



# THE EFFECT OF USING A COMPUTER-ASSISTED INSTRUCTION ON THE PERFORMANCE AND MOTIVATION OF GRADE 11 LEARNERS IN CIRCLE GEOMETRY

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**ABSTRACT**—Demotivation and Conventional Teaching Instructions (CTI) may be some of the contributing factors to the low success rate in high school Geometry and to the reduction in the number of learners who are taking mathematics in South Africa. The current study aimed to investigate the effect of Computer-Assisted Instruction (CAI) and CTI on the performance and motivation of Grade 11 learners in Circle Geometry. The use of interventions (CAI and CTI) in teaching Circle Geometry, their effect on motivation, and differences in the average pre-test and post-test scores constituted the research questions. CTI were described as any teaching methods familiar to the teacher in the control school. The use of computers to interact instructionally while learning was termed CAI. A quasi-experimental design was employed. Using convenience sampling techniques, one school where CAI was implemented formed the experimental group (n=71), the other school where CTI was implemented formed the control group (n=65). A questionnaire measured the motivation of learners. In addition, a purposive sample of six learners participated in semi-structured interviews whose results were meant to complement those of the test and questionnaire. A socio-constructivist theory framed the study. The results of this investigation indicated that CAI improved the performance and motivation of learners.

**Keywords:** *Computer-Assisted Instruction; Conventional Teaching Instructions; Geometry; Motivation.*

## INTRODUCTION

The postmodern era has brought with it alternative ways of teaching and learning mathematics that are learner-centred (Slattery, 2006). Teachers now have a variety of teaching styles that they may use when teaching mathematics, for example, logicism, Platonism, formalism, intuitionism, absolutism, fallibilism, and constructivism [University of South Africa (UNISA), 2011; Paulsen, 2009]. To this end, Computer-Assisted Instruction (CAI) and Conventional Teaching Instructions (CTI) have become an integral component of mathematics education. Shann (2006) emphasizes that the advancement of technology is dependent on the development of mathematics. In the same vein, for mathematics to develop it may require the use of technology. Therefore, mathematics and technology are closely dependent on each other and may have a symbiotic relationship.

The decreasing number of learners taking mathematics in South African secondary schools and the poor quality passes in mathematics over the years (Ngobese, 2013; Tachie & Chireshe, 2013; Cassim, 2012; Mamba, 2012; Gauteng Department of Education (GDE), 2010; Makgato & Mji, 2006), provided a justifiable rationale to conduct the current study. Among other factors, the poor Geometry performance by learners may be attributed to teaching methods that make learners not to understand; this triggers demotivation, which forces learners to choose the “easier” mathematical literacy at the expense of mathematics (Siyepu, 2013; Spaull, 2013; Idris, 2009; Cassim 2006; Makgato & Mji 2006). The lack of motivation to take mathematics by most South African learners is evidenced by the small number of learners who do the subject in Grade 12 (Cassim, 2012; Ngobese, 2013). For instance, evidence shows that the number of learners who wrote mathematics in the



Ekurhuleni North<sup>1</sup> district of Gauteng<sup>2</sup> province in South Africa decreased from 5818 learners in 2010 to 3123 learners in 2011, and to 3110 learners in 2012 (Ngobese, 2013). These observations are also corroborated by similar statistics at the provincial level (see, Table 1).

**Table 1: Provincial performance in mathematics from 2009 to 2011**

Candidates	2009	2010	2011
Total wrote	39 688	33 763	28 605
Total achieved at 40% +	10 314	12 969	12 142
% Achieved at 40% +	26.0	38.4	42.4

*Source: Cassim (2012)*

However, in order to change learners' negative views of failure and hatred of mathematics, it is the teacher's responsibility to provide instruction and a learning environment that may motivate them (Mansukhani, 2010). Given this background, the current study saw a need to explore teachers' instructional methods and learner motivation when addressing issues relating to the observed exodus of learners in high school Geometry classrooms. The idea that learners are enthusiastic about computers (Diamond, 2012; Teal, 2008; D'Souza, 2005) was explored in the current study, as an instructional avenue to address instructional issues of teaching Circle Geometry, with the anticipation that this approach would elevate learners' motivation, and eventually attract more learners to do mathematics. Furthermore, it was anticipated that employing constructivism that used a computer program as a learning tool (UNISA, 2011), would improve the poor Geometry performance of South African high school learners, who are said to be from the post-technology era (Van Niekerk, 2010).

### **The aim of the study**

The aim of the study was to investigate the comparative effects of Computer-Assisted Instruction (CAI) and Conventional Teaching Instructions (CTI) on the performance and motivation of Grade 11 learners in Circle Geometry.

### **A THEORETICAL FRAMEWORK FOR THE STUDY**

The constructivist perspective (Shoemaker, 2013; Woolfolk, 2010; Ornstein & Hunkins, 2009; Teal, 2008; Cobb, Yackel & Wood, 1992) was used as a theoretical framework underpinning the present study. The experimental group used a computer program, GeoGebra, to (re)invent strategies for solving Circle Geometry problems while the control group was expected to use any other tool besides a computer program to (re)invent strategies for solving Circle Geometry problems.

Socio-constructivism is a component of constructivism that was also explored in the current study. In this regard, the current study aimed to determine the intervention that allowed learners to productively interact with each other and with their learning tools in a way that would give them an opportunity to move beyond instrumental understanding to relational understanding in Circle Geometry (Skemp, 1976).

### **METHODOLOGY**

The study employed a non-equivalent control group design consisting of a pre-test, post-test, and a questionnaire (McMillan & Schumacher, 2010). This is one of the designs used in studies that lack random assignment of participants to experimental and control groups. This design was used in order to preserve the normal running of the participating schools and to minimise threats to the external validity of the study, since natural learning environments were maintained (Gay, Mills, &

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1. Ekurhuleni North is a district in the Gauteng province.  
2. Gauteng is one of the nine provinces in South Africa.



Airasian, 2011). Similarly, Shoemaker (2013), Dhlamini (2012), Spradlin (2009), Tucker (2009), and Pilli (2008) used a quasi-experimental non-equivalent control group design arguing that it prevented disruption of the educational setting. The researcher administered CAI in two experimental classes to preserve uniform conditions in the implementation of a CAI. The teacher at the control school implemented CTI in two control classes to preserve conventional conditions.

To provide more depth and detail into the research study, enhance credibility, and compensate for the limitations of the quantitative design, interviews were also incorporated (Johnson & Christensen, 2012; McMillan & Schumacher, 2010). This is because data from quantitative instruments in the form of numbers, could be strengthened or weakened with data collected from interviews, in the form of words, from participants' perspectives (Creswell, 2012; McMillan & Schumacher, 2010).

### **Population and sample**

The population for the study consisted of Grade 11 mathematics learners from 65 secondary schools that are located in the Ekurhuleni North district of Gauteng province in South Africa who share the same characteristics of having persistently performed poorly in Geometry, resulting in a decrease in the number of mathematics learners over the years. The study sample consisted of 136 learners from two secondary schools that were drawn by convenience sampling methods from the population of the study.

### **Computer software**

The computer software, GeoGebra, was used in the present study. This software allows learners to draw shapes and lines, measure angles and lengths while providing instructions. By drawing accurate diagrams, learners are able to determine the sizes of unknown angles and to prove Circle Geometry theorems, to prove that lines are parallel, a shape is a cyclic quadrilateral, and that a line is a tangent to a circle.

### **Instrumentation**

The instruments for data collection were a Circle Geometry test, a motivation questionnaire and an interview schedule.

#### ***A circle geometry test***

The test consisted of four questions that totalled 50 marks. The questions were drawn from the Curriculum and Assessment Policy Statement (CAPS) document that contains typical Grade 11 examination questions. This document was used by the Department of Basic Education (DBE) to train teachers on how to teach topics that were reintroduced into the South African Grade 11 mathematics curriculum in 2013. A Spearman-Brown reliability coefficient of 0.82, and therefore a good reliability of a test, was obtained. According to Johnson and Christensen (2012), the Spearman-Brown formula determines how consistently the items in a test measure a single construct or concept such as performance in Circle Geometry. In order to maintain similar conditions in both the CAI and the CTI groups, the same test was used as a pre-test and a post-test, before and after the interventions (CAI and CTI).

#### ***The circle geometry motivation questionnaire***

The effect of CAI and CTI on the motivation of learners towards Circle Geometry was determined by administering a questionnaire to learners from both the experimental group (n=66) and control group (n=65), after the interventions. The questionnaire adopted by Bryan (2009) was modified in the current study to measure learners' motivation towards Circle Geometry. In the questionnaire used in the current study, learners responded to each of the 30 Circle Geometry motivation questionnaire items on a 5-point scale where *1=never*; *2=rarely*; *3=sometimes*; *4=often*; and, *5=always*. A learner's total Circle Geometry motivation questionnaire score was interpreted as



follows:

120-150 = high motivation  
90-119 = moderate motivation  
60-89 = low motivation  
30-59 = very low motivation

The Cronbach's Alpha Reliability value of  $\alpha = 0,759 > 0,7$ , and therefore acceptable was obtained from the results of the pilot questionnaire (Johnson & Christensen, 2012; Cooper & Schindler, 2001, cited in Cohen, Manion & Morrison, 2011).

### ***Semi-structured interviews***

At the end of the interventions, a purposive sample of 12 learners, six from each group, was selected to participate in the semi-structured interviews. Interviews were conducted on both groups to document the effect of CAI and CTI on learners' performance and motivation levels towards CAI and CTI, by comparing the interview responses to the questionnaire responses and test results. The semi-structured interviews were a modification of the interview questions used by D'Souza (2005). In accordance with convergent validity (Johnson & Christensen, 2012; Cohen, Manion & Morrison, 2011), the results of the pilot questionnaire and semi-structured interviews agreed.

### **DATA ANALYSIS**

Analysis of Covariance (ANCOVA) was used to either accept or reject the null hypothesis and the alternative hypothesis on mathematics performance, and to answer research question 1 and research question 2. The questionnaire scores and interview responses were used to answer research question 1 and research question 3, and to either accept or reject the null hypothesis and alternative hypothesis on motivation.

The following null hypotheses and alternative hypotheses were cast for the present study:

**Null hypothesis on Mathematics performance ( $H_0$ ):** There is no statistically significant difference between the average mathematics performance scores of Grade 11 learners who participate in the Computer-Assisted Instruction (CAI) program and those who do not, in the topic of Circle Geometry.

**Alternative hypothesis on Mathematics performance ( $H_1$ ):** There is a statistically significant difference between the average mathematics performance scores of Grade 11 learners who are taught using Computer-Assisted Instruction (CAI) and those taught using Conventional Teaching Instructions (CTI), in the topic of Circle Geometry.

**Null hypothesis on motivation ( $H_2$ ):** There is no significant difference between the average motivation scores of Grade 11 learners who participate in the Computer-Assisted Instruction (CAI) program and those who do not, in the topic of Circle Geometry.

**Alternative hypothesis on motivation ( $H_3$ ):** There is a significant difference between the average motivation scores of Grade 11 learners who are taught using Computer-Assisted Instruction (CAI) and those taught using Conventional Teaching Instructions (CTI), in the topic of Circle Geometry.

The following were the over-arching research questions to guide the present study:



- How can a Computer-Assisted Instruction (CAI) and Conventional Teaching Instructions (CTI) be used in the teaching of Grade 11 Circle Geometry?
- Is there a statistically significant difference in the average pre-test and post-test performance scores of Grade 11 learners taught Circle Geometry using CAI and those taught using CTI?
- How does CAI or CTI affect the motivation levels of Grade 11 learners in the topic of Circle Geometry?

### Data analysis for test scores

**Table 2: Mean and standard deviation of pre- and post-test scores in both groups**

Pre-test	n	$\bar{x}$	SD	Post-test	n	$\bar{x}$	SD
Experimental group	71	6.56	6.08	Experimental group	71	32.35	7.64
Control group	65	5.45	5.52	Control group	65	27.12	9.66

Table 2 shows that the mean score of the experimental group increased more than that of the control group. This indicates that learners' performance in the experimental group improved more than in the control group. One of the reasons why the mean score of the control group was lower than that of the experimental group in the pre-test could have been because of the convenience sampling method that was used in selecting participating schools. Probably, the experimental group had some pre-existing advantages such as intelligence, motivation, and a more positive attitude as compared to the control group, however, these pre-existing advantages were eliminated through the use of Analysis of covariance (ANCOVA) (Gay *et al.*, 2011; McMillan & Schumacher, 2010). The standard deviation of the experimental group had a smaller increase as compared to that of the control group indicating that the gap between learners who understood Circle Geometry and those who did not was bigger in the control group than in the experimental group.

**Table 3: Analysis of covariance to analyse test scores in the main study**

Dependent	Post-test
Sample size	136

#### Levene's test for equality of error variances

F	DF 1	DF 2	P
1.3802	1	134	0.242

#### Homogeneity of regression slopes

Source	Sum of Squares	DF	Mean Square	F	P
Heterogeneity of slopes	231.920	1	231.920	3.147	0.078
Individual residual	9728.704	132	73.702		

#### Tests of Between-Subjects Effects

Source	Sum of Squares	DF	Mean Square	F	P
Corrected model	1172.434	2	586.217	7.828	0.001
Intercept	52903.150	1	52903.150	706.393	<0.001
pre-test	244.588	1	244.588	3.266	0.073



group	831.082	1	831.082	11.097	0.001
Residual	9960.625	133	74.892		
Total	132336.000	136			
Corrected Total	11133.059	135			
Coefficient of determination R <sup>2</sup>	0.1053				
R <sup>2</sup> -adjusted	0.09186				

#### **Estimated Marginal Means**

Group	n	Mean	Std. Error	95% Confidence interval
Control	65	27.2575	1.0760	25.1293 to 29.3857
Experimental	71	32.2291	1.0293	30.1931 to 34.2650

#### **Pairwise comparisons**

Factors	Mean difference	Std. Error	P <sup>a</sup>	95% CI <sup>a</sup>
Control - experimental	-4.9716	1.4924	0.0011	-7.9235 to -2.0196
Experimental - control	4.9716	1.4924	0.0011	2.0196 to 7.9235

<sup>a</sup>Bonferroni corrected

#### **Summary statistics for dependent variable and covariate(s)**

Variable	Mean	Standard deviation
Post-test	29.8529	9.0811
Pre-test	6.0294	5.8676

Table 3 shows that the Levene's test for equality error variances was =  $0.242 > 0.05$ , indicating that the homogeneity of variances assumption for ANCOVA was met. The homogeneity of slopes was  $P = 0.078 > 0.05$ , showing that there was no interaction between the covariate and the independent variable. Therefore, the ANCOVA results for the present study were reliable. The results of the *F test* supported the effect of CAI in teaching the topic of Circle Geometry to Grade 11 learners,  $F(1, 133) = 11.097, P < 0.05$ . This showed that CAI was more superior as compared to CTI in teaching the topic of Circle Geometry in Grade 11. Hence, the null hypothesis on mathematics performance was rejected and the alternative hypothesis accepted.

The Bonferroni test is a post hoc test used to determine which means are significantly different when comparing more than two means. Since in this study only two means were compared, the post hoc test was not necessary because it gave a similar result to the *F test*  $P = 0,001 < 0,05$ . A statistically significant difference was therefore confirmed to exist between the average CAI score and the average CTI score; so the null hypothesis was rejected.

Therefore, learners taught using CAI performed better than those taught using CTI. It may be argued that CAI proved to be more appropriate in employing a socio-constructivist perspective, which resulted in learners developing Couco, Goldenberg, & Mark's (1995) habits of the mind, Kilpatrick, Swafford, and Findell's (2001), and Hiebert and Lefvre's (1986) conceptual knowledge, and Skemp's (1976) relational understanding in Circle Geometry, as compared to CTI.

Detailed explanations of the research design and researcher role, the use of natural settings and ANCOVA, efforts to keep enough distance (about 20 km) between the two groups and to maintain similar conditions such as, performance, teachers, instruments and their administration, assisted in

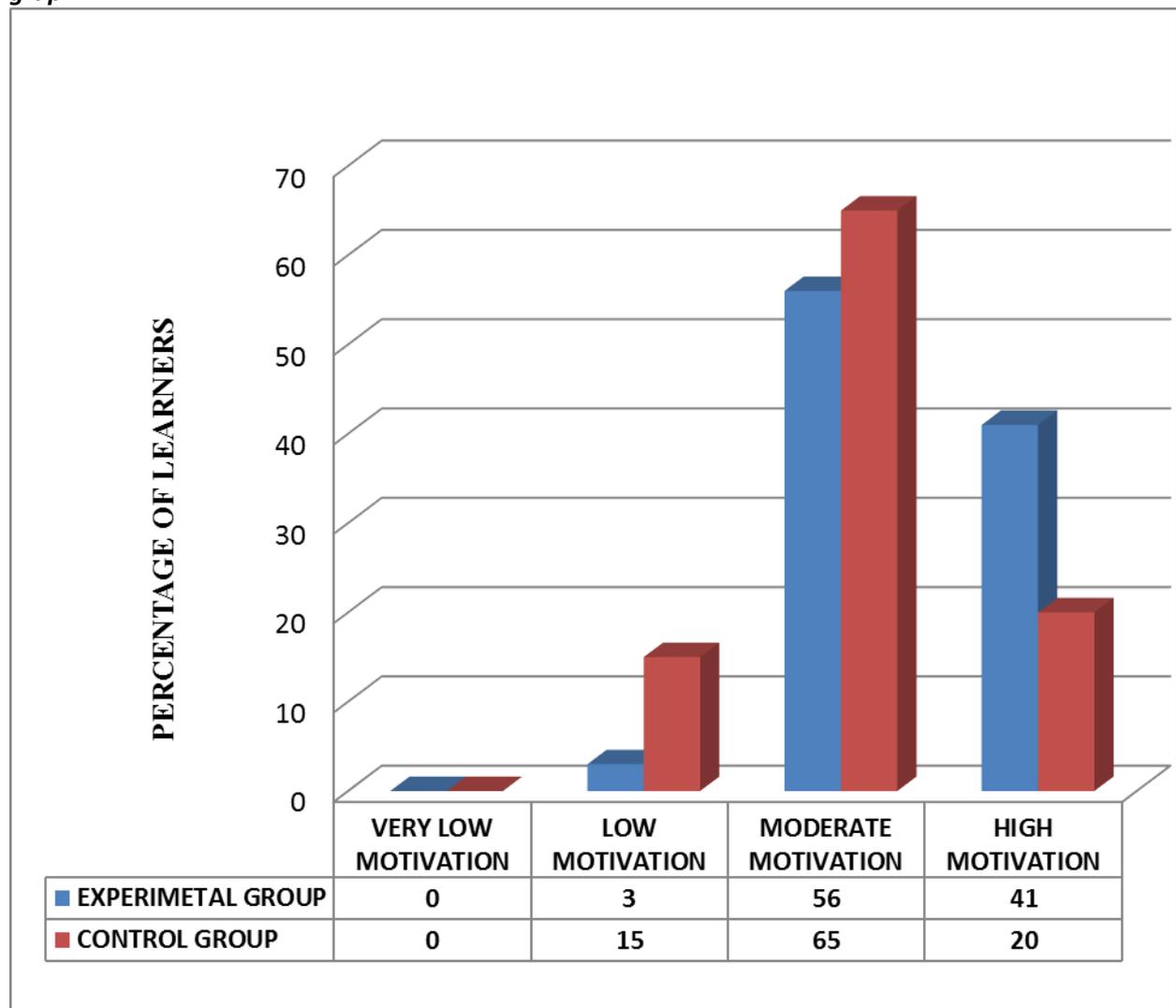
minimising threats to the validity of the present study findings (Dhlamini, 2012, Cohen *et al.*, 2011; Gay *et al.*, 2011; McMillan & Schumacher, 2010).

### Data analysis for the questionnaire

The results in Figure 1 show that 0% of the respondents from the experimental group experienced very low motivation, 3% had low motivation and 56% had moderate motivation, while 41% had high motivation. The mean motivation score for the experimental group was 77%, representing moderate motivation. The standard deviation of the same group was computed at 12.96.

In the control group 0% of the respondents experienced very low motivation, 15% had low motivation, 65% had moderate motivation, and 20% had high motivation. The mean motivation score for the control group was 71%, representing moderate motivation. The standard deviation was 15.17 for this group. Even though both the mean motivation score and the standard deviation are almost the same in both groups, the double bar graph shows that double the number of learners in the experimental group (41%) than in the control group (20%) had high motivation. In addition, five times the number of learners in the control group (15%) than in the experimental group (3%) had low motivation.

**Figure 1: Results of participants' levels of motivation in a double bar graph**



### **Data analysis for the interviews**

The interviewee respondents were selected as follows: (1) Respondents E1, E2, C1, and C2 had obtained the lowest post-test scores (0 – 14); (2) respondents E3, E4, C3 and C4 had obtained average post-test scores (25 – 29), (3) respondents E5, E6, C5 and C6 had obtained the highest post-test scores (40 – 50). When the experimental group respondents were asked if they enjoyed Circle Geometry before they were introduced to CAI, E6 and E5 responded that they did not enjoy it because *“we don’t use computers so often”*, and *“circle geometry was difficult and complicated”*. Responding to the same question after the treatment (implementation of CAI), E4 said *“it was difficult but with computers it was easy”*. However, E2 said *“I was enjoying circle geometry before CAI was introduced because teachers explained and we understood”*, suggesting that the motivation that E2 had towards the topic of Circle Geometry was not necessarily as a result of the treatment. When participants in the control group were asked if they enjoyed Circle Geometry before they were introduced to CTI, C1, C4, C5, and C6 said they did. In particular, C2 said *“sometimes”*, while C3 said *“it was difficult and challenging”*.

In addition, when asked to provide their feeling about CAI the respondents in the experimental group provided the following responses:

**E1:** *“Circle geometry was difficult but computers made it easy to understand, they do not waste time and they make the job easy”*.

**E2:** *“CAI is better than other methods, you are independent, you follow stuff and you develop skills”*.

**E3:** *“I prefer computers because it’s easy, you have material, the computer tells you what to do and you just click, unlike in class where you have to think”*.

**E4:** *“I used to think that I was a lower learner but CAI is the best way that is easier and simpler, it is different from the class and we can discuss with other learners”*.

**E5:** *“CAI has helped me to improve step by step, it attracts us, explains better than textbooks, and it is interesting”*.

**E6:** *“We are not used to computers, they are fun, enjoyable, understandable, and easier than in class because on the computer you just press and draw, the computer assists you in finding angles and lengths, than in class”*.

In addition to the above responses, E3 alluded, *“it is much easier to explain to other learners using the computer because it is broad and clear”*.

When asked how they felt about using CTI and Circle Geometry, C1 seemed to suggest that it was fine but further emphasised that the conventional method of instruction (CTI) could be improved. Responding to the same question C2 said CTI was *“good”* even though she did not get it right (referring to understanding this topic and also giving a good performance to it). In addition, C3, C4, C5 and C6 indicated that CTI was good and *“helpful”* as they felt it helped them to understand Circle Geometry better than it was the case before.



On the idea of using CAI to teach the topic of Circle Geometry in Grade 11, the following responses emerged from the experimental group:

**E1:** *“It should have started in Grade 8”.*

**E3:** *“Computers should be used when writing tests”.*

**E4:** *“For questions that you don’t understand you can go to the computers, and discuss”.*

**E5:** *“Teachers should take us to the computer laboratory to learn more circle geometry using computers”.*

**E6:** *“I hope our teacher can continue to use CAI after this study has ended”.*

Regarding the same question about using CTI to teach the topic of Circle Geometry in Grade 11, C1 said it was fine but could be improved if other teachers also came to teach them the sections of this topic which were difficult for them to understand. In addition to the initial response, C1 further proposed the *“use of the internet to improve CTI, group work, and motivating learners by showing them the importance of circle geometry”*, thus acknowledging the value of using technology to enhance comprehension and performance in the topic of Circle Geometry. Responding and providing extra views to the same question, C2 and C4 suggested for more learner participation in a CTI lesson, highlighting the importance of placing learners in groups where the fast-learners would teach their slow-learning group mates. The response of C3 to this interview item suggested that CTI could be more *“practical”* if real objects had been used to demonstrate situations. Finally, C6 suggested that learners had to use different textbooks for them to understand.

## **DISCUSSION AND CONCLUSIONS**

### **Research question 1**

Evidence from the interviews showed that experimental learners felt that CAI allowed them to discuss with each other; be more involved in solving Circle Geometry problems; and they felt more independent. On the other hand, CTI learners felt that their participation in the class was limited. Therefore, it may be argued that CAI was better in implementing socio-constructivism as compared to CTI.

### **Research question 2, Null and alternative hypothesis on mathematics performance**

The mean score of the experimental group increased by a bigger margin (25.79) when compared to the mean score of the control group (21.67). This meant that from the pre-test to the post-test, learners in the experimental group improved more than learners in the control group. In the pre-test, the standard deviations of both groups of learners were almost the same. However, in the post-test, the standard deviation of the control group (9.66) was bigger than that of the experimental group (7.64). This was an indication that the marks of the experimental learners were closer together than those of the control learners. In other words, the gap between learners who understood and those who did not understand was bigger in the CTI group than in the CAI group. It may be that the individual attention, hands-on and learner-centeredness approach provided by the computer program resulted in the CAI group having an increase in the number of learners who understood, as compared to the CTI group.

The Analysis of Covariance (ANCOVA) results showed that there was a statistically significant difference between the average mathematics performance scores of Grade 11 learners who were taught using CAI and those taught using CTI in the topic of Circle Geometry. In another way, learners who received CAI performed better than those who received CTI.

In their studies, Bayturan (2012), Jackson (2005), Lin (2008), Trexler (2007) and Lindsey (2005) also concluded that CAI was more effective than CTI in improving learner performance. Therefore, CAI may be argued to be a possible solution to the poor performance of learners in Geometry and mathematics, observed by Ngobese (2013), Chauke (2013), Cassim (2012; 2006), GDE (2010) and Mansukhani (2010).

### **Research question 3, null and alternative hypothesis on motivation**

Figure 1 shows that the experimental group had double (41%) the percentage of learners who had higher motivation than the control group (20%). The control group had a slightly higher percentage (65%) of learners who felt moderate motivation than the experimental group (56%) and five times (15%) the percentage of lowly motivated learners than the experimental group (03%). The mean motivation scores of both the experimental and control groups showed moderate motivation of 77% and 71% respectively. The standard deviations were almost the same, the experimental group having a standard deviation of 12.96 while the control group had a standard deviation of 15.17.

The results of the interviews agreed with the results of the questionnaire in that the experimental group felt that CAI was a better teaching instruction than CTI, and they enjoyed it. Learners in the control group felt that CTI could be improved if the teacher used groups whereby the best performers assisted the least learners. Other suggested improvements to CTI included the use of the internet by the teacher to continuously communicate with learners when they are at home, the use of different textbooks, allowing learners to go in front of the class and demonstrate their solutions to other learners, and motivating learners by showing them the importance of Circle Geometry in real life. Learners in the experimental group felt that CAI made Circle Geometry easier and understandable.

In accordance to the socio-constructivist perspective, learners in the experimental group felt “independent” to facilitate and develop their own solutions to Circle Geometry problems. They showed confidence and were more “interested” in Circle Geometry than before. This led them to request their teacher to continue using CAI after the end of the study. On the other hand, learners in the control group felt that their participation during lessons was limited and they wished if it could be improved through peer teaching and group discussions.

CAI proved to be effective in motivating learners in the topic of Circle Geometry. Similar results were also obtained by Keaney (2012) and Teal (2008). Therefore, the teaching method used by a teacher may be one of the reasons for learner demotivation in mathematics (Beres, 2011), which may result in poor performance and to a decrease in the number of mathematics candidates.

### **CONCLUSION**

The results of this investigation indicated that the use of the computer software, GeoGebra, in the teaching and learning of Circle Geometry improved the performance and motivation of Grade 11 learners. The Computers also provided a more socio-constructivist environment than Conventional Teaching Instructions (CTI). Therefore, CAI, with appropriate software is one of the alternative methods of instruction that has the potential of improving the performance and motivation of learners in Circle Geometry and in mathematics, since it allows every learner to be actively involved in the creation of their own knowledge and understanding, as they draw lines and shapes, measure angles and lines, create and solve their own mathematical problems while interacting with each other and with their cultural tool (Woolfolk, 2010). In other words, improved motivation may increase persistence and perseverance, which may lead to improved habits of the mind (Cuoco *et al.*, 1995), conceptual knowledge (Kilpatrick *et al.*, 2001; Hiebert & Lefevre, 1986) and relational understanding (Skemp, 1976), resulting in improved performance



In this regard, teachers should vary their methods of instruction as a way of motivating and accommodating the post-modern learners, within heterogeneous classes. Computers in the schools should be installed with mathematical software that promote a socio-constructivist approach, not just drill and practice. Both teachers and learners should be trained on how to effectively use computers in Circle Geometry and in other mathematics topics, with confidence. The South African Department of Basic Education (BDE) should find ways of allowing learners who would have learned using technology to use it when writing examinations, since it is the same technologies that they will encounter at the workplaces.

Recommendations for further studies included, replicating the study with a larger sample and in other mathematics topics, comparing the performance and motivation of males to females, rural schools to township schools; and investigating the effects of other technologies such as tablets and / pads, in the teaching and learning of mathematics.

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