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Increasing female participation in advanced level mathematics: A perspective from students and teachers in Zimbabwe

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ABSTRACT

The non-participation of girls in advanced mathematics has become a concern over a number of years. This study sought to find ways of increasing female participation in Mathematics at advanced level based on an understanding of the constraining factors to female participation in mathematics. The descriptive survey research design was adopted in this study in which questionnaires, interviews and observations were used as data collection instruments. Questionnaires were completed by ninety nine female students (sixty 'O' levels and thirty nine 'A' levels) and nine mathematics teachers. Interviews were conducted with three mathematics teachers, 10 'A' level female students who were not taking mathematics and twenty 'O' level female students. Classroom observations were also conducted in six Mathematics lessons. Each lesson lasted for forty minutes. The results of the study have revealed the following factors as limiting female participation in mathematics: perceived difficulty of the subject, lack of self confidence, anxiety, negative teacher attitudes, negative stereotypes about girl's math abilities, cultural belief that mathematics is a male domain and lack of knowledge about mathematics careers entail. The research findings also revealed that to promote female participation in advanced level mathematics, parents and teachers should: enhance girls' confidence about their math abilities; create a conducive classroom climate that enhances interest and curiosity in mathematics; expose girls to female role models who have succeeded in mathematics and provide information advice and guidance on mathematics careers. The study recommends that gender and cultural biases attached to mathematics should be de-emphasized at home and school and that mathematics teachers should adopt some of the more recent reform-based instructional strategies that actively engage students while the Government should give incentives to girls who study mathematics at higher levels in order to encourage young females to pursue mathematical careers.

Keywords: Mathematics, female students, anxiety, gender stereotypes, career guidance.

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INTRODUCTION

Science, mathematics and technology play a critical role in the development of national economies. All facets of human life have been permeated by mathematics as a subject (Alutu and Eraikhuemen, 2004). As observed by Aguele and Agwagah (2007), there can be no science without mathematics, consequently there can be no technology without science hence there can be no modern society without technology. Thus, mathematics is the cornerstone of national development without which no nation can excel scientifically and technologically. As a result, nations that aspire to develop scientifically and technologically should give great attention to the teaching of mathematics at all the levels of education.

Wadesango et al. (2012) observe that mathematics is a tool which forms the basis for entry into specialized careers like science, engineering, economics and

Table 1. Enrolments of students taking Mathematics at 'A' level in Chegutu Urban High Schools from 2011- 2012.

School	Year	Male students	Female students	Total enrolment
A	2012	11	1	12
	2011	7	0	7
B	2012	8	0	8
	2011	10	1	11
C	2012	6	2	8
	2011	9	1	10

computing, among others. Realizing the importance of Science and Technological Education in national development, the Ministry of Education, Sports, Arts and Culture has made the teaching of science and mathematics compulsory throughout the education system up to Ordinary Level. The rationale behind this policy is that all learners who will have gone through our basic education system, which goes up to O-Level should have acquired a base to enable them appreciate the scientific environment in which various innovations and training are taking place.

Despite having such a policy, girls do opt out of mathematics in high school thus restricting their educational and career options (Herzig, 2004). Mpuchane (2011) noted that low participation of women in Science, Technology, Engineering and Mathematics (STEM) activities is a challenge not only unique to developing nations but to developed nations as well. As observed by Watt (2007), girls opt out of science, technology, engineering, and mathematics at higher rates than boys. Enrolments in Advanced level mathematics in Chegutu Urban High Schools confirms that indeed there is low participation of girls in mathematics at 'A' level as evidenced by preliminary investigation statistics shown in Table 1.

Enrolment statistics at one local University level is further evidence of low participation of females in mathematics in Zimbabwe (Table 2).

This observation of low participation of females in mathematics has led to investigations into the possible causes of this disparity. A number of factors have been identified as causes of this gender gap. Gender differences in interests, abilities, and personality characteristics have been implicated as reasons for this disparity. Guiso et al. (2008) have established a link between the gender math gap and society-level female socialization data. Nosek et al. (2009) on the other hand have shown that nation-level implicit gender stereotypes have an influence on nation-level gender differences in eighth-grade science and mathematics achievement. These implicit gender stereotypes may communicate to girls that boys are innately better than girls at math and science. Kane and Mertz (2012) further illustrate that

Table 2. Enrolments of B.Sc Mathematics students at a local University from 2009 - 2012.

Year	Male students	Female students	Total enrolment
2012	7	0	7
2011	2	0	2
2010	8	1	9
2009	19	4	23
Total	36	5	41

societal influence of gender stereotypes and bias against women in science is related to gender differences in aptitude. Steele et al. (2002) further note that women and girls with a belief that these stereotypes are true may experience increased concerns that they will be judged on their gender or be held to a different set of expectations compared to males and, in testing situations, confirm the negative stereotype both in their own eyes and in the eyes of others: a phenomenon, typically referred to as "stereotype threat".

Attitudinal differences have also been observed to explain the gender gaps in mathematics observed in post-secondary education. Watt (2006) has noted that high self esteem, self confidence and valuing of mathematics is highly linked to mathematics course enrollment and career planning. Watt (2006) also found that men were more likely than women to plan to take higher-level mathematics subjects and to plan mathematics careers. Thus, early gender differences in values and self-image play into gender differences in course-taking and ultimately, in learning and career planning. The ways children are socialized also contribute towards their attitudes in Mathematics. Mawere et al. (2011) who propound that parents encourage boys to be more physically active and to learn how to address their own problems while girls are brought up to be obedient, tender and caring. Asimeng-Boahene (2007) further asserts that boys and girls in Africa are brought up under different environmental settings. As these children grow, boys tend to be self-

confident and independent while girls are seen to be emotional, subservient and affectionate. This kind of grooming makes it easier for boys than girls to adapt to the important learning tools in Science and Mathematics classrooms which include discussion, problem solving, and laboratory exercises. This thus contributes to gender disequilibrium in Mathematics and Science education.

Attitudes and expectations of parents and teachers also limit female participation in mathematics. Asimeng-Boahene (2007) asserts that generally, parents' expectations have been a disincentive for Mathematics and Science education for girls. Girls tend to be given time consuming domestic responsibilities, which leave them with not much time for private study. Parents thus contribute to the girls' low interest in Mathematics and Sciences in that they give girls more domestic responsibilities than boys, and therefore less study time. This affects the girl child and causes them to lose interest in their studies especially in mathematics because of the challenging nature of the subject. According to Gutbezahl (1995) parents' expectations for girls in mathematics have an enormous impact on girls' performance in mathematics. Parents tend to have lower expectations for girls than boys and this attribute to their daughter's success in mathematics more to effort than ability. What the parents believe about mathematics can influence their child's beliefs. For instance if parents have mathematical anxiety, this will have a direct impact on the comfort level of their children toward mathematics, and also towards a mathematics career. Stereotypes by parents about careers affect girls' perception on the usefulness of mathematics.

Gutbezahl (1995) further asserts that girls tend to internalize parents' negative expectations, which become self-fulfilling prophecies. If girls believe that they cannot achieve in mathematics, then automatically they will not achieve. The parents' negative attitudes and expectations therefore contribute to the low participation of girls in mathematics as they would feel less confident in themselves. Female Education in Mathematics and Science in Africa (FEMSA) studies that were conducted in eight African countries by O'Connor (2000) found teachers' attitudes and instructional approaches as contributing immensely to the gender gap in mathematics. O'Connor (2000) further reveals that poor expectations for girls' performance on the part of teachers leads to the kind of science and mathematics classroom dynamics, where girls are treated very differently from boys. The study reveals that teachers do not encourage girls during mathematics and science lessons, and in fact, at times, actively discourage them. Some teachers direct more challenging, high order thinking questions to boys, while only simple recall type of questions to girls. This reinforces and confirms in the minds of both boys and girls that mathematics and science subjects are for boys only. Boys therefore, over time, develop at these subjects which they consider a male domain. Therefore, girls withdraw from any active participation during science and mathematics for fear of being taunted by their male classmates.

Mathematics anxiety according to Karimi and Venkatesan (2009) is the outcome of low self-esteem and the fear of failure. Mathematical anxiety causes problems for processing the incoming information as well as the previously learned information for problem solving. Mathematical anxiety is one of the most notable of psychological problems that stands in the girls' way. Garry (2005) cited in Karimi and Venkatesan (2009) asserts that many students who suffer from mathematics anxiety have little confidence in their ability to do mathematics and tend to avoid mathematics courses. This has greatly limited their career choice options. A research done by Paton (2012) indicates that mathematics anxiety is one of the reasons why very few students study mathematics at 'A' level and why the number of students taking mathematics at University level is generally low. He further argues that because mathematics is traditionally viewed as a male domain, females may be socialized to think of themselves as mathematically incompetent. This may lead females to avoid mathematics and when females do participate in mathematical activities they may experience more anxiety than males.

Paton (2012) who propounds that a number of mathematical anxiety researchers suggest that the basic nature of the way we teach mathematics and the preparation of teachers of mathematics are some of the underlying causes of mathematical anxiety. It has also been suggested by Burton (2001) that imposed learning styles, syllabi and examination structures can account for an increase in girls' mathematics anxiety and result in a consequent lack of confidence. The above statements clearly indicate that the activities in the mathematics classroom matter a lot as they may affect the learners' interest in the subject. Much of this anxiety happens in the classroom due to the teachers' lack of consideration of different learning styles for students. Generally, it appears that girls are reported to be more anxious during mathematics than boys. Mathematical anxiety is therefore one of the major factors that limit the participation of girls in mathematics.

Gorard et al. (2012) have found that secondary students' prior attainment in mathematics significantly predicted their interest in mathematics. Thus, interest in mathematics appears to be a potentially important factor for participation in non-compulsory advanced mathematics. Matthews and Pepper (2007) found that students' perceptions of the usefulness of mathematics for university and a career was a crucial factor in their choice of 'A' level mathematics. However, students' perceptions of their own competence were also an important factor, particularly for female students. This was problematic because female students were more likely to underestimate their mathematical competence

than male students and therefore less likely to pursue further studies in mathematics.

The non-participation of girls in mathematics has been a concern over a number of decades as a result a number of research studies have been conducted to look at possible causes for this. However, work in this area in the Zimbabwean context seems to be limited. Based on empirical findings from literature of the constraining factors to female participation in mathematics, it is the major thrust of this study to propose solutions on what can be done to increase female participation in mathematics.

Research questions

The following questions were posed to guide the study:

1. What factors limit female participation in mathematics at Advanced level in Zimbabwe?
2. How can female participation in Advanced level mathematics be increased?

METHODOLOGY

Research design

The study used the descriptive survey research design. Leedy (1980) observes that the descriptive survey design involves looking at phenomena of the moment with intense accuracy. The design implies the assumption that whatever is observed at any one time is normal and under the same conditions would conceivably be observed at any one time in the future. The descriptive survey design survey entails studying a limited number of cases with the view of drawing up conclusions that cover the generality of the whole group under review. Thus, the descriptive survey in this case was used to find ways in which female participation in Advanced level mathematics can be increased.

Population and sample

The population for this study consisted of one hundred 'A' level female students (30 doing 'A' level mathematics and 70 not doing mathematics), two hundred and seven (207) 'O' level female students and nineteen (19) mathematics teachers from high schools in Chegutu urban district. The sample of the study comprised of thirty nine A level female students (18 doing 'A' level mathematics and 21 not doing mathematics), sixty 'O' level female students and nine mathematics teacher who were chosen by a simple random sampling technique.

Data collection

The data for this study was collected through the administration of a student questionnaire, focus group discussions with students, structured interviews with mathematics teachers and classroom observations. The questionnaires consisted of both open-ended and close-ended questions. Section A was a 8 item Likert-type of questionnaire factors that limit female participation in mathematics. Respondents were free to agree or disagree with any statement on the questionnaire on a continuum ranging from Strongly Agree to Strongly Disagree as follows: Strongly Agree 4 points; Agree 3 points; Disagree 2 points; Strongly Disagree 1 point. Prior to the main data collection, a pilot study that involved one hundred 'O' level and fifty 'A' level female students was conducted in another district to ensure suitability and readability of the questionnaire. Based on the pilot study results, modifications were made. After this, the instrument was distributed among the participants involved in the present study. Section B asked participants about how to increase female participation in mathematics. Classroom observations were conducted to gain an insight into the interactions in the mathematics classrooms.

Data analysis

The data collected were analyzed using descriptive statistics: simple percentages and numerical values. For data analysis purposes, the scales Strongly Agree and Agree were merged into Agree while the Strongly Disagree and Disagree were merged into Disagree. Open ended questions were analyzed by identifying emerging themes.

RESULTS AND DISCUSSION

What factors limit female participation in mathematics at Advanced level in Zimbabwe?

This research questions required respondents to indicate the extent to which they felt each of the following factors limit female participation in mathematics. Data was analyzed by merging the agree (A) and the strongly agree (SA) responses and treating them as agree responses. On the same note, the disagree (D) and the strongly disagree (SD) responses were also merged and reported as disagree responses. The results are shown in Table 3.

The data from Table 3 show that 96% of the students agree that their perception of mathematics as a difficult subject limits their participation at Advanced level. Focus group discussions with 'O' level female students and 'A' level female students not doing mathematics further confirmed that girls surely perceive mathematics to be difficult. Mathematics teachers who were also interviewed indicated that girls consider mathematics to be a difficult subject and this affects their participation in the subject. This is consistent with findings of Allexshaht-Snider and Hart (2001) and Saraswathi (2003) who noted that some pupils harbor the belief that mathematics is generally difficult and unattainable to many learners. Focus group discussions with 'A' level female student not doing mathematics further revealed that they could not proceed with mathematics to 'A' level because they believe that mathematics is a difficult and taxing subject which can only be attained by the intellectually endowed. Some of them indicated that they had failed it at 'O' level hence they could not participate further in mathematics at 'A' level. Similar sentiments are also echoed by Brown et al. (2008) who explored reasons why students opt not to study mathematics at 'A' level and reported perceived difficulty as a major reason why students do not continue

Table 3. Factors limiting female participation in mathematics.

Item	Statement	SA (%)	A (%)	D (%)	SD (%)	Total
1	Perception that mathematics is a difficult subject	89	7	2	2	100
2	Perception of teacher attitude towards girls	91	3	4	2	100
3	Mathematics as male domain	50	5	42	3	100
4	Mathematics anxiety	88	7	3	2	100
5	Lack of personal confidence in mathematics	96	4	0	0	100
6	Lack of knowledge on usefulness of mathematics	97	0	3	0	100
7	Lack of exposure to women role models in mathematics	95	3	2	0	100
8	Parental and cultural factors	91	6	2	1	100

with mathematics.

The attitudes and approaches of teachers also play a major part in the participation of girls in mathematics. The majority of the girls blamed teachers for causing them to lose interest in the subject. Some of the girls indicated that teachers only concentrate on those pupils who are intelligent, especially the boys. From Table 3, about 94% of the girls confirmed that their teachers' attitudes impacted negatively on their interest and participation in the subject. However, the teachers do not agree that their attitudes contribute to the students' negative attitude in the subject. O'Connor (2000) observed that it is interesting to note that teachers generally see themselves as blame-free for this situation and seem unwilling to find any fault with their own teaching approaches. From the classroom observations, the researchers noted in one class that the teacher was mainly concentrating on the boys who seemed to be quite aware of the topic that was being learnt. Some of the girls ended up not paying attention during the lesson. This is in consonant with Asimeng-Boahene (2007), who notes that teachers tend to have poor expectations for girls' performance in mathematics, and they in turn treat them differently from their male counterparts.

The data in Table 3 indicates that 55% of the girls view mathematics as a male domain which thus limits their participation in the subject while 45% do not see mathematics as a male domain. About 65% of the interviewed teachers were also of the view that that Mathematics is perceived as a man's subject by most females as a result they do not participate in mathematics at higher levels hence professions requiring higher level knowledge of mathematics are dominated by males. The findings are consistent with Farooq and Shah (2008), DeHaven and Wiest (2003), and Watt (2007) who observed that female student's participation in mathematics is influenced by a society that tends to view mathematics as a male domain resulting in the perpetuation of the idea that males are naturally more mathematically gifted than females. Paton (2012) further notes that because mathematics is traditionally viewed as a male domain, females may be socialized to think of themselves as mathematically incompetent and therefore females may avoid mathematics.

Over 94% of the female students believe that mathematics anxiety and lack of personal confidence in mathematics limits their participation in mathematics. Focus group discussions with the female students indicated that they felt anxious during mathematics lessons. The findings reveal that the females are mathematics anxious and such anxiety accounts for their limited participation in 'A' level mathematics. The findings are consistent with those of Jones (2008) who found girls in Wales more mathematics anxious than boys. Other studies by Brown et al. (2008) have also found lack of confidence as an important reason for females not continuing with mathematics. The findings of this study are consistent with Matthews and Pepper (2007) who found that students' perceptions of their own competence was also an important factor, particularly for female students who are more likely to underestimate their mathematical competence than male students and therefore less likely to pursue further studies in mathematics. The findings are in agreement with those of Pajares (2005) who observed that girls report lower confidence than boys do in their math and science abilities.

A student's perception of the usefulness of a subject now and in the future impacts their decision making and their participation in that subject. If students do not believe that mathematics is useful in their everyday lives then they do not see its utility in their lives. Ninety seven (97) percent of the students agreed that lack of knowledge on the usefulness of mathematics in science related careers limits female participation in mathematics. A small number of students said that they found mathematics to be a dull subject and they could not see the use of mathematics in their future life, for their course or career plans; instead other subjects were deemed to hold more importance to them. The findings are consistent with those of Anderson and Gilbride (2005) who discovered that knowledge about a profession increases interest in that profession thus knowledge is a key determinant when contemplating career goals.

Role models are very critical in enhancing confidence, performance and elevating aspirations of the female learners. The majority of the learners (98%) agreed that lack of exposure to women role models in mathematics is

one cause of low participation of female in mathematics. During focus group discussion, the students revealed that they are not given adequate information about possible careers that require Advanced level mathematics and that they are not being exposed to women role models who have been successful in mathematics careers. The students noted that parents and teachers can act as role models by providing support, motivation and sharing their love and interest for the mathematics. In this way, participation in mathematics can be increased. The findings are in agreement with those of Jacobs et al. (2005) who noted the role of parents in motivating their daughters in participating in mathematics. The findings are consistent with Tomas and O'Grady (2009) who found young women to have fewer role models who encourage them to take mathematics and science courses and to consider engineering and technology careers.

Parents are the most influential people in a learner's life. Their beliefs, expectations, aspirations, support as well as cultural based factors have an impact on participation in mathematics. The majority of the students agree that parents as well as society influence participation in mathematics. The learners believe that if their parents show confidence in their math abilities this goes a long way in improving their attitude towards the subject. The participants in this study bemoaned lack of parental support and encouragement at home. Parental encouragement and support will influence enrolment and career choices in mathematics. The findings are consistent with Jacobs et al. (2005). Teacher who were interviewed also indicated that girls are socialized at an early age to be care-givers, nurturers and people-oriented. This socialization then shapes subsequent academic interests and career aspirations. Hence they choose careers health sciences and social sciences as compared to technical fields. Studies by Andreescu et al. (2008) have also identified the role of cultural factors in explaining gender gaps in mathematics and science fields.

How can female participation in advanced level mathematics be increased?

The teachers and students suggested a number of strategies that can be employed to increase female participation in Advanced level mathematics. These are discussed below:

Provision of information, advice and guidance

Student participation in mathematics is largely hinged on the encouragement students get from their parents and teachers. Parents and teachers should therefore make students understand the value of mathematics in their lives as well as career prospects. Both parents and teachers should provide information to students to raise awareness of the personal benefits of choosing mathematics as well utilizing initiatives such as career guidance days and open days (from institutions of higher learning) to guide students in their education and career choices. Hodgen et al. (2013) on the other hand lament limited information, advice and guidance available to students and suggest that, making students aware of the personal rewards and benefits of advanced mathematics qualifications can lead to increased participation. Obi et al. (2012) on the same note indicate that the importance of guidance and counseling programmes in secondary schools, include bringing to the students an increased understanding of the educational, vocational and social information needed to make wise career choices.

Exposing girls to female role models who have succeeded in math and science

Strong female role models are critical to helping young women discover their passion for mathematics and boosting their confidence in their academic abilities. Mathematics teachers as wells secondary schools are encouraged to invite prominent women who have excelled in mathematics-related careers and professions to share their thoughts and experiences regarding reasons they entered the field, obstacles they overcame in relation to their career path, the type of work they do on a daily basis, practical information (e.g., about pay and benefits), and positive and negative aspects of their jobs. Studies by Halpern et al. (2007) have shown that exposure to positive role models have a positive impact on young women's math performance and can help dispel negative stereotypes. Halpern et al. (2007) further suggest the use of biographical readings about women scientists, mathematicians, and engineers to help students find positive role models. Watt (2006) has also noted the role of maths-related female role models in countering the stereotypes that promote men in maths-related domains.

Fostering a conducive classroom climate that enhance interest and curiosity in mathematics

The majority of the girls highlighted the need for teachers improve on their ways of teaching so that the girl child gains confidence and feels comfortable during mathematics lessons. This will help to kindle increase and sustain interest in math. The majority of the girls who were interviewed suggested that teachers should provide equal opportunities for both boys and girls in the mathematics classrooms as well as being sensitive to the needs of the female students. The mathematics teacher should therefore create a collaborative and student

centered classroom environment, where students have opportunities to reason and construct their understanding as part of a community of learners. Mathematics instruction should provide students opportunities to engage in mathematical inquiry and meaning making through discourse. Stein (2007) is of the idea that mathematics should be taught in a way that encourages students to use mathematical discourse to make conjectures, talk, question, and agree or disagree about problems in order to discover important mathematical concepts. Teachers can encourage this by remaining flexible and responsive to students' response and feedback (NCTM, 2000).

Develop, foster and build girls' confidence about their abilities

Researchers has shown that females have less confidence in their math abilities than their males counterparts and begin to lose interest in maths or science careers from early adolescent (Herbert and Stipek, 2005). The girls noted that both their parents and teachers should find means of strengthening girls' beliefs regarding their abilities in maths and science. Teachers and parents should make the girls aware that abilities in mathematics are not fixed and therefore can be improved upon through consistent effort and hard work. The school and the home environment should thus be supportive to build girls' interest and confidence. Asimeng-Boahene (2007), notes that teachers also encourage participation and foster self-confidence by giving consistent positive reinforcement for their comments and questions.

Conclusion

Both the sampled female mathematics students and the mathematics teachers acknowledged that several factors account for low participation of female in high school mathematics. The study has revealed that low participation in Advanced level mathematics is due to perceived difficulty of the subject, lack of self confidence, anxiety, negative teacher attitudes, negative stereotypes about girl's math abilities, cultural belief that mathematics is a male domain and lack of knowledge about mathematics careers entail.

To promote female participation in advanced level mathematics parents and teachers should: enhance girls' confidence about their math abilities; create a conducive classroom climate that enhances interest and curiosity in mathematics; expose girls to female role models who have succeeded in mathematics and provide information, advice and guidance on mathematics careers.

RECOMMENDATIONS

Based on the findings and conclusions drawn from this study, it is recommended that:

1. Teachers and parents should de-emphasize gender and cultural biases attached to mathematics.
2. The Government should give incentives to girls who study mathematics at higher levels in order to encourage young females to pursue mathematical careers.
3. Mathematics teachers adopt some of the more recent reform-based instructional strategies that actively engage students.

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