have an effect on the understanding of algebraic graphs could therefore be accepted. If the learner understands how to choose scale for drawing algebraic linear graphs, they will be able to construct, interpret and make predictions from the graphs. This will make them to understand the graphs. Thus enabling the teachers and the learners to resolve the difficulties encountered in the

learning of algebraic linear graphs well as encouraging and motivating the learners to doing mathematics.

5.8   LIMITATIONS OF THE STUDY

The study might have suffered because of the following.

5.8.1 Available literature.

Not much research has been carried out about the influence of scaling on the understanding of algebraic graphs in Lesotho. Thus the literature and results based on the South Africa, the United States of America and the Holland had to be used for generilization and application in the predominantly rural situation in Butha-Buthe district of Lesotho.

5.8.2 Interruption in the programme

Interruption during the programme especially while the extra tutoring was going on for the experimental group could have had a negative influence on the results. A few students were absent from the lessons during the extra tutoring due to illness and family problems.
However, the researcher has to organized make-up lessons for them.

5.8.3 Language Medium

Most of the students were not good at reading the written English language.

Thus this must have affected the reading of the questions in the pre-test,

questionnaire and post-test. The inability of the subject to express

themselves in the English language during the interview also affected the

correctness of their responses.

5.9 RECOMMENDATION

It is recommended that;

More research is done into Lesotho learners to determine the effect of scaling in algebraic graphs across all grades in the secondary and high school.

Teachers should be made sensitive to the role scaling in graphical presentation so that learners can understand graphs as well as using a sound teaching method to teach the concept of scaling in algebraic linear graphs so that learners can learn and understand.

Comparative studies in a bigger study population should be undertaken. Longitudinal studies are also needed to determine whether the result of the programme such as this one, remain over a long period of time as well as to discover the extent of the retention.

5.10 CONCLUDING REMARKS

In this study, the effect of scaling on the understanding of algebraic graphs amongst grade 9 (form B) learners, based on a teaching and learning programmed was analyzed. Scaling has a definite influence on the understanding of algebraic graphs. This was evidenced in this study as learners have demonstrated in the tests, questionnaires and interviews. The use of scaling to construct a graph will therefore help learners to continue doing mathematics especially in a problem-solving context. This result has brought in a new perspective to the studies of Leinhardt et al (1990), Mckenzie (1986), Wainer (1990, 1991 & 1992). According to their studies learners have difficulties in the understanding of algebraic linear graphs. One of the tasks needed for construction is scaling task. Thus the influence of scaling in the understanding of algebraic graphs has brought in a new perspective to the studies of the above mentioned researchers. Having acquired the ability to determine the scale of a graph, the learners will feel motivated and encouraged in solving mathematical problems using graphs. The active participation of the learners in the teaching programme gave us the opportunity to obtain a satisfactory result from this study. This is why the theory of constructivism was advocated for teaching the learners the concepts of scaling in algebraic graphs.

It is hoped that the results will help to convince educators of the benefits of teaching learners to use scaling to construct a graph both in algebra and beyond.

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APPENDICES

APPENDIX I: LETTERS

APPENDIX 2: TASKS

APPENDIX 3: QUESTIONNAIRE

APPENDIX   4:   INTERVIEWS

APPENDIX 1: LETTERS.

LETTER TO PRINCIPAL.

LETTER TO EDUCATION OFFICE.

APPENDIX   2

TASK 1.

EXERCISE 1

(1)   The scale shown below is 2cm representing one hour.

Which one of the follwing possibilities is correct about the number of hours and minutes represented by the letter B?

(a) B is equal to 60 minutes.
(b) B = 3.3 cm.
(c) B = 3.3 hours.
(b) Point B is greater than point C.

(2) Which one of the following information is not correct about the graph?

(a) The scale is 2 cm representing one hour.
(b) 0.5 cm represents 15 minutes on the graph.
© Every one single division represents 60 minutes.
(d) Points A, B, C and D cannot be calculated.

(3) If you are travelling and you stop at point a, how many minutes have passed?

(a) 90 minutes.
(b) 150 minutes.
(c) 120 minutes.
(d) 1.5 minutes.

(4) Each of the small divisions on the graph represents ------ -----?

(a) 60 minutes.
(b)   6 minutes.
(c) 600 minutes.
(d) 10 minutes.

(5) The diagram below shows Phindile's journey from home to school. Use the diagram to answer questions 5-8.

The total distance traveled by Phindile from home to school is

(a)   120 km.
(b)   10 km.
(c)   12 km.
(d) 1200 km.

(6) Which one of the following is correct about the number of minutes Phindile took to walk from home to school?

(a)   120 minutes.
(b)   1200 minutes.

101

(c)   No time was spent.
            12 minutes.

(7) (1) Phindile took 120 minutes to walk from home to school.
      (2) Phindile walks a ditance of 10 km from home to school
      (3) Phindile's speed from home to school is 5 km/h.
      (4) Phindile's speed is 12 km/h.

All the above are correct except

   (a) 1
   (b) 2
   (c) 3
   (d) 4

(8) Phindile's journey from home to school was represented on a graph with a scale of

   (a)   2 cm to represent 4 km on the vertical axis and 2 cm to represent 12 minntes on the horizontal axis.
   (b)   2 cm to represent 2 km on the vertical axis and 2 cm to represent 20 minutes on the horizontal axis.
   (c)   2 cm to represent 4 km on the vertical axis and 2 cm to represent 20 minutes on the horizontal axis.
   (d   2 cm to represent 40 km on the vertical axis and 2 cm to represent 20 minutes on the horizontal axis.

(9)   The graph below represents the rate at which the price of milk increases as a result of inflation for 12
      days.

What is th price of milk after 7½ days?

(a) M 4.00
(b) M 8.00
(c) M 12.00
(d) M 18.00

(10)

Use the graph above answer question 10

What are the coordinates of the point represented by A?

(a) (9,16).
(b) (16,9).
(c) (4,16)
(d) (3,16)

TASK 2.

EXERCISE 11

INSTRUCTIONS: Answer all questions. When presented with a choice, ring the letter next to the alternative chosen.

The diagram below represents the x-axis of a linear algebraic graph. Use the diagram to answer questions 1-2.

(1) What is the scale for the axis?
   (a) 1cm represents 2 units.
   (b) 2cm represents 1 unit.
   (C) 2cm represents2 units.
   (d) X-axis has no scale.
(2) What is the value of the point represented by the letter A?
   (a) 5.8 units.
   (b) 7.5 units.
   (c) 570 units.
   (d) 11.5 units.
(3) A scale is chosen for the y-axis as 2cm =1 unit.What is the value of 1 unit, 2 units, and 4 units?
   (a) 2cm, 4cm, and 6cm.
   (b) 4cm, 2cm, and 8cm.
   (c) 2cm, 6cm, and 8cm.
   (d) 2cm, 4cm, and 8cm.
(4) The next three terms in the following sequence 3, 6, 9, 12, __, __, __, are;
   (a) 15, 16, 17.
   (b) 15, 18, 19.
   (c) 15, 18, 21.
   (d) 15, 21, 18.
Use the diagram below to answer questions 5-9.

(5) What scale was used in constructing this graph?
   (a) 1cm = 1cm on x-axis and 3cm = 1unit on y-axis.
   (b) 1cm = 5 units on x-axis and1cm = 3 units on y-axis.
   (C) 5cm = 1unit on x-axis and 3cm = 1unit ony-axis.
   (d) None of the above.
(6) The value of the point represented by A is __?
   (a) A = 10 units.
   (b) A = 5 units.
   (c) A = 2 units.
   (d) A = 4 units.
(7) What are the coordinates of the point represented by the letter H?

104

(a) H = (-5,0)
(b) H = (0,-5)
(C) H = (5,0)
(d) H = (0,5)

(8) From the graph, if x = 10, what is the value of y?
(a) Y = -9.0
(b) Y = -10.0
(c) Y = 9.0
(d) Y = 3.0

(9) If y = 18.0, what is the value of x?
(a) X = 18.0
(b) X = -25.0
(C) X = -18.0
(d) X = 25.0

The diagram below represents the amount earned by limpho for selling magazines subscription on part-time. Use the diagram to answer questions 10-13.

(10) What scale was used in drawing the graph?
(a) 2cm = 1unit on the horizontal-axis and 1cm = 6 units on the vertical-axis.
(b) 2cm = 1unit on the horizontal-axis and 1cm = 2 units on the vertical-axis.
(c) 6cm = 1unit on the vertical-axis and 1cm = 2 units on the horizontal-axis.
(d) No scale was used.

(11) How much did limpho earn for selling 3 magazines?
(a) M36.00
(b) M48.00
(C) M3.600
(d) M360.00

(12) If Limpho earns M60.00, how much magazines did he sell?
(a) 3
(b) 5
(C) 9
(d) 4½

(13) How much will Limpho earn if he sells six magazines?
(a) M60.00
(b) M56.00
(C) M36.00
(d) M72.00

Below is a graph of two equations y = 8 and y = 2x + 1. Use the diagram to answer question 14-15.

(14) Which one of the following possibilities is not correct about the graph of the two equations?
   (a) 1cm = 2 units on the y-axis.
   (b) 2cm = 1 unit on the x-axis.
   (C) The scale for drawing the two graphs is the same.
   (d) None of the possibilities is correct.

(15) The coordinates of the point where the two graphs meet are (_,_)?
   (a) (3,8)
   (b) (3½,18)
   (c) (3½,8)
   (d) (8,3½)

APPENDIX 3

QUESTIONNAIRE.

QUESTIONNAIRE FOR STUDENTS.

INSTRUCTIONS.

(1) ANSWER ALL QUESTIONS.
(2) ALL ANSWERS WILL BE TREATED IN THE STRICTIEST CONFIDENCE.
(3) WHEN PRESENTED WITH A CHOICE, RING THE LETTER NEXTTO THE ALTERNATIVE

CHOSEN.

(1) In drawing a graph, the table of values determines which scale to use.
   (a) Not agreed
   (b) Agreed
   (C) Strongly agreed
(2) If you choose a convinient scale in drawing a graph, it is easy to interpret the graph.
   (a) Not agreed
   (b) Agreed
   (C) Strongly agreed
(3) Any graph not drawn to scale is difficult to interpret.
   (a) Not agreed
   (b) Agreed
   (c) Strongly agreed
(4) The scale chosen and the tables determine the nature of the graph.
   (a) Not agreed
   (b) Agreed
   (C) Strongly agreed
(5) It is most convinient to solve a problem with a graph if you understand the scale that is used.
   (a) Not agreed
   (b) Agreed
   (c) Strongly agreed
(6) You can easily draw a graph for a table of values if you understand how to choose a scale.
   (a) Not agreed
   (b) Agreed
   (C) Strongly agreed
(7) Once you understand how to chose a scale for a table of values you con conviniently draw linear graphs of linear mapping.
   (a) Not agreed
   (b) Agreed
   (c) Strongly agreed
(8) One of the tasks involved in drawing a graph is the scaling task.
   (a) Not agreed
   (b) Agreed
   (C) Strongly agreed
(9) To predict from a graph, one need to know how the graph is constucted.
   (a) Not agreed
   (b) Agreed
   (C) Strongly agreed
(10) Scaling and rescaling of the axes of a graph allows one to understand the meaning of the graph or the situations it represents.

   (a) Not agreed
   (b) Agreed
   (C) Strongly agreed
(11) The use of scale in graphing gives one the opportunity to find multiple solutions to a graph.
   (a) Not agreed
   (b) Agreed
   (C) Strongly agreed
(12) Scaling allows one to see all the elements or units between the units on the axes.
   (a) Not agreed
   (b) Agreed

(C) Strongly agreed

APPENDIX 4

INTERVIEW 1

(1)   Do you like solving problems in algebraic graphs?

(2)   What is the first thing that you must do before you plot the points on the graphs?

(3)   If your answer in (2) is that you must choose a scale, does it mean that you cannot
        draw any graph without a scale?

(4)   Would you like doing graphical problems in mathematics if you know how to choose a scale
from a table of values?

(5)   Can you interpret a graph if you know the scale used in drawing the graph?

(6)   Can you suggest how important scaling is in drawing a graph?

INTERVIEW 2.

Question 1: What does the scale: 2cm representing 1 unit mean?

Question 2: A scale was chosen as one centimeter representing five units. On your graph sheet there were
five square divisions representing one centimetre.

(i) What is the value of one square division?

(ii) How many centimetres give 3 units?

(The researcher presented the graph sheet to them)

Question 3: A scale of 2cm representing 1 unit was chosen for a table of values to draw a graph. Which one of the following possibilities will increase the size of the graph?

(a) 1cm representing 1 unit

(b) 2cm representing 2 unit

(c) 1cm representing 2 unit

(d) 3cm representing 1 unit.

Question 4   From 3 which one of the scale will reduce the sizes of the graph

Question 5: Consider the following scales:

(i)   1cm representing 2 units.

(ii)   2cm representing 1 unit.

Which of the scales will provide a better graph for solving problems?

Question 6: On the axis of a linear graph, starting from the origin, at 1cm mark = 1990; 2cm mark = 1992; 3cm mark = 1994, which year will the 7cm mark represent?

Question 7: From question 6, what will be the cm mark for the year 1995?

Question 8: You are given the following values on a table.

X	1	2	4	7	8
Y	10	20	40	70	80

But the dimensions of your graph are 18cm horizontally and 22cm vertically. What do you do so that you can adequately represent the information on the graph?

Question 9: Would you like solving graphical problems in mathematics if you knew how to choose scales in order to construct a graph? Why?

114