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# Does Social Class Influence Learner Reasoning in Geometry?

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*Keywords : geometry, mathematics education, reasoning, social class.*

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# Does Social Class Influence Learner Reasoning in Geometry?

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## I. Introduction

South Africa came last out of 62 countries! This was reported about the quality of mathematics education in South Africa in the 2012 World Economic Forum's 5th Financial Development Report. This result is disturbing since mathematics is compulsory for learners at school; in addition mathematics is one of the key areas of study in formal educational institutions in South Africa (Adolphus, 2011). Mathematics serves as a gatekeeper to top earning careers and hence serves as a prerequisite to becoming economically successful (Iannelli & Paterson, 2005). Research (Noyes, 2009) has indicated that learners' success or failure in mathematics is a key factor in the determination of their subsequent life chances.

In general, the quality of education in a majority of disadvantaged schools in South Africa has been questioned in the light of apartheid education which denied the majority of South Africans access to adequate education (Mji & Makgato, 2006). This denial of access to information was one of the cornerstones of apartheid in South Africa, with an attempt to disallow those disadvantaged communities information that could be used to better themselves socially, politically and economically.

There have been many changes to the mathematics curriculum; from anecdotal experience the most disrupting was the move for mathematics to have an optional Paper 3 in 2006. The contents of Paper 3 included geometry, probability and statistics. These are key sections for learners if they intend pursuing mathematics in higher education institutions. Learners could choose whether or not they wanted to write the Paper 3 examination. The result of this change in the curriculum had a negative impact on the pass rate in mathematics for schools in rural areas and schools in lower socio-economic contexts (Gardiner, 2008). Many teachers did not teach these sections and hence learners were not adequately prepared to write the optional Paper 3. This in turn disadvantaged the learners. Learners could not cope with the content of first-year university mathematics due to their lack of knowledge in mathematics sections that were consigned to Paper 3. Thus instead of bridging the gap between the different socio economic classes and allowing more access for learners from different socio-economic backgrounds this entrenched them in the cycle of economic stagnation.

From studies conducted within the scope of mathematics education in South Africa, it appears as if there is a silence around issues surrounding the effect of the social class structure on the learning of geometry in mathematics. Research focusing on whether or not the social class structure of South African schools has an effect on learners' reasoning in geometry is therefore warranted.

In this article I discuss data collected through the use of a questionnaire, geometry evaluation worksheets and semi-structured interviews. The theoretical lens of the Van Hiele and social development theory was used to explore the learners' reasoning in geometry within this study. While the study was part of a larger study, this article aims at answering the following question: Does social class influence learner reasoning in geometry?

The article commences with a literature review of key issues; this section is followed by the research methodology, findings and discussion. The article concludes with the conclusion.

## II. Literature Review

### a) *Social class and mathematics education*

Class in this article conforms to Weber's definition, "a group of people with similar status or

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occupying the same situation" as cited in Berberoglu (1994, p. 5). Berberoglu (1994) proposed that social class and the class structure are forces that affect an individual in every aspect of life. Education is frequently related to social class (Iannelli & Paterson, 2005), schools are implicated in producing and reproducing inequalities related to social class and language by favouring knowledge and pedagogical practices that privilege the skills and experiences of the middle and upper middle-class learners (Zevenbergen, 2001).

To be successful in school, learners are required to access the opportunity structures made available by the school. For disadvantaged learners this may present a problem because of their limited opportunity structure (Smyth, 2004). Social class and success in mathematics are interlinked (Lubienski, 2000) since it is the educational system that trains young people to live in society when they are adult. As a result each individual is being groomed to carry out the social role expected of the class to which they belong. Mathematics has traditionally been viewed as a discipline where success is limited to a minority as opposed to a majority of children. By being associated with this notion, mathematics is seen as a subject that preserves the divide between social classes by limiting the participation of the less privileged rather than being used as an instrument of empowerment (Stinson, 2004).

*b) The social class structure in South Africa*

Social class provides an important framework for understanding how integration is being conceptualised and effected in South Africa. When the apartheid system began breaking down, the flow of children within the system took place in a fairly predictable way; children 'of colour' moved into what was once called 'white' schools (Van der Berg, 1999). This movement was about class following its own interest.

The class structure of post-apartheid South Africa was largely informed by the model developed using the SALDRU (Southern Africa Labour and Development Research Unit) survey that was compiled in 1993 on the post-apartheid class structure. This model was later updated in 2002 (Seekings & Nattrass, 2002). Data from this survey defined the upper class as those households headed by people in managerial, technical or professional occupations, or with substantial income from assets or entrepreneurial activities. The middle-class was comprised of households that were headed by educators, nurses, white collar workers, as well as skilled or supervisory workers. The working-class was comprised of households headed by semi-skilled or unskilled workers; and finally the underclass was comprised of households with no members in employment and negligible income from entrepreneurial activities or assets (Seekings & Nattrass, 2002).

Race, ethnic and gender relations are essential components of class structure and therefore have a major impact on class relations and class struggles (Barbeau, Krieger, & Soobader, 2004). Due to the circumstances of South Africa, race and class intersect (Seekings, 2003); hence various other factors like family size, educational level of parents, occupational status of parents, housing status, types of home, number of vehicles and tuition received were also taken into account before allocating a learner in this study to a specific social class background.

*c) Mathematics education and geometry in South Africa*

With democracy in South Africa came many new curricula for mathematics. The intention of the new curriculum was rooted in building a democratic South Africa (Department of Education, 2003b) to ensure that the divisions of the past were healed and to establish a critical society that is based on democratic values, social justice and fundamental human rights (Department of Education, 2003a).

This was one of the reasons why two major changes in mathematics occurred in 2006: firstly, mathematics or mathematics literacy was made compulsory for all learners in South Africa and secondly, Paper 3 became optional. As discussed earlier, Paper 3 comprised the sections geometry, statistics and probability.

Geometry, which is frequently referred to as the mathematics of space, involves the properties of space in which bodies are situated, and in which they move (Bursill-Hall, 2002). Learning the names and dimensions of shapes prepares learners for the real world, as well as for more advanced mathematical concepts. Learning how three-dimensional shapes and objects operate helps one understand how a football is thrown, how cars move and how buildings are constructed. .

In geometry the learner can search for patterns and use these to generalise, experiment, analyse, visualise, describe and provide proofs for their conjectures. Unfortunately geometry is a neglected field (Olkun, Sinoplu, & Deryakulu, 2005). Moreover, research indicates that learners perform badly in geometry because of the disjointed and abstract way in which geometry is taught (Mogari, 2004). In addition, learners appear to believe that geometry is abstract in nature and that it is a difficult subject in which to succeed (Barrantes & Blanco, 2006).

Geometry provides a rich context for the development of reasoning, including making conjectures and validating them. In addition, visualisation and spatial reasoning are used to solve problems both within and outside mathematics (Van der Sandt, 2003). This implies that studying geometry also provides opportunities for divergent thinking and creative problem solving which in turn helps develop learners' logical thinking abilities (Nakin, 2003). Apart from knowing how learners develop logical thinking skills we also need to know how they develop thinking skills in geometry.

## III. Theoretical Framework

*a) The Van Hiele Theory*

The Van Hiele theory describes the different levels of thinking that learners pass through as they learn geometry in mathematics (Mistretta, 2000). Two mathematics educators in the Netherlands, Pierre van Hiele and Dina van Hiele-Geldorf, noticed the difficulties that learners were having in the learning of geometry. Their observations led them to develop a theory involving levels of thinking in geometry that learners pass through as they progress from recognising a figure to being able to write a formal geometrical proof. Their theory explains why many learners encounter difficulties in geometry especially with formal proofs.

The Van Hieles identified five levels of understanding: visualisation, analysis, informal deduction, formal deduction and rigour (Ryan & Williams, 2007). The first three levels relate to thinking within the capability of elementary school learning while the next two involve thinking needed in high school and university level geometry (Mistretta, 2000). The levels are sequential and hierarchical with each having its own language. This implies that the educator must identify the level on which the learner is operating or else both the educator and the learner may be on different levels during instruction. Thus for effective teaching and learning to occur in the geometry classroom the educator must be mindful that learners differ in capabilities and in social development.

*b) Social Development Theory*

Becoming socialised involves the process of learning to behave in socially approved ways, playing approved social roles and developing social attitudes. Social development is defined as acquiring the ability to behave according to social expectations (Hurlock, 1978).

In terms of cognitive development, Vygotsky's theory of social development supports the notion that learning precedes development. Vygotsky's social development theory rests on two main principles: the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD). The MKO refers to anyone who has a better understanding than the learner, with respect to a particular task, process or concept. The MKO could refer to an educator, older adult, a peer or even computers (Mace, 2005). The ZPD occurs when learner development proceeds through a learner's participation in activities slightly beyond their competence. With the assistance of adults or more skilled children, the cognitive processes are internalised and transformed to form the individual plane. This occurs when a child's development proceeds through their participation in activities slightly beyond their competence. With the assistance of more highly skilled individuals, cognitive processes are internalised and transformed to ensure that the child learns how to do the activity independently.

Social development theory supports the notion of the educator working in partnership and collaboration with learners in order for the learners to discover and create their own meaning and understanding (Woolcock & Narayan, 2000). Social development theory favours teaching strategies like scaffolding, reciprocal teaching and guided instruction. Scaffolding refers to a temporary support structure that an educator creates to assist learners in completing a task that they would not be able to complete on their own. It is in this fashion that the classroom becomes a community of acquisition (Mace, 2005) – acquisition by the learner.

## IV. Methodology

In this qualitative, interpretive study, data was collected from schools in KZN, South Africa. Access to schools was granted by the KZN Department of Education, school principals and parents of the learners in the Grade 12 classes. Of the 12 schools that were approached only five responded positively. Three of the five schools were selected based on convenience; one of the three schools was used for the pilot study. A total of 160 Grade 12 mathematics learners participated in the pilot and main study. The pilot study was used to ensure the reliability and validity of the research instruments.

The schools in the main study were called Green Park High and Bleak Stone High. Both schools catered for more than one socio-economic group and more than one race group. Green Park High catered for the predominantly middle class learner and the school had a higher population of Indian learners. Bleak Stone High catered for the predominantly working-class learner and the school had a higher population of black learners.

The learners in the main study were selected using purposive sampling. The research study necessitated two sets of learners belonging to specific socio-economic backgrounds within each school, i.e. one set from a working-class background and the other set from a middle class background. The main study involved 24 Grade 12 participants who came from different social backgrounds and race groups. The participants were comprised of 11 boys and 13 girls. The learners were between 16 and 18 years old. Data was collected by using a questionnaire, a geometry evaluation worksheet and a semi-structured interview schedule.

*a) The questionnaire*

The questionnaire constituted two sections comprising 16 questions in total. The first section focused on the learner's background in terms of personal and family background. This section of the instrument focused on sensitive questions about matters such as parents' occupation, family's financial background and type of housing; therefore confidentiality and the learner's right to withdraw from the study were stressed both verbally and in writing.

The second section of the questionnaire was based on the learner's mathematical background. This section was designed to locate the learner within a mathematics context in terms of the learner's views on the different sections in mathematics as well as to gain an understanding of the learner's mathematical ability in geometry. This information was further supplemented by data collected from the school principals as well from the head of department of mathematics at each school.

## V. The Geometry Evaluation Worksheet

The learner questionnaire was followed by a geometry evaluation worksheet. The geometry evaluation worksheet consisted of two geometry questions and eight sub-questions. The questions were randomly constructed based on different aspects of Euclidean geometry as shown in Figure 1 and 2 below.

Answer the following questions in the spaces provided and please remember that the diagrams are **NOT** drawn to scale.

1. AB is the diameter of circle centre O and AC is a chord. Chord AD bisects angle BAC and E lies on AC produced, such that DA = DE. DO, BD, BC and DC are drawn. Prove that:
   1.1. OD is parallel to AC.
   1.2. Angle BDC = Angle ADE.

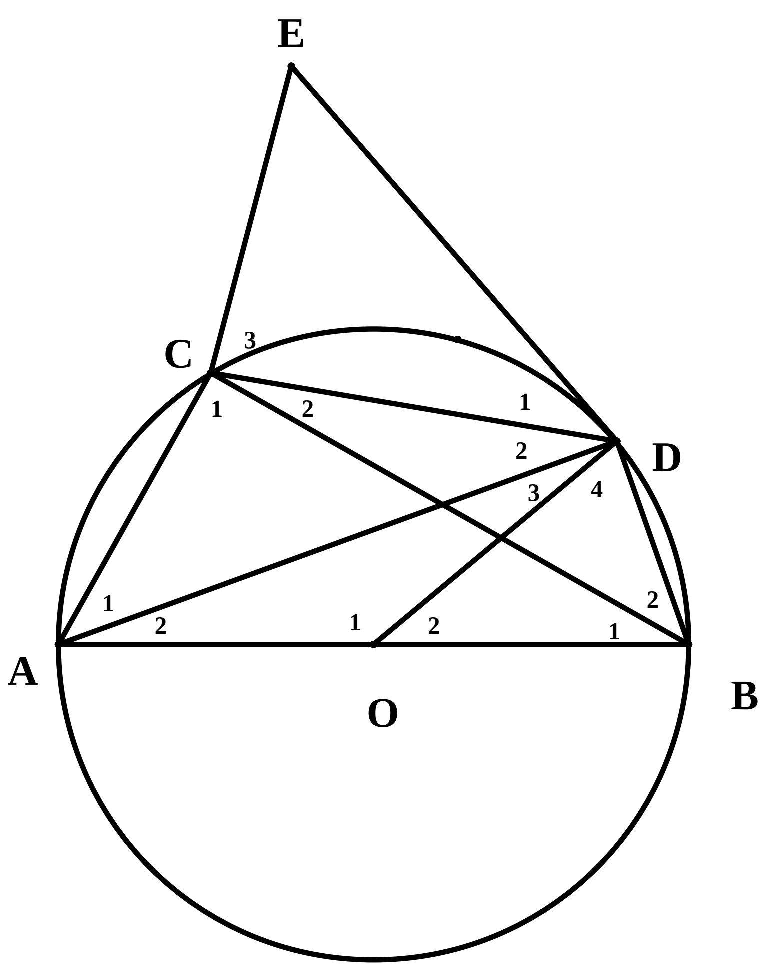


*Figure 1 :* Geometry evaluation worksheet: Question 1

1. In the diagram below, M is the centre of the circle which passes through A, B, C and D. BCDM is a parallelogram and BD is drawn. It is also given that angle MBD = x.

1.1. Express with reasons, each of the following angles in terms of x:

- 1.1.1. Angle $D_2$
- 1.1.2. Angle $M_1$
- 1.1.3. Angle A
- 1.1.4. Angle C by using the properties of the quadrilateral BCDM
- 1.1.5. Angle C by using the properties of quadrilateral ABCD

1.2. Hence calculate the value of x.

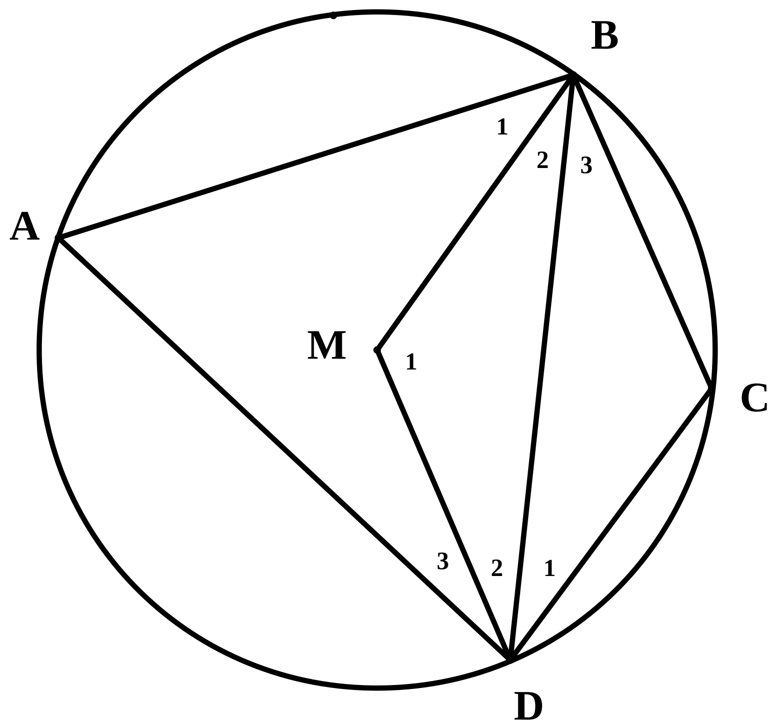


*Figure 2 :* Geometry evaluation worksheet: Question 2

The primary aim of the geometry evaluation worksheet was to provide the learners with an opportunity to demonstrate their techniques implemented during the geometry solution process. This was also an opportunity to investigate these techniques as well as to compare the geometric reasoning with respect to the different social class groups at the different schools. This strategy was followed by a semi-structured interview schedule.

*a) The semi-structured interview schedule*

The semi-structured interview schedule was comprised of a set of standard questions that each learner was asked. In addition, responses were probed to ensure that there were no misunderstandings. Learners were also probed with respect to their individual attempts on the geometry evaluation worksheet. In addition, the interview provided an idea as to what the learner understood while answering the questions; the interview provided insight into the thought processes and reasoning the learner followed when answering the geometry evaluation worksheet. These interviews were audio-recorded with the permission of the learner. This was done to ensure there were no misinterpretations and misquotes.

## VI. Findings and Discussion

*a) Performance in the geometry evaluation worksheet*

The social class groups differed considerably with respect to their geometric reasoning, their logic as well as the type of language used to express their reasoning. Learners were inclined to answer questions in a similar manner to their peers at the school. This is in agreement with social development theory which suggests that to be socialised, children must know what approved behaviour is, and they need to model their behaviour along the approved lines. In this study it was evident that in order to gain their peers' approval, the learners had to identify with the majority class group at each school.

Green Park High had a predominantly middle-class learner population and the working-class learners in this school had similar ideas and reasoned in a similar manner as the middle-class learners of the school. In addition, the visual markings made on their (the working class learners') diagrams were similar to the ones made by the middle-class learners.

On the other hand, in Bleak Stone High, which catered mainly for working-class learners, the middle-class learners worked in a similar way to the working-class learners. These learners also spoke in the same manner, they reasoned in a similar manner and they used the same types of visual techniques on their diagrams.

It could therefore be inferred that the learners in each of the above-mentioned schools were conforming to the majority class group in their school.

*b) Learners' reasoning in geometry*

While analysing the geometry evaluation worksheet the learners' geometrical reasoning was examined. The results obtained showed that learners from Green Park High reasoned more logically and sequentially than the learners from Bleak Stone High. This was evident from each learner's step-by-step interpretation of how they had gone about solving the questions in the geometry evaluation worksheet. Some of the participants' responses follow:

"I found that there was a diameter, from the diameter I worked with the semi-circle… I took it further to see what other angles I could find …"

"I look at the statements … and then I look at the diagram …"

"I analysed the diagram to see what I could find out and then … I read the question, I looked at the diagram again, matched the question to the diagram to find out the … common points … I looked at the question again and started answering the question."

"I approached it the similar way I looked at the diagram first and identify what I could … and then I looked at my question and … I come back to that diagram and apply my question to my diagram … then answer the question."

In addition, the learners at Green Park High used more imaginative metaphoric language and referred to what they were 'seeing' in their minds:

"I can see the solution in my mind."

"I can mentally picture the diagram".

Usually what they said they were 'seeing' was three-dimensional, when in fact what was on paper was illustrated in two dimensions. Based on the manner in which these learners approached the geometry problems it is also evident that learners at both schools needed to visualise the problems in order to complete them as can be deduced from the Green Park High interview transcript:

"First I read the question and then … I used my colours and … I put … all different colours … it looked complicated but once you put the colours in you try and figure it out, it was alright ..."

The learners at Green Park High demonstrated that they were aware of what they were seeing and what they were not seeing. In some instances learners had to mentally or physically manipulate the evaluation worksheet in order to complete the various questions.

"I turned the page around … so that I can see things."

"I will turn this page (proceeds to turn the page around) and using my knowledge I learnt in Grade 11 … see whether I can find angles …"

These visual images of what the learners were seeing helped them to explain how they were seeing things and to convince me why their solutions were correct. This step-by-step method also proved to be beneficial in that when the responses to the geometry evaluation worksheet were compared it was evident that a greater percentage of the learners from Green Park High had attempted or completed the questions correctly as compared to the learners in Bleak Stone High.

Learners' responses to the geometry evaluation task were analysed. The results indicated that 50% of learners at Green Park High had either attempted or completed the questions on the geometry evaluation worksheet correctly. In contrast, only 29% of learners at Bleak Stone achieved the same result. Moreover, learners from Bleak Stone High, who were from predominantly working-class backgrounds, did not demonstrate well-defined logic in their geometry reasoning. This could have been as a result of the learners not knowing the work, being at a different Van Hiele level to that of the question, or not having access to the language to express themselves adequately within the formal context of a school, as can be seen from the following examples:

"Whatever came to mind I just wrote it down."

"I tried to work backwards."

"… I know I wrote it there I probably just wrote it there, I don't know why."

The interview schedules for learners from Bleak Stone High indicated that the majority of the learners were going through a process; it appeared as if they were grasping at straws when attempting these questions.

"… I don't know and I know that x always stands for something so that's why I use x." "For the first question I couldn't find OD parallel to AC, so I assumed it was parallel … so I put OD is parallel to AC. I knew it was linked so I used it for the second one too."

Their focus was on finding the answer and the majority of the learners failed to follow a sequential step-by-step process. The process used was one that accidentally led to the correct answers in some instances. It was evident that the learners were at a different Van Hiele level than at which the question was pitched. The majority of the learners made assumptions and worked from there as can be seen in the following excerpt taken from the interview transcript:

"It looked confusing at first, whatever came to mind I just started writing, writing and eventually I ended up with the answer."

"I guess I want to solve for something … so I assumed it was parallel."

"I must have assumed it was straight."

As is shown above, the learners' geometrical reasoning was affected by a variety of factors. Mathematical language is crucial to reasoning because it provides the medium, in which claims are developed, made, justified and verified (Ball Loewenberg & Bass, 2000). Learners who are proficient in the language of the school are more likely to understand the messages and content being conveyed by the educator than learners who are less familiar with the language and hence unable to "crack the code" of school language (Zevenbergen, 2001).

## VII. Conclusion

Researchers (Howie, 2003; Legotlo, Maaga, & Sebego, 2002; Setati & Adler, 2001) have commented on the poor mathematics results obtained by learners in South Africa. This is distressing since mathematics acts as a gatekeeper to higher paying careers and an improvement of social status in society. A clear example of this is the section geometry; this is a much-needed section in mathematics and would assist learners in moving beyond their existing social class boundaries. Thus, when in 2006 geometry in mathematics was relegated to an optional paper the exclusion problem was exacerbated.

Based on evidence obtained in this research it was ascertained that middle-class and working-class learners reasoned in geometry in different ways with regard to their schools and their social class backgrounds. The learners in Green Park High, who were predominantly middle-class, reasoned in geometry by presenting evidence of a sequential thought process which was further justified by logical explanations for their thought processes. These learners used language that was appropriate in the geometry classroom in order to verbalise their thought processes. They used language that was within the mathematics context; more specifically the geometry context. The learners made satisfactory attempts at interpreting the geometry questions and went about their solution process using the appropriate geometry theorems and definitions.

In contrast, the learners in Bleak Stone High, who were predominantly working-class, had a tendency to reason in geometry in a manner that demonstrated a different logic. The same learners also did not demonstrate a sequential systematic process in their thinking. It would appear that the manner in which the learners went about attempting their geometry questions was an attempt at finding an answer regardless of whether or not the answer was realistic. These learners exhibited difficulty with the interpretation and solution of the questions. Based on evidence obtained in this study I would argue there is evidence to claim this difficulty is due to at least one of four reasons:

- The learners were not familiar with the language used in the geometry evaluation worksheet.
- The learners were not exposed to similar types of geometry questions on a regular basis.
- The geometry questions were on a different level to that of the learners' ability level.
- The learners were performing at a lower Van Hiele level to that at which the questions were targeted.

The learners did not apply the appropriate geometry theorems and definitions; they very often mixed up definitions as well as theorems. This demonstrated that the learners did not have a firm foundation in terms of mathematics syllabus requirements for circle geometry, which forms a large part of a geometry examination paper.

The root of the differences and segregation in the study occurred outside the classroom. It lay with the social class system of South Africa where it is inevitable that class and race intersect. It was evident that mathematics was not neutral, mathematics played a part in the perpetuation of power (Gates, 2001) – mathematics as used and applied in society and mathematics education as carried out in many classrooms oppose democratic values. Along similar lines, some researchers (Khuzwayo, 2005; Zevenbergen, 2001) maintain that mathematics education has established a systematic access denial on the grounds of a person's race, language, and social class. This situation could be alleviated if educators complete short courses in geometry to assist their learners with understanding this abstract section in mathematics, and if schools are equipped with both human and material resources equitably, regardless of the social milieu in which the school is situated.

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