Exploring grade 12 mathematics students' characteristics and views they hold about geometry

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ABSTRACT

The purpose of this study was to explore selected mathematics students' characteristics and relate these to views students hold about geometry. The mathematics students' characteristics that the researchers focused on, related to: their gender, age, the parents they stayed with, the percentage mark they expected in an upcoming test and final year examination, whether they attended extra-classroom geometry tutorials and how frequent, whether they intended to study further, as well as which careers they wished to follow. These different characteristics were selected based on literature readings relating to, for instance, students' choice of career, including differences between males and females in career choice. The question pose in this study was: What were mathematics students' characteristics and views about geometry? In order to answer this question the quantitative research design was used. Data was collected using Johnson modified version questionnaire. Participants were 231 grade 12 mathematics learners at Further Education and Training phase from 5 schools in 3 districts within Mpumalanga province. The results shows that students' estimations of marks they expected to get in tests was significantly higher than expected marks, that is a mark of 60% or more in the upcoming test (66.2%) than what they actually achieved. The results also show that students (81.4%) felt that they put more effort into solving a difficult geometry problem. It is recommended that teachers be exposed to workshops that will enhance their teaching approaches that will help students to develop interest and confidence in the learning of geometry.

Keywords: Grade 12, students, mathematics, characteristics, geometry.

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INTRODUCTION

In a country like South Africa it may be viewed as extremely difficult for high school students to choose a career. There are a number of reasons that may be associated with this challenge. Firstly, because of its history a number of African people in the country are poor and invariably not educated. Considering that parents and teachers play a significant role in the choice of career, it is inconceivable that students would not receive influential reference points from their parents. Secondly, a majority of Grade 12 students in the country fail to acquire university entry grades. This, in effect, means in focusing on ability, it is difficult to see how critical careers

such as being scientists and economists will be easily filled in future. Furthermore, mathematics in South Africa is not taken by many students at school level. Of those who take it, very few pass the subject.

Statistics show a continuous downward trend in the mathematics pass rate going from: 59.1% in 2013, 53.5% in 2014 and 49.1% in 2015 (Department of Basic Education, 2015). The section of mathematics that students perform extremely poorly is Euclidian geometry. In this regard, in an overview of student performance in a 2014 mathematics paper with different sections including geometry, it is pointed out "…candidates lacked the

necessary insight to deal with … complex questions in Euclidean Geometry (Department of Basic Education, 2015: 121). Further, in a section on suggestions for improvement, it is argued (p. 131):

a) More time needs to be spent on the teaching of Euclidean Geometry in all grades. Time must be spent on teaching the theory, recognising the theorems in a simple diagram and deconstructing a complex diagram to identify theorems.
b) Learners need to be told that there is no short-cut to mastering the skills to answering questions in Euclidean Geometry. This requires continuous and deliberate practice.
c) Teachers need to insist on learners naming angles properly.

It was on this basis that the characteristics of students were explored against their views of geometry.

The aim of this paper is to report on selected mathematics students' characteristics and relate these to views they hold about geometry. In order to do this class test and Johnson (2008) modified version questionnaire were used to determine students' characteristic and their views about geometry. The class test was meant to determine students' actual marks they received in the test as opposed to their estimated mark. For this paper, Johnson's questionnaire focused on the result from the learners' section only. Learners' questionnaire is divided into two parts. Part 1 focuses on perceptions of learners on self-efficacy in Euclidian Geometry and Part 2 elaborates on learners' feelings about learning Geometry, and their characteristics as well as nature of the problems they encounter in their classroom.

Constructivism

This study is grounded on constructivism which regards knowledge of content and pedagogy as not being sufficient on its own for the effective teaching of mathematics (Taimalu and Oim, 2005); knowledge of learners and their characteristics is another vital aspect of the relationship that is required. Constructivism is a widely used term with a particular perspective on the teaching and learning of mathematics. It is characterized by the view that students are not without ideas about the events and phenomena in the world around them. They have formed ideas in making sense of everyday experiences, but these ideas often conflict with the scientific view. Constructivist teaching involves finding out what students' views currently are and helping to focus construction of new knowledge towards ideas generally held in the scientific community (Wellington, 1994: 62). The role of the teacher is therefore to develop approaches to encourage conceptual change. It is therefore imperative that teachers are efficacious in teaching mathematics, as their competence directly affects the students' learning of mathematics. This is emphasized by Ausubel's famous line, "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach them accordingly" (Ausubel, 1968). It is thus important to assess the level of understanding and the efficacy of teachers in order for the students to be taught accordingly, and for meaningful learning to take place.

Constructivist perspective is on how students learn and it also elaborates that acquisition of mathematical knowledge results from learners forming mental models in response to the challenges that come from actively engaging geometrical problems and environments (Singh et al., 2012). The challenge in teaching geometry is to create experiences that engage the students and support their own explanation and application of the mathematical models needed to make sense of these experiences (Ayotola and Adedeji, 2009). Studies have illustrated that students who learned in a classroom with a constructivist approach to learning showed greater cooperation and collaboration, higher level of learning, more confidence and more willingness to participate in learning activities (Erdamar and Demirel, 2008).

Learner efficacy

Learner efficacy may be seen as the extent to which learners believe in their own ability to complete tasks and accomplish predetermined goals. Low self-efficacy may lead learners to believe most geometry tasks such as application of geometric theorems to be harder than they actually are. This often results in poor task planning, as well as increased stress in learners which lead to poor performance in geometry. By determining the beliefs a learner holds regarding his or her power to affect situations, it strongly influences both the power a learner actually has to face challenges competently and the choices he/she is most likely to make. Success raises self-efficacy, while failure lowers it (Marlowe and Hayden, 2013).

High self-efficacy may affect motivation in both positive and negative ways. In general, learners with high self-efficacy are more likely to make efforts to complete a task, and to persist longer in those efforts, than those with low self-efficacy. The stronger the self-efficacy or mastery expectations, the more active the efforts. However, those with low self-efficacy sometimes experience incentive to learn more about certain mathematical concepts and start putting blame on teachers for not being able to explain a particular concept, whereas someone with a high self-efficacy will put more effort to complete any given task.

Most learners with high self-efficacy will attribute failure to external factors, while a person with low self-efficacy will blame low ability. For example, someone with high self-efficacy in regards to geometry may attribute a poor test grade to be harder than usual test, illness, lack of

effort, or insufficient preparation. A person with a low self-efficacy will attribute the result to poor mathematical ability.

Anxiety in mathematics can also lead to learner low self-efficacy. Such anxiety may result in poor performance that makes learners to be uncomfortable and avoid mathematics (Ashcraf and Ridley, 2005). These authors describe mathematics anxiety as characterized by feelings of tension, apprehension and fear about performing in mathematics (Ashcraf and Ridley, 2005). Also, they argue that fear leads to lower competence in geometry and negative attitude towards geometry (Ashcraf and Ridley, 2005).

Students related characteristics

It is argued that "[L]earning any new task requires understanding the gap between what one currently knows and what one hopes or needs to know (Ehrlinger et al., 2016: 94). This argument in a sense suggests that students' learning geometry for example, need to be aware of what they know and what they will achieve in learning this part of mathematics. Following on that, the researchers requested the students to indicate what percentage mark they expected in an upcoming test and final year examination. Specifically here, the aim was to establish what literature refers to as 'overestimation.' Over estimating relates to individuals over rating their performance (Moore and Healy, 2007: 3). Overestimation manifests itself in situations where, for instance, a student after taking a ten item quiz believes they have answered eight questions correctly when in fact only three were correct (Moore and Healy, 2007). Exploring students' overestimation was important because they are known to overestimate their performance in tests and examinations (Clayson, 2005).

It is reported in literature that students who attend extra-classroom programs benefit academically (Pierce et al., 1999; Posner and Vandell, 1994). This is a view that has been endorsed by others, for example the Afterschool Alliance (2014: 3) points out that "[A] large body of evidence exists that confirms quality afterschool programs help children become more engaged in school, reduce their likelihood of taking part in at-risk behaviours or acting out in school and help raise their academic performance." It was on the basis of the argument for good marks by students who attend extra-classroom programs that the students were asked about their attendance of these.

Literature focusing on the factors that lead to students' career choices abounds. It is however not comprehensively addressed here because this study was not really focusing on that. It is perhaps enough to point out that the choices that students make about careers can be grouped into three interrelated factors. These are: (i) the influence of important people such as parents, teachers, friends; (ii) material issues such as employment, the prestige attached to a job, status is society, how much a job pays; and (iii) issues relating to beliefs about the chosen career such as how satisfying a job is or work experience (Paolillo and Estes, 1982). It is important to have an idea of the type of career choices students have as they are still at school. This is because as Ferry (2006) argues, a "… major turning point in adolescents' lives involves the career choice that they make while in high school (Hellenga et al., 2002; Rainey and Borders, 1997). Domenico and Jones, (2007) point out that there "… is need to study female adolescents in the early stages of career development, as aspirations are often crystallized during this time." It was important therefore to explore the career choices of the students in general and females in particular in this study. The importance stems from the fact that females are seen to join the world of work in lower-status and -paying jobs while their concentration is in limited careers (Tinklin et al., 2005). Such lower-status and -paying jobs in a South African context could be careers in nursing, teaching and the police for instance.

METHODOLODY

The paper explored Grade 12 mathematics students' characteristics and views they hold about geometry. Quantitative research design was used. Here a Johnson's (2008) questionnaire was modified for the purposes of the study. Data were analysed using SPSS, and as such focus is mainly on descriptive statistics.

Participants

Participants were 231 Grade 12 mathematics learners in Further Education and Training phase from five schools within three districts in Mpumalanga Province. The participants were selected through their teachers. There were 63 teachers, all from Mpumalanga province. The teachers were registered at a South African university for the Advanced Certificate in Education (ACE FET) with specialisation in Mathematics. The teachers were requested by the first author to assist with the distribution and collection of data from a questionnaire they had been briefed about. The teachers had indicated that numbers of students in their classrooms ranged between 48 and 60. As a result they were given envelopes with between 50 to 60 questionnaires. Only five teachers from different schools were able to return envelopes with completed questionnaires. From the five schools, there were 231 participants taking Grade 12 mathematics. Of the total, 50 (34 females and 16 males) students were from School A; 55 (27 females and 28 males) from School B; 42 (30 females and 12 males) from School C; 44 (31 females and 13 males) from School D; and 40 (32 females and 8 males) from School E. As the students were in Grade 12, the researchers assumed that "…they were mature enough to form independent opinions about geometry in relation to their self-efficacy, their personal approach and confidence towards their characteristics and views they hold about geometry and their achievement in it" (Ayotola and Adedeji, 2009).

Instrumentation

The original questionnaire by Johnson (2008) consists of two sections – Teachers' and Students.' In this paper the focus was on

the latter. The Johnson (2008) students' section was modified in the sense that the first section included variables such as for example, age, gender (student characteristics). In the second section, students were requested to respond to items statements by registering their choices on a Likert type scale. Here, the purpose was to explore selected mathematics students' characteristics and relate these to views they hold about geometry. With respect to the former, each student was requested to provide information relating to a number of characteristics about themselves. The mathematics students' characteristics that the researchers focused on, related to: their gender; age; the parents they stayed with; the percentage mark they expected in an upcoming test and final year examination; whether they attended extra-classroom geometry tutorials and how frequent; whether they intended to study further; as well as which careers they wished to follow. These different characteristics were selected based on literature readings relating to, for instance, students' choice of career, including differences between males and females in career choice.

With respect to views about geometry, students were requested to respond to three statements. In the first two statements, students had to rate their responses in a Likert-type scale ranging from 1 = Definitely False to 6 = Definitely True. Similarly, the last statement was rated from 1 = Strongly Disagree to 4 = Strongly Agree. It should be pointed out that the last statement is negative. As a result, the ratings were accordingly reversed in the analysis. Also, only females were included in analysing the first statement. The three statements were:

a) Compared to the males in my mathematics class, I am good at geometry.
b) When a geometry problem is difficult for me to solve, I just put more effort into solving it.
c) Geometry is boring.

With regards to the first question, the focus was on finding out the females' confidence about their performance in geometry relative to their male counterparts. Specifically, the aim was to determine what is described in literature as 'over placement' (Healy and Moore, 2007, 2008). These authors describe over placement as relating to "… overconfidence about one's ranking relative to others" (Healy and Moore, 2008: 3). The second question was specifically asked in order to have a sense of how seriously the students attempted to solve especially difficult geometry problems. The last question was intended to find out whether students found geometry boring or not.

RESULTS

Participants' biographical characteristics

Participants were 231 Grade 12 mathematics learners in Further Education and Training phase from five schools within three districts in Mpumalanga Province. The participants were selected through their teachers. There were 63 teachers, all from Mpumalanga province. The teachers were registered at a South African university for the Advanced Certificate in Education (ACE FET) with specialisation in Mathematics. The teachers were requested by the first author to assist with the distribution and collection of data from a questionnaire they had been briefed about. The teachers had indicated that numbers of students in their classrooms ranged between 48 and 60. As a result they were given envelopes with between 50 to 60 questionnaires. Only five teachers from different

schools were able to return envelopes with completed questionnaires. Smith (2013) has provided a formula for calculating the sample size that is ideal for a research study, in consideration of a specific population. The formula is (Smith, 2013, for the explanation of the different variables):

Necessary Sample Size = (Z score)^2 * StdDev*(1 − StdDev) / (margin of error)^2

It is worth pointing out that the sample size in this study was a function of students of the 5 teachers who returned completed questionnaires. In requesting the 63 teachers, the researchers at the time felt that the necessary sample size would be attained. However, this did not turn out as expected. Based on that, the researchers felt that the margin of error confidence interval was the best statistic to report. In interpreting this statistic as an example, if a country had a yes or no referendum, the result would be reflected as 77% of voters said yes to the proposition of the referendum with a margin of error of +/- 5%. The margin of error confidence interval was calculated from:

Margin of error = $\sqrt{[(Z\ score)^2 * StdDev * (1 − StdDev) / Necessary\ Sample\ Size]}$

Here, for a confidence of 95% the Z score was 1.96 and the standard deviation was set at 0.5. The calculated margin of error confidence interval was found to be: +/− 0.064 (6.4%). This statistic suggests that on the findings reported here a margin of error of approximately +/− 6% should be considered.

Table 1 shows the frequency distributions, percentages, means and standard deviations (where applicable) relating to the students' biographical characteristics. The table shows that of the 231 grade 12 mathematics students, 154 (66.7%) were females. The students' ages ranged between 17 and 23 years (M = 17.2, SD = 1.19). About half (52.4%) indicated that they stayed with both parents at home. On the other hand, 10 (4.3%) did not have parents. About 156 (67.5%) revealed that they received tutoring in geometry at least once a week. Meanwhile close to one in four (a quarter) students (21.6%) indicated that they did not receive tutoring at all. Most students (88.3%) revealed that they would definitely pursue further studies after Grade 12. Information technology was the career of choice for more than half (51.1%) of the students.

Class test

Students were asked what they thought they would get in an upcoming geometry test as well as in the final examination preparatory test. Table 2 shows the marks student expected to receive as well as the actual marks they received in the test they wrote. It may be observed

Table 1. Frequency distributions, percentages, means and standard deviations.

Demographic characteristics	Category	N	%	M	SD
Gender	Male	77	33.3		
	Female	154	66.7		
Age	15 – 17 years	47	20.3	17.2	1.19
	18 – 19 years	153	66.2		
	20 years +	31	13.4		
Parents staying with	Both	121	52.4		
	Single	100	43.3		
	None	10	4.3		
Tutoring	Daily	53	22.9		
	2 – 4 times a week	57	24.7		
	Once a week	46	19.9		
	Once a month	14	6.1		
	At the end of the term	6	2.6		
	Once a year	5	2.2		
	None	50	21.6		

Table 2. Frequency distribution and percentages students expected to receive in two tests as well as the actual mark they obtained.

Parameter	Expected mark				Actual mark	
	Upcoming test		Exam preparatory test			
	n	%	n	%	n	%
0 – 39%	9	3.9	4	1.8	107	46.3
40 – 49%	17	7.4	9	3.9	80	34.6
50 – 59%	37	16.0	29	12.6	44	19.1
≥60	153	66.2	174	75.2	0	0.0
I don't know	15	6.5	15	6.5	–	–

from the table that most students indicated that they expected marks of 60% or more in the upcoming test (153, 66.2%). The range of marks these students expected was from 29 to 100% (M = 68.39; SD = 15.14). Similarly, for the exam preparatory test most (174, 75.2%) students reported likewise. In the actual geometry test however 107 (46.3%) failed it and none obtained a mark of 60% or more. In fact, the marks range was 19 to 59% (M = 40.14; SD = 9.05). An unpaired sample t-test was computed because the 15 students who indicated: I don't know were excluded. This computation revealed that what students estimated of what they would get was significantly much more than what they got [t (445) = 24.12, p < 0.0001].

Views about geometry

In reporting students' views about geometry, responses from the three questions they had to respond to, are outlined. The responses were then disaggregated based on students' characteristics. In essence, each question provides impressions relating to both students' characteristics and their views about geometry. The first statements were:

a) Compared to the males in my maths class, I am good at geometry.

Table 3 shows frequency distributions and percentages of ratings relating to how female students felt about being good at geometry than males. It may be observed from the table that more than half (91; 59.1%) of the females felt that they were not good at geometry compared to males in the maths class. Nonetheless, fairly equivalent percentages of females (138; 89.6%) and males (66; 85.7%) indicated that they would definitely study further. Regarding the careers they would follow, in essence the

Table 3. Frequency distributions and percentages of ratings relating to how female students felt about being good at geometry than males.

Parameter	n	%
Definitely false	14	9.1
False	49	31.8
More false than true	28	18.2
More true than false	28	18.2
True	26	16.9
Definitely true	9	5.8

students chose the same albeit in varying degrees. For example, the top three careers selected by females were: Information Technology (57.8%); chartered accountancy (18.2%); and either law or medicine (8.4%). On the other hand the males selected: Information Technology (57.8%); medicine (26.0%); and law (16.9%). It is noticeable however that chartered accountancy (13.0%) was the fourth career the males chose.

b) When a geometry problem is difficult for me to solve, I just put more effort into solving it.

Here the analysis involved students' ratings about what they felt. The ratings were then disaggregated according to selected characteristics. Specifically here the disaggregation included whether students had parents or not, whether they would study further as well as achievement in the form of the test students wrote. Figure 1 shows a graph depicting of students' ratings on what they feel they do when faced with a difficult geometry problem. It may be observed from Figure 1 that most students (188; 81.4%) felt that they put more effort into solving a difficult geometry problem. About putting an effort into solving a difficult problem, most students revealed that the statement was True than False to Definitely True More. This was irrespective of whether they stayed with a single parent (81; 35.1%) or both parents (98; 42.5%). With respect to students who had no parents, these were very few (10; 4.3%) and therefore did not affect the analysis in any way. On disaggregating the findings according to whether students would definitely study further, it was found that of the total students, 167 (72.3%) felt the statement was More True than False to Definitely True. Regarding performance in geometry, students indicated that the statement was More True than False to Definitely True, there were 101 (43.8%) whose marks were between 40 and 59%. Similarly, a high percentage (87; 37.7%) of those who scored between 0 and 39% reported the same views.

c) Geometry is boring

In this analysis, firstly, the ratings students indicated are provided. The ratings were then disaggregated according

to gender and test marks. Figure 2 shows a graph depicting students' ratings on whether geometry is boring or not. The figure shows that 186 (80.5%) students felt the statement was Definitely True to More True than False to them. When the data was disaggregated according to gender, similar findings were obtained. In fact, 125 (81.1%) females and 61 (79.3%) males felt the statement was Definitely True to More True than False to them. This may also be seen from the perspective of the marks students obtained in the test they wrote. For instance, of the 107 who obtained marks between 0 and 39%, 87 (81.3%) indicated the same view about geometry as boring. Similarly, of the 44 students who obtained a marks between 50 and 59%, 33 (74.9%) felt geometry was boring.

DISCUSSION

In this study a high proportion of the students indicated that they attended extra classroom geometry tutorials at least once a week. However, students' performance in geometry did not reflect the literature (Gardner, et al., 2009) accepted view that such tutorials should be beneficial with respect to their performance. There may be a variety of reasons for not performing well in geometry. It could be that the tutors were not as knowledgeable as expected by the students. On the other hand, it could be that the students themselves were not as serious in the tutorials as expected by their tutors.

What this study has also revealed is that students' estimations of marks they expected to get in tests was significantly higher than what they actually achieved. This suggests that the students tended to overestimate what they could achieve in geometry. This is not an unusual phenomenon.

For instance it is argued that when individuals lack a skill or knowledge of something, "… they greatly overestimate their expertise and talent, thinking they are doing just fine when, in fact, they are doing quite poorly" (Dunning et al., 2003: 83). It is not surprising therefore that 80.9% of the students obtained scores between 0 and 49% in the test. This finding is in spite of the students overestimating their achievement. In fact, the findings reported here are consistent with the view that if "… one has a low score, one has a better chance of overestimating one's performance" (Kruger and Dunning, 1999: 1123).

In terms of a career, it is interesting that the students on the main were interested in Information Technology, chartered accountancy, law and medicine. This is interesting because all these careers were among the top ten highest paying jobs in South Africa in 2014 (News24, 2015).

More pleasing here was the fact that career choice was not gender specific. This is pleasing because in Holland for instance it is reported that compared to males, females are less likely to apply for a job that offers
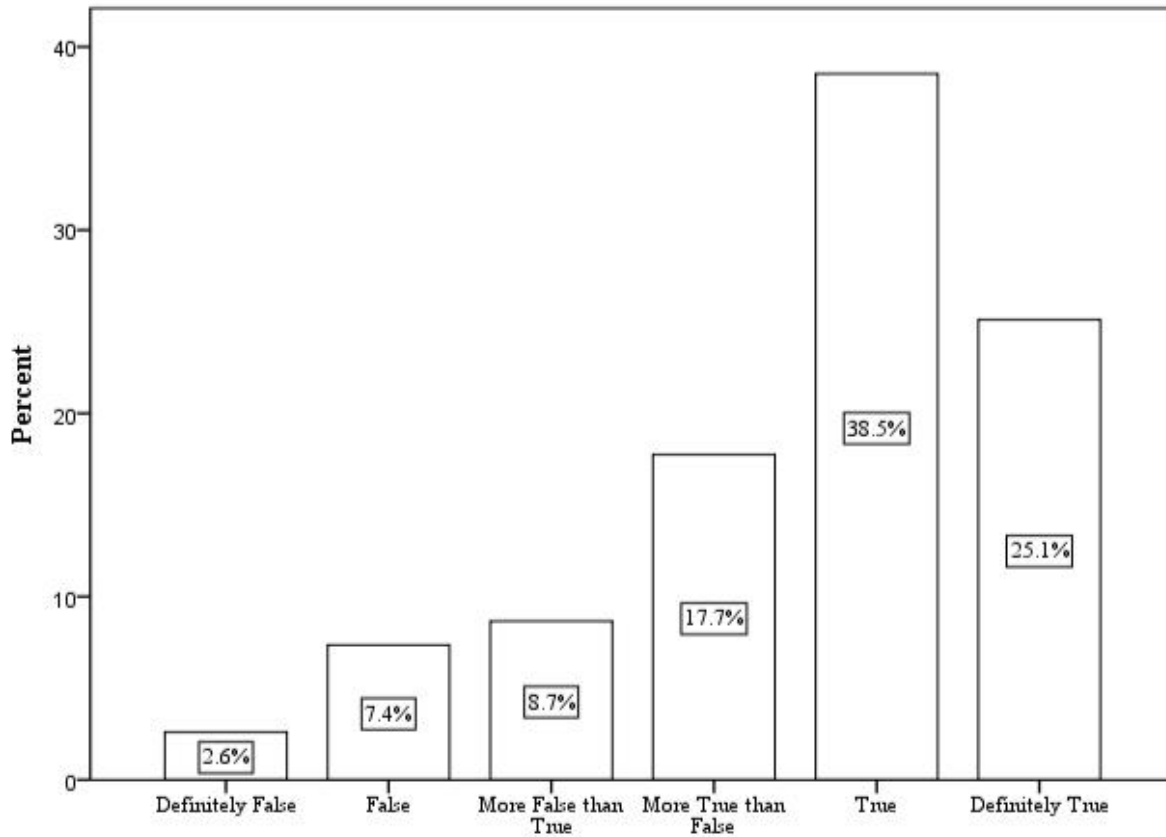
Figure 1. Students' ratings of their views when faced with a difficult problem.
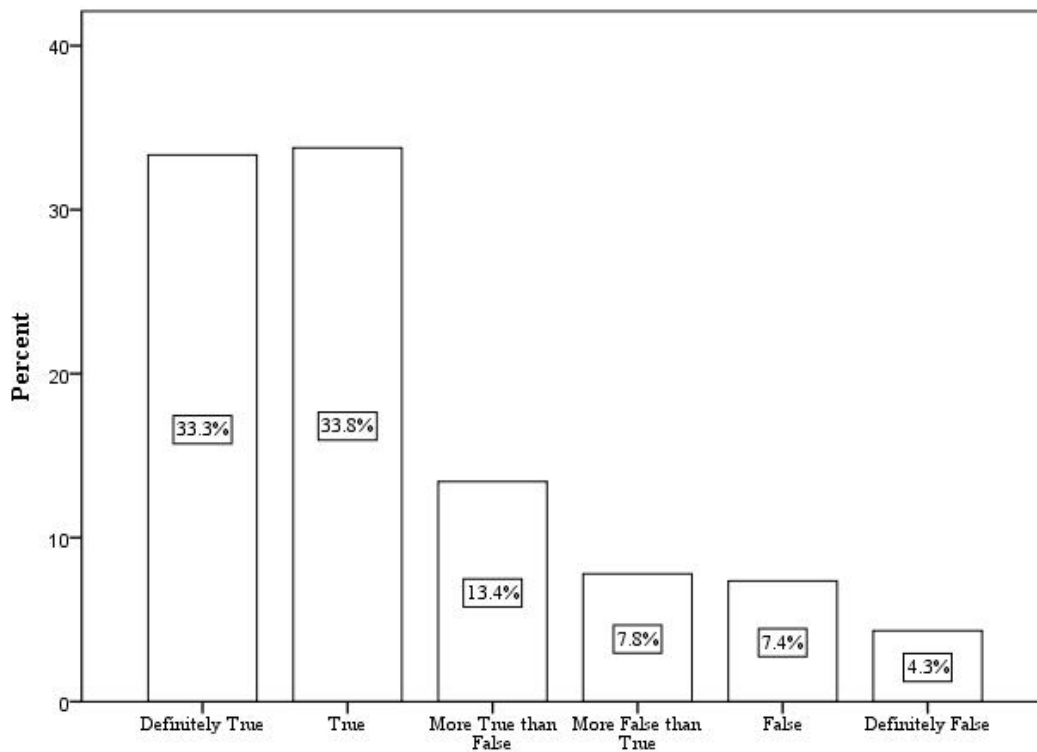

Figure 2. Students' ratings of their views about geometry being boring.

competitive payment (Flory et al., 2010). It is possible that the students chose these careers on the basis of prestige and monetary reward. In fact, in Kenya for instance, high school students indicated that their choice of careers was influenced by the expectation of outcome (Edwards and Quinter, 2011). It is also reported for instance that among Hong Kong and Taiwanese students, factors such as influence by parents and friends were important while among Australian students the influence was mainly from subject matter aptitude (Auyeung and Sands, 1997). Expectation of outcome here relates to decisions arrived at on the basis of what a career choice is likely to provide. Also, pleasing in these findings was the fact that females hardly mentioned lower-status careers while their concentration was not on limited careers as reported in literature (Tinklin et al., 2005). That about half the students chose information technology seems to be reasonable and prudent. About information technology, it is pointed out by (Anthem Webmaster, 2014) that the biggest advantage of choosing information technology for a career is that it has very low cost of education as compared to many other career choices. You do not need a 4 year degree to become an I.T. professional. Instead, you can get quick training to be certified in specific areas of Information Technology. This way you save huge amounts of money that you may have otherwise spent on years of college tuition. The more knowledge and certifications you acquire the more you will advance in your career.

CONCLUSION

In conclusion, in this study we have observed how students' characteristics affected the views they hold about Euclidean Geometry. This was done in order to improve the mathematics pass rate, particularly on the section that focused on geometry as pointed out by the (Department of Basic Education, 2015). It may be observed that there were various reasons for learners not performing well in geometry. In this case, tutors were not as knowledgeable as expected by the learners. Learners themselves were not as serious in the tutorials as expected by their tutors. Looking closely at students' characteristics, it may be concluded that learners greatly overestimate their expertise and talent, thinking they are doing just fine when, in fact, they were doing quite poorly. With regard to career choice, it may be observed that learners chose careers on the basis of prestige and monetary reward. The value of this study may partly be located in its contribution towards the establishment of students' positive views towards geometry. In the event that affective responses on mathematics in general and more specifically on geometry are linked to teaching approach. It may then be accepted that these responses may be improved and the students' views on geometry also be improved.

RECOMMENDATION

It is recommended that tutors content knowledge and pedagogical content knowledge be improved in order to contribute positive to students' performance. In order to narrow the gap between the students' estimation of what they know and their actual performance it is crucial to include technology-enhanced approach in geometry exercises so that students may interact and engage more with the learnt concepts. In this regard, further studies may be conducted on technology-enhanced approaches to teaching Euclidean geometry. Such technology-enhanced approaches have a potential to impact positively on how students view geometry. This suggests that learners should be exposed to more recent and innovative ways of learning Euclidean Geometry.

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