

Problem-based Learning Strategies and Gender as Determinant of Grade 9 Students' Academic Achievement in Algebra

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ABSTRACT This study examined the effects of problem based learning strategies and gender on students' academic achievement. A 3X2 pre-test and post-test control group quasi-experimental group design was adopted in the study. The instruments constructed and used for the study were: Problem Based Learning Strategies which are in two parts (PBLSa), (PBLSb) and Conventional Teaching Guide (C.T.G). Two hypotheses were generated and tested in the study at 0.05 alpha levels. One of the major findings of this study was that (PBLSa) and (PBLSb) are more effective than conventional method in students' academic achievement in algebra ($\bar{x}$ = 3.05; SE = .720), (= 4.23; SE = .714), (= 3.36; SE = .726) in that order. The study also revealed there is no significant main effect of gender on students' academic achievement, female (= 15.63) and male (= 15.41). However, the study recommended that problem-based learning strategies should be embraced by both the teachers and learners in order to enhance students' academic achievement in algebra.

INTRODUCTION

Education is a vital aspect of all human activities, which enables the society to fashion and model individuals to perform well in the environment. According to Boit et al. (2012:179), the purpose of education is 'to equip the citizenry to reshape their society and eliminate inequality.' Again, in the domain of education quality is connected with high students' academic performance or attainment which can improve the quality of human resources, and is directly related to increased individual earnings and productivity, economic growth and governments' ability to alleviate poverty (UNESCO 2005). Though educators and researchers are yet to reach a consensus on the nature of educational quality and its determinants, it is typically measured by higher achievement in examinations.

However, the main objectives of this study are (1) to determine the effect of Problem-Based Learning Strategy on students' academic achievement in algebra, and (2) to explore the effect of gender on students' academic achievement in algebra. In achieving the objectives of the study, some related factors were explored and the findings and recommendation were made to the educators and students in order to improve classroom performance. In the recent years, the need to maintain a globally competitive workforce and the trend of interest in science and technology has prompted researchers to place much emphasis on mathematics because

all other science related subjects are expressed, formulated and communicated through mathematics. Also, mathematics is important even in shaping how individuals deal with the various aspects of private, social and civil life (Anthony and Walshaw 2009). Despite the importance of mathematics, it is quiet unfortunate that many nations are grappling with students' underachievement in mathematics as it has become a global menace with students' persistent failure in both teacher-made tests and external examinations. This has made the teaching and learning of mathematics to become a major area of focus which calls for urgent intervention. Many scholars have observed that mathematics is one of the most poorly taught, widely hated and poorly understood subjects in schools. (Ali et al. 2010).

Academic achievement has become a major preoccupation of policy makers, think tanks, mathematics educators and all stakeholders in a bid to proffer a lasting solution to the problem of poor achievement in mathematics. The final report of the National Mathematics Advisory Panel (2008:12) indicates that "American students have not been succeeding in the mathematical part of their education at anything like a level expected of an international leader" In South Africa, empirical studies nationally have confirmed the high rate of poor performance in mathematics. The Department of Education released the Annual National Assessment (ANA), which provided a bleak picture of educational

performance. The performance in mathematics is however extremely worrying. The report showed that the largest number of South African students has been assessed to score below 30 percent in Grades 3, 6 and 9 and when a student scores between 0-29 percent, it is described as “not achieved”.

Furthermore, the under-performance of learners in secondary school mathematics in South Africa has become an issue of concern to the whole country. In 2008 only 23.34 percent learners who sat for the mathematics senior certificate managed to achieve more than 50 percent (Department of Education 2008). The situation has not improved, in 2012 only 22.68 percent learners achieved more than 50 percent for mathematics in the final grade 12 examinations.

In 2011, at the international scene South Africa was among 45 countries that participated at the grade 8 and 9 levels in The Trend in International Mathematics and Science Study (TIMSS) and the result was not encouraging at all.

Cuevas (1984) stated that research efforts should be directed towards studies that would explore the relationship among selected aspects of mathematics performance. Algebra is an integral part of the mathematics curriculum and one of the oldest aspects of mathematics. Studies have indicated that success in algebra is important in careers outside of academia. Capraro and Jaffrion (2006) stated that algebra often serves as a gate keeper to success in high school, post-secondary education, and many career paths, bringing with it prospects for enhanced income and a better quality of life. Educators also argue that algebra is part of humankind’s cultural heritage and is needed for informed and critical citizenship, despite its importance; its learning has remained a significant challenge to students all over the world. In the final report of Mathematics Advisory Panel, the panel noted that American students are struggling with many aspects of mathematics and sees “algebra as a central concern” (National Mathematics Advisory Panel 2008: 13)

In South African schools, the teaching of algebra focuses on manipulative skills of simplifying, factorising, solving equation, functions and graph, variables, word problems and patterns. These are introduced to pupils around the ages of 13 -14 years. Debates on the place of algebra in mathematics curriculum have been ongoing. In view of this, the study sought to

contribute to the growing body of literature by investigating the effects of problem-based learning strategies and gender on the teaching of an aspect of mathematics.

Algebra: A Fundamental Aspect of Mathematics Curriculum

Algebra is a fundamental aspect of mathematics curriculum which involves substitution, factorisation, and problem solving and drawing of graphs. It forms a large component of the mathematics curriculum for high school and for further study in mathematics related courses. It is often the first course in which students are exposed to abstract reasoning and problem solving (Vogel 2008). Studies have revealed that the abstract nature of algebra increases its difficulty (Carraher and Schliemann 2007; Howie 2005). Algebra involves both concrete or procedural level and abstract reasoning. It is an aspect of mathematics dealing with symbolizing and generalizing relationships and mathematical structures, and operating within those structures (Kieran 1992: 391). Radford (2012) pointed that algebra is one of the most frightening branches of mathematics. The final report of the National Advisory Panel (2008) indicated that American students were struggling with many aspects of mathematics and the panel sees algebra as of central concern. The learning of algebra is difficult and it has been suggested that a progressive introduction to algebra in the early grades may facilitate students’ understanding of the concept (Carraher and Schliemann in Lester 2007).

Problem-based Learning Strategies (PBL) and Students’ Academic Achievement

PBL was pioneered in the medical school program at McMaster University in Canada in the late 1960s by Barrows (1996) and his colleagues (Neville 2009) for educating medical students to become physician to foster their own capabilities for reflection outside of school in ordinary life. The roots of PBL can be traced to the progressive movement, especially to Dewey’s (1944) belief that teaching should appeal to students’ natural instincts to investigate and create. Barrows and his colleagues were inspired by Dewey’s maxim.

The PBL curriculum was developed in order to motivate the students, assist the students in

seeing the importance of learning to future roles, maintain a higher level of encouragement towards learning, and to show the students the importance of responsible, skilled attitudes (Barrow1996).The new teaching approach also spread to the teaching of non-medical disciplines and subsequently been adopted by other medical school's curriculum adapted for undergraduate instruction (Peters and Amador 2006), as well as grade-12 (Gasser 2011; Barrows 1996). The use of PBL has enlarged from its initial introduction into medical school programs to include education in the areas of other health sciences, mathematics, economics, philosophy, law, business studies and management, education, Technology, engineering and sciences, to mention but a few (Gasser 2011).

Colliver (2000) remarked that the positive effects of PBL on test scores may be attributable to selection bias because most reviewed studies are non-randomized. More recent studies analyse the effects of PBL on several categories of student outcomes. Dochy et al. (2003), for instance, performed a meta-analysis (using both a vote counting and a combined effect size method) to look upon the link between PBL and students' knowledge and knowledge application. They observed (a) a negative impact of PBL on students' knowledge base and (b) a positive and statistically significant effect of PBL on students' knowledge application. However, Dochy et al. (2003) indicated that this should be treated with caution as it is strongly influenced by outliers. Gijbels et al. (2005) looked at the impact of PBL on three levels of knowledge (understandings of the concept, understanding of the principles that link concepts, and linking of concepts and principles to conditions and procedures for application). They found the most positive effects at the level of knowledge which concerns understanding principles that link concepts. Smits et al. (2002) focused particularly on the effects of PBL on student knowledge as found in studies in medical education and concluded that overall the evidence that PBL has positive effects is rather weak. In conclusion, previous literature on the effectiveness of PBL in terms of increasing student knowledge (as compared to conventional teaching methods) shows mixed result

Problem-based learning models have problem-solving steps that range from four to eleven (Ames et al. 1977). However, the most popularly

used ones have between There are many problem-based learning models which were made popular by McMaster University in the late 1960s through application into the school curriculum (Albarnes and Mitchell 1993). The steps are described in different terms, for the purpose of this study (PBLSa) and (PBL Sb) have been used these are Selvaratnam and Frazer (1982) and Gallagher et al. (1992) modified learning strategies used as treatment.

Gender and Students' Academic Achievement

Gender differences in mathematics achievement dated back to the 1960s. The early results provided a scenario showing that boys consistently performed better than girls (Maccoby1966). Contrary to that, Maccoby stated that boys and girls performed comparably during primary school, until the boys' mathematical skills increased faster than girls', beginning around the ages of 12 or 13, reaching a significant difference in achievement scores by high school. Again, gender equality issue in education has been a major concern in many countries, including SouthAfrica, because of its link with health and nutrition, economic development, and civic responsibilities. the concept of 'gender equality in education' follows the UNESCO (2003) interpretation, which refers to the notion of boys and girls experiencing the same advantages or disadvantages in attending school, receiving teaching methods, curricula, and academic orientation, and producing equal learning achievements and subsequent life opportunities

Studies have shown that Mathematics is stereotyped as male domains in the academic setting (Fennema and Sherman 1977; Nosek et al. 2009). The stereotype is shared by parents and teachers, parents believe that their sons' mathematical ability is higher than their daughters' (Furnham et al. 2002; Frome and Eccles 1998). Teachers, too, tend to stereotype mathematics as a male domain. In particular, they overrate boys' ability relative to girls' (Anderson and Tindal 2001). There are several reasons why the issue of stereotypes in mathematics learning is of concern, in the language of cognitive social learning theory; stereotypes can influence competency beliefs or self-efficacy. Therefore, studies have shown that parents' and teachers' stereotypes about gender and mathematics predict and influence learners' perceptions of their abil-

ities and mathematics achievement (Bouchey and Harter 2005; Keller 2001).

However, in recent studies, elementary-school boys still report significantly higher mathematics competency beliefs than girls do (Else-Quest et al. 2010; Lindberg et al. 2008). From the traditional point of view, researchers upheld that girls might do as well as, or even better than boys on tests of computation, which necessitate moderately simple cognitive processes (Anastasi 1958). These same researchers concluded that male superiority emerged for tests requiring more advanced cognitive processing, such as complex problem solving.

Objectives of the Study

The aforementioned background is an indication that there has been an appalling achievement of students in algebra. It is therefore pertinent to gear research work towards finding a solution to it. Hence, this study revealed the effect of PBL, and gender on students' academic achievement in algebra. The study investigated the variables that could determine students' academic achievement in algebra. Several studies have explained the link between different variables and the effects on students' academic achievement in algebra as pointed out earlier. However, no concrete effort has been geared towards the contribution of PBL and gender on students' academic achievement. In order to capture the interplay of them within the domains of teaching and learning, this idea prompted the present researcher to embark on the effects of the stated variables on grade 9 students' academic achievement in algebra.

Hypotheses

The following hypotheses were tested at 0.05 significant levels:

1. There is no significant difference in the mean achievement scores of students exposed to the two treatments and conventional method of teaching.
2. There is no significant main effect of gender on students' achievement in algebra

RESEARCH METHODOLOGY

The 3X2 pre-test, post-test quasi-experimental factorial design was adopted for the study.

The researcher uses control and experimental groups but does not randomly assign participants to groups (Creswell 2009). A pre-test and post-test was administered to both groups, but only the experimental group receives the treatment. In this study a subject teacher from each of the schools received the training and was told the intervention strategy to be employed when teaching algebra (PBL). The strategy was basically used to improve students' problem solving skills; the control group was used as the comparison group.

Population and Sample Size (n) Justification

The population consisted of Grade 9 students in the East London district. The sample size consisted of four intact classes of grade 9 students from two schools within East London district with (109) subjects as the research population made up of (65) girls and (44) boys. The two schools were purposively selected based on the following criteria, they are both of equivalent status, co-educational, students of both schools have been exposed to basic prerequisite concepts necessary for the understanding of the treatment concepts and the schools have not taught the students the topic. The sample size was relatively small in order to cater for the assumption of ANCOVA and for the generalization of the study results.

RESULTS

The data was analysed using descriptive and inferential statistics which involves the computation of pre and post-tests mean scores. A 3x2 ANCOVA on the students' post test score achievement by treatment, gender and conventional method were carried out testing the hypotheses and differences among groups, using pre-test scores as covariates. The Pairwise Comparison of Scheffe's Post-Hoc Analysis was also done showing sources of significant difference among the groups. All hypotheses were tested at $P < 0.05$ level of significance

Table 1 also shows two-way non-significant effects of treatment and gender ($F_{(3,109)} = .120$; $p > .05$), treatment and language proficiency ($F_{(3,109)} = 1.653$; $p > .05$), gender and language proficiency ($F_{(1,109)} = 1.083$; $p > .05$).

Hypothesis One H_{01} : There is no significant difference in the mean achievement scores of

Table 1: Summary of 3x2x3 Analysis of Covariance (ANCOVA) of students' post-test achievement by treatment, language proficiency, gender, and conventional method of teaching

Source	Type III sum of square	df	Mean square	F	Sig.	Partial Eta square
Corrected Model	9.662 ^a	4	2.416	.327	.860	.291
Intercept	159.661	1	159.661	21.581	.000	.711
Pre-test	2.263E-02	1	2.263E-02	1.083	.359	.313
Treatment	64.842	3	21.614	5.402	.002	.158
Gender	1.755	1	1.755	.237	.627	.037
Language proficiency	6.850	1	6.850	.926	.338	.171
Treatment*gender	9.784	3	3.261	.120	.280	.016
Treatment*language proficiency						
Gender*language proficiency	16.663	3	5.554	1.653	.153	.051
Treatment*gender*language proficiency	2.431E-02	1	2.431E-02	1.083	.353	.000
Error						
Total	6.484	3	2.161	.663	.565	.019
	769.402	104	7.398			
	27106.000	109				
	779.064	108				

a. R Squared = .012 (Adjusted R Squared = -.026), Significant at $p < .05$

students exposed to the two treatments and conventional method of teaching.

Table 2 showed that there is significant difference between the mean achievement scores of students exposed to PBLSa and PBL Sb, those exposed to PBL Sb had the highest adjusted mean score ($\bar{X} = 4.23$; $SE = .714$) than those exposed to Conventional Method ($\bar{X} = 3.36$; $SE = .726$) and PBLSa ($\bar{X} = 3.05$; $SE = .720$) in that order. In determine the source of significant differences among the three groups. Table 3 presented the pairwise comparison of Scheffe's Post Hoc test carried out.

Table 3 revealed that $3 > 2 > 1$ and $2 \text{ vs. } 1 = \text{sig.}$ Similarly, $3 \text{ vs. } 1 = \text{sig.}$ which is indicated that Table 3 showed that the significant difference revealed in Table 1 is as a result of significant differences between PBLSa and PBL Sb groups and between PBLSa and Conventional groups

and between PBL Sb and Conventional groups. The implication is that students exposed to the PBLSa performed significantly better than those exposed to the PBL Sb and as well better than those exposed to the Conventional strategy.

Table 3: Pairwise comparison of Scheffe's post-hoc analysis showing sources of significance of post-test achievement according to treatment groups

Treatment	N	Mean	MTDTS	LPTS	LIQS
PBLa	27	3.05	*		*
PBLb	28	4.23	*	*	*
CONV.	29	3.36		*	

Pairs of groups significantly difference at $P < .05$

a. PBLSa= Problem-Based Learning Strategies Group (a)

b. PBL Sb=Problem-Based Learning Strategies Group (b)

c. Conventional Method Group

Table 2: Estimated marginal means for students across the treatment groups**Dependent Variable: Achievement Post-test**

Treatment	N	Mean	Std. error	95% confidence interval	
				Lower bound	Upper bound
PBLSa	27	3.05	.720	5.867	8.213
PBL Sb	28	4.23	.714	6.732	8.462
CONV.	29	3.36	.726	7.456	9.877

a. Evaluated covariates appeared in the model: PRETEST = 5.44

b. Based on modified population marginal mean

Also, those exposed to Conventional Strategy performed better than those exposed to the PBL Sb. To this end, all the three pairs of groups contributed to the significant effect of treatment on achievement. Therefore Ho1 is rejected.

Hypothesis Three Ho₂: There is no significant difference in the mean achievement scores of male and female students exposed to the two treatments and conventional method of teaching.

Table 1 revealed that there is no significant interaction effect of treatment and gender on students achievement in algebra ($F_{(3,109)} = .120; p > .05$). Therefore, Ho2 is accepted. However, to compare the level of students' achievement according to gender. Table 4 showed the comparison.

From Table 4 female students obtained slightly higher achievement mean score (= 15.63) than their male counterpart (= 15.41) but the difference was not significant.

Table 4: Comparison of male and female academic performance

	Gender	N	Mean	Std. error mean
ACAP	Male	44	15.4091	.37839
	Female	65	15.6308	.38951
	Female	65	15.6308	.38951

a. Evaluated at covariance appeared in the model: PRETEST = 5.44

b. Based on modified population marginal mean

DISCUSSION

The result indicated a significant main effect of treatment on students' achievement in the test. This became evident with the outcome of post-test in the experimental class after the intervention the teacher incorporated in his teaching approaches the use of PBL. Students were engaged in the new innovative teaching on the use of PBL, which gave room for learners to participate actively in class and appreciate the new idea. Therefore, there is need to introduce instructional intervention strategies for algebra improvement. Samuelsson (2008) corroborated this finding. It showed that students exposed to the problem-based learning strategy (PBL Sa) outperformed their counterpart in the (PBL Sb) and conventional groups. The finding is in line with that of Kenny (2012) that the learning strat-

egy in algebra is a major cog in the wheel of progress if it is not appropriate. However, the result is contrary to the findings of Smits et al. (2002) that PBL having positive effect is weak and that the outcome of its effectiveness compared to conventional method showed mixed results

Again, students exposed to the second treatment (PBL Sb) equally performed better than their counterpart in the conventional group, this is an indication of the weakness of using conventional method in teaching algebra especially with language being embedded in algebra, therefore, problem-based learning strategy should be an alternative route to teaching of algebra and should be used to replace the conventional method. However, with the intervention of problem-based learning as treatment for the way in which the problem can be addressed, the experimental group in this study were able to perform better after the post-test treatment.

The findings revealed that students' achievement will be greatly improved if they were sequentially taken in algebra through problem-based learning strategies because it is the process of working towards the understanding and resolution of a problem. (Barrow and Tambly 1980) PBL also allows for self-reliance as students become less dependent on the teachers. However, the result is contrary.

The findings also showed that there is no significant interaction effect of treatment and gender on grade 9 students' academic achievement in algebra thereby suggesting that gender does determine grade 9 students' academic achievement in algebra. This study corroborated the findings of Kliapproth et al. (2013) and Blossfeld et al. (2009) that academic achievement shows no gender difference. While Elsequest et al. (2010) and Lindberg et al. (2008) reported that boys have higher competence in mathematics than girls that female have lower self confidence in mathematics all the findings are contrary to this study.

CONCLUSION

This study explored the issue of PBL and gender. This should provide an insight into some of the problems in the mathematics classroom. The idea generated should contribute to national and international academic debates on the teaching and learning of mathematics.

RECOMMENDATIONS

The following recommendations were made on the basis of the findings of the study:

- ♦ This study proved that problem solving is a more effective method of instruction for teaching and learning mathematics especially algebra as compared to conventional (lecture) method of teaching. Therefore the teachers of mathematics should use problem solving method to improve the academic achievements of the students.
- ♦ Government should transform the textbooks of mathematics in problem based learning form because the traditional textbooks do not meet the criteria of problem solving approach.
- ♦ Extensive training program, seminars and workshops should be organized for mathematics teachers in secondary schools to employ problem solving method in the classrooms.
- ♦ Mathematics teachers should be trained on the use of problem based learning approach.

Based on the findings of this study teacher should be encouraged to pay more attention to the training of students in the development of reasoning skills as well as problem solving skills.

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