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Gender Differences in Mathematics Achievement and Retention Scores: A Case of Problem-Based Learning Method

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Abstract

This study was undertaken to assess gender differences in mathematics achievement and retention by using Problem-Based Learning (PBL). The design of the study was pre–posttest quasi-experimental. Four hundred and twenty eight senior secondary one (SS I) students using multistage sampling from ten grant-aided and government schools were involved in the study. Two hundred and sixty one male students and one hundred and sixty seven female students were taught algebra using PBL method of instruction. Algebra Achievement Test (AAT) constructed by the researchers was the main instrument used for data collection. Two hypotheses were raised for the study and tested using t-test at .05 level of significance. The study revealed that male and female students taught algebra using PBL did not significantly differ in achievement and retention scores, thereby revealing that male and female students are capable of competing and collaborating in mathematics. In addition, this finding showed that performance is a function of orientation, not gender. The studies recommend the use of PBL by mathematics teachers to overcome the male image of mathematics and enhance students' (male and female) achievement and retention.

Key words: Problem-based learning; Gender; Achievement; Retention; Mathematics; Algebra

Introduction

Many people do not know that mathematics is more than what is taught at school, and different from what most people think it is. The students have a wrong image of mathematics- that mathematics is many formulae to learn, without knowing why; mathematics is a never changing, not lively subject; something for nerds and loners, and thus, maybe, also something for boys and men and not for girls and women. Gender is a set of characteristics distinguishing between male and female, particularly in the cases of men and women. Depending on the context, the discriminating characteristics vary from sex to social role to gender identity. Gender differences in mathematics achievement and ability has remained a source of concern as scientists seek to address the under-representation of women at the highest levels of mathematics, physical sciences and engineering (Asante, 2010).

Literature Review

Literature about gender and academic performance in mathematics exist with different views and findings. Studies conducted in countries of the North have shown that boys performed better than girls in mathematics (Fennema, 2000; Kaiser-Messmer, 1994; Muthukrishna, 2010). Asante (2010) cited studies (Fox, Brody & Tobin, 1980; Hedges & Nowell, 1995; Peterson & Fennema, 1985; Randhawa, 1994) showing that boys generally achieved higher than girls on standardized math tests. However, an interesting body of international literature suggests that female students perform better than male students (Arnot, David & Weiner 1999; Hydea & Mertzb, 2009). A large scale study in the U.S.A. by Hydea & Mertzb (2009) revealed that girls have reached parity with boys in mathematics performance, including at high school where a gap existed in earlier decades. They affirmed that girls are doing better than boys even for tasks that require complex problem solving.

The Second Southern and Eastern Africa Consortium for Monitoring Education Quality (SACMEQ) Survey (2000-2002) by International Institute for Educational Planning (HEP)-UNESCO (2004) shows no significant gender differences among students in South Africa. The same study shows that girls scored significantly higher than boys only in Seychelles. On the other hand, in Tanzania, Kenya, Mozambique, Zanzibar and Malawi, boys scored significantly higher than girls did. In the other school systems, including the ones in South Africa, the differences were not significant.

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An alternate body of research has shown that the gender differences in mathematical performance are diminishing (Frost, Hyde, & Fennema, 1994; Hyde, Fennema & Lamon, 1990). Perie, Moran, and Lutkus (2005) found that the gap has been narrowing in the United States of America. Research in Australia indicates that gender differences in mathematics achievement are reducing and shifting (Forgasz, Leder, & Vale, 2000). Vale (2009) found that many studies conducted between 2000 and 2004 in Australasia showed no significant differences in achievement in mathematics between male and female students, though males were more likely to obtain higher mean scores.

Internationally, researchers have undertaken studies in various contexts to examine factors that influence gendered achievement in mathematics. Many of such studies have focused on factors related to differences in the performance of boys and girls in mathematics (Abiam & Odok, 2006; Mahlomaholo & Sematle, 2005; Opolot-Okurut, 2005; Zhu, 2007). Feminist researchers have tried to make meaning of the experiences of girls and boys in the mathematics classrooms, and to interpret male-female power relations (Jungwirth, 1991; Waiden & Walkerdine, 1985). Their findings revealed that girls are often marginalized and given subordinate status in the mathematics class. The findings suggest that perceptions of teachers are that girls' performances in mathematics are dependent on rote learning, hard work and perseverance rather than natural talent, flexibility and risk taking which are the learning styles of boys.

Gender differences in mathematics teaching, learning and achievement have also been explained on the basis of gender differences in cognition and brain lateralization (Fennema & Leder, 1990). In a similar argument, Paechter (1998) argues that male and female students do experience the world in different ways. Firstly, they are differently positioned in society. The second is their different learning styles and how they perceive and process reality. These researchers emphasize that most mathematics classroom discourse is organized to accommodate male learning patterns, hence their high achievement in mathematics. Mutemeri and Mygweni (2005) argue that the idea that mathematics is for boys may result in low motivation in girls and could widen the gender gap in mathematics achievement in favor of boys.

Boaler (1997) is of the view that the different learning goals of girls and boys leave girls at a disadvantage in competitive environments. Boys and girls preferred a mathematics curriculum that enabled them to work at their own pace as their reasoning was different. Girls value experiences that allow them to think and develop their own ideas, as their aim is to gain understanding. Boys, on the other hand, emphasize speed and accuracy and see these as indicators of success. Boys are able to function well in a competitive environment of textbook based mathematics learning.

Other important factors that emerge in research on gender and mathematics are cultural, family influences, socio-economic status of parents, as well as cultural and traditional influences (Kaino & Salani, 2004). Asante (2010) citing Collins, Kenway and McLeod (2000) argued that schools establish symbolic oppositions between male and female students through gendering of knowledge and defining of certain subjects as masculine. In contrast, female students are conditioned in the society to believe that mathematics is a male subject, and it is acceptable for them to drop it. Studies done in Botswana by Finn (1980), Duncan (1989), and Marope (1992) cited in Kaino (2001) indicated that cultural expectations of society could result in differences in performance between girls and boys in mathematics. In Nigeria, it has been argued that nurture entrenches male dominance over the female gender (Bassey, Joshua & Asim, 2007).

The above review suggests that many factors may be associated with the gender gap, including issues such as classroom interactions, students' attitudes, students' interest and self-esteem, teachers' gendered attitudes, curricular materials, beliefs, social and cultural norms. These differences put together have implications for the kind of instructional procedures that are to be adopted for setting up an appropriate teaching and learning environment for mathematics instruction that is suitable for both genders. The choice of gender as variable for this study is predicated on the current world trend and research emphasis on gender issues. The millennium declaration of September 2000 (United Nations, 2000) has as its goals the promotion of gender equity, the empowerment of women and the elimination of gender inequality in basic and secondary education and at all levels by 2015. Mathematics is a science subject and some gender-based science researchers (Howes, 2002; Sinnes, 2006) have reported that females in principle will produce exactly the same scientific knowledge as males, if sufficient rigor is undertaken in scientific inquiry. Though the issue of gender inequality in science, technology, and mathematics education (STME) is global, it is believed that bridging gender gap is one major way of achieving egalitarianism and enhancing human development. There is need therefore to give boys and girls exactly the same opportunities and challenges. It is in the light of the above that this study used problem-based learning (PBL) to explore the issue of a gender difference in academic achievement and retention at secondary school level in Benue State of Nigeria.

Problem-Based Learning (PBL)

PBL is a term used for a range of pedagogical approaches that encourage students to learn through the structured exploration of a research problem. It is an active learning strategy which enables the student to become aware of and determine his/her problem solving ability and learning needs, to be able to make knowledge operative and to perform group works "in the face of real life problems" (Akınoğlu & Tandoğan 2007). The PBL method requires students to become responsible for their own learning. The PBL teacher is a facilitator of student learning, and his/her interventions diminish as students progressively take on responsibility for their own learning processes. This method is characteristically carried out in small, facilitated groups and takes advantage of the social aspect of learning through discussion, problem solving, and study with peers (Hmelo-Silver, 2004). The facilitator guides students in the learning process, pushing them to think deeply, and models the kinds of questions that students need to be asking themselves, thus forming a cognitive apprenticeship.

In PBL, class activities are constructed around a problem or problems. The instructor no long lectures. Instead, when the instructor integrates PBL into the course, students are empowered to take a responsible role in their learning. The instructor is not the authoritative source of information and knowledge. Students have to take the initiatives to inquire and learn; and the instructor only guide, probe and support students' initiatives. What students learn during their self-directed learning is applied back to the problem with re-analysis and resolution. Problems are used as a stimulus for students to start the learning process. The students reason through the problem and find out what they already knew and what they should know in order to solve the problem. It is through this active and reflective thinking process that students become responsible for their own learning. Through the application of their knowledge to the problem, the students test and integrate what they are learning. In general, PBL aims to motivate students to participate in the learning process and to help foster problem solving skills.

The Key Research Question

Is there a gender gap in mathematics achievement and retention? The study tested the following hypotheses at .05 level of significance.

1. Male and female students taught algebra using problem-based learning (PBL) approach do not differ significantly in their achievement mean scores.
2. Male and female students taught algebra using problem-based learning (PBL) approach do not differ significantly in their retention mean scores.

Method

The pre-test and post-test quasi-experimental design was adopted for the study. The sample consists of 261 male and 167 female senior secondary school one (SS1) students in 10 secondary schools across education zone B of Benue State of Nigeria. The students and schools were selected through multistage sampling. The students were taught algebra by using problem-based learning method. Algebra Achievement Test (SAAT), constructed by the researcher was used to collect data. AAT which was validated by experts in mathematics and science education has 25 multiple choices (each with four options) and 7 essay items constructed from SS1 mathematics curriculum and was scored out of 100 marks. Using Kuder–Richardson (KR – 21) formula, the internal consistency of the multiple-choice items was found to be 0.80. Similarly, an inter-rater index of 0.863 was obtained to test the internal consistency of the essay items using Kendall's coefficient of concordance. The inter rater scores were further tested for significance of the mean scores difference using paired-samples t-test analysis. This indicated no significant difference between rater 1 (M=48.87, SD=13.09) and rater 2 (M=48.66, SD=12.957), t (60)=1.82, p=.074.

Problem-based learning lessons based on the SS2 mathematics curriculum were with topics in change of subject formulae, substitution in formulae, direct, inverse, joint and partial variations, factorization, formation and word problems in quadratic equations were used. Mathematics teachers of three years' experience and above were trained by the researcher to facilitate the problem-based learning. The training exercise was based on the purpose of the study, the topics to be taught, the use of the lesson plans, the use of the AAT as well as general conduct of the study. It was ensured that all the teachers used equal length of time (four weeks) to facilitate learning of the topics. Throughout the exercise, the researcher went round to supervise and ensure smooth learning in all classes. Independent t-test was used to test the hypotheses at 0.05 level of significance.

Results

As seen from Table 1, the post-test achievement mean score of the female students is 47.03 with standard deviation of 8.91, while that of the male is 45.62 with standard deviation of 9.68. The difference between the pre-test and post-test mean scores of the male students is 28.30 and that of the female students is 28.78. The difference between post-test mean scores of male and female students is 1.41. Although this difference is in favor of female students, the difference between the pre-test and post-test of those is not quite much. The implication is that there is not much difference between the achievement scores of male and female students.

Table 1. Achievement mean scores, standard deviations and t-test value of subjects for gender in PBL

Gender	**N**	**Pre-Test**		**Post-test**		**Mean**	**t**	**df**	**p**
		$\overline{X}$	δ	$\overline{X}$	δ				
Female	167	18.25	3.46	47.03	8.91	28.78			
							1.553	426	0.121
Male	261	17.32	4.34	45.62	9.68	28.30			
Mean Diff.		0.93		1.41					

Gender factor is not significant. This is evident from Table 1 with t(426)=1.553, p=.121. The implication is that there is no significant difference between the achievement mean scores of male and female students taught algebra using PBL strategy. Thus, the hypothesis of no significant difference is not rejected.

As shown in Table 2, the female students had a retention mean score of 50.72 with standard deviation of 8.25, while the male students had 50.29 with standard deviation scores of 9.68. The difference between the retention mean scores and post-test of the female students is 3.69, while the difference for male students is 4.67. The difference between the retention mean scores of the male and female students is 0.43 and it is in favor of the female students. This shows that the female students retained knowledge just a little more than male students.

Table 2. Retention mean scores, standard deviations and t-test value of subjects for gender in PBL

Gender	**N**	**Retention-test**		**Post-test**		**Mean**	**t**	**df**	**p**
		$\overline{X}$	δ	$\overline{X}$	δ				
Female	167	47.03	8.91	50.72	8.25	3.69			
							1.553	426	0.121
Male	261	45.62	9.68	50.29	9.68	4.67			
Mean Diff.		1.41		0.43					

The t-ratio for gender factor as shown in Table 2 is 0.508 which is not significant (p= .611). This indicates that there is no significant difference between the retention mean scores of male and female students taught algebra using PBL. Thus, the hypothesis of no significant difference between the retention mean scores of male and female students is not rejected.

Discussion and Implications

The study found that female students outperformed their male counterparts (both post-test and retention), though the difference is not statistically significant. The findings of this study is consistent with the one in the United States of America by Hydea and Mertzb (2009) which says girls have reached parity with boys in mathematics. This is an indication that girls can do better than boys in tasks that require complex problems, such as PBL, which the present study used. This finding is also in agreement with the narrow gender gap in achievement in U.S.A (Perie, Moran & Luktus, 2005) and in Australia (Forgasz, Leder & Vale, 2000). This is however at variance with Ogunkunle (2007), in Nigeria, where part of the findings established significant difference in favor of males and another part in favor of the females. It also disagrees with earlier studies of Fennema (2000) and Asante (2010) which showed significant gender differences.

The reason for the equal performance of male and female students may not be unconnected with the fact that both see themselves as equals and capable of competing and collaborating in classroom activities. This affirmation is opposed to the views of Fennema and Leder (1990) that gender difference in mathematics is based

on gender differences in cognition and brain lateralization. The approach of PBL to learning and teaching showed that performance in mathematics is a function of orientation rather than gender.

Conclusion and Recommendations

It is evident from this study that students' achievement and retention in algebra are not dependent on gender, but function of method. Both sexes are capable of competing and collaborating in classroom activities. It must be stressed that this was a case study. Further research would need to be undertaken to examine the trends that emerged in this study in greater depth. A sounder approach would be to examine situational factors that may be influencing gender differences, for example, classroom cultures, teacher attitudes, parental and teacher attitudes and others.

The study suggests that there is a need to give boys and girls exactly the same opportunities and challenges in the mathematics class. PBL should therefore be used as an additional teaching strategy to other traditional methods of teaching mathematics. Male and female students need to compete, collaborate and gain from one another in mathematics teaching and learning. Thus, mathematics teachers are enjoined to use PBL as an instructional approach that will foster greater healthy rivalry in mathematics instruction.

Teacher professional development programs should make more concerted efforts to advise teachers about the ways in which to approach the teaching of mathematics to avoid disadvantaging particular groups of girls or boys. Mathematics teaching and evaluation strategies should be gender bias-free. This way, males and females will tend to see themselves as equals capable of competing and collaborating in classroom activities. Male and female teachers should work jointly with boys and girls and adopt a more socially just and inclusive approach to creating equal opportunities for all students.

If this method, proposed by this study, is adopted in mathematics teaching and learning, it will boost the performance of students in skills acquisition, problem solving ability and development of the right type of attitude toward mathematics as a subject. Guidance and counselling machineries in the school should be energized to encourage more female students' active participation in effective mathematics learning. Female students should be informed that mathematics could be studied and passed just like any other subjects and that the subject is an essential tool, a prerequisite for further education in a host of vocations.

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