A Perspective on Gender Disparity in Mathematics Education

Abstract: Using the theoretical concept of equity as a measure of outcomes, this paper discusses mathematics classroom conditions and teacher behaviour that negatively affect the experiences of girl students in secondary schools. The paper draws both on the author's experiences and observations as a former high school mathematics teacher for seven years and also on relevant literature in the field, in discussing these adverse conditions and suggesting strategies to change them. The paper concludes by stressing that teacher leadership should be the fulcrum of any policy development and implementation designed to address female mathematics experiences in the classroom. As part of the conclusion, a suggestion is made for future research in gender equity in mathematics education.

Introduction

In both Canada and the Unites States, differences in mathematics achievements between girl and boy students in large scale standardized tests and assessments were observed in the 70s, 80s, and early 90s (Benbow & Stanley, 1983; Linn & Hyde 1989; Byrnes & Takahiro, 1993; Fennema, 2000; Lauzon, 2001). In Canada, national assessments in mathematics have been carried out periodically through the School Achievement Indicators Program (SAIP). The 1994 SAIP mathematics assessment of 13 and 16 year olds across Canada shows that boys of that age group outperformed girls of the same age group in mathematics problem-solving (Lauzon, 2001). Similarly, Clark (1992) reports that in the mathematics component of the Canadian Test of Basic Skills (CBS) for adolescents in 1990, Newfoundland male students scored 50 percentile points and females scored 39 percentile compared to a national norm of 50 percentile. Clark (1992) laments why this difference of 11 percentile points in achievement exist despite the fact that girls participate at the same rate as boys in all domains of mathematics education.

In the case of the United States, Benbow and Stanley (1983) report that for 40,000 young adolescents who took the College Board Scholastic Aptitude Test (SAT), little difference between males and females in the SAT-Verbal scores was detected. However, in the SAT-mathematics, the distribution of scores displayed significantly a higher mean and larger variance for males than was observed for females. In terms of the distribution of scores, the male and female ratios were as follows: 2:1 for adolescents with SAT-mathematics scores of at least 500; 4:1 for those with scores of at least 600; and 13:1 for those with scores of at least 700. These ratios demonstrate that there is a yarning gap between males and females mathematics achievements in the 600 points and above range.

Given the above stunning statistics, the purpose of this paper is to critically discuss classroom conditions and teacher behaviour that may contribute to poor mathematics learning outcomes for secondary school female students and strategies that can be used to solve this problem. The paper draws on relevant literature in the field, along with the author’s professional experiences and observations as a former mathematics teacher. The paper is divided into five sections. The first section discusses the conceptual framework that informs the paper. The second section argues why it is still necessary to research secondary school female mathematics educational outcomes. The third section discusses classroom conditions that may contribute to poor female student mathematics educational outcomes; while the fourth section discusses strategies to promote girls’ mathematics education in the classroom. The final section, the conclusion, discusses teacher leadership as an important fulcrum to promote female mathematics educational outcomes at the high school level.

Conceptual Framework

Equity is a contentious concept in any democratic society, because it is subject to multiple meanings and interpretations. According to Meyer (1989), many people take equity to mean fairness. While fairness conjures notations of social justice criteria, it is still an ambiguous term and liable to various interpretations as there are different political ideologies in society. Clark (1992), for example states that “equity means that we should spend more resources on different groups in order to bring about equal group outcomes” (p.3). However, this model of equity assumes quite implicitly that putting more resources into programs for different groups would yield equitable outcomes. In the present climate of government fiscal restraints, any suggestions for spending more resources on girl students’ mathematics education is unlikely to garner a wide spread public political support. As well, the model assumes that it is the lack of resources that hinders female students from achieving equitable mathematics outcomes rather than certain deep-rooted practices and structures in schools and classrooms that contribute to the gender mathematics gaps. This view resonates with that of Subrahmanian (2005) who, in writing for the United Nations Girls’ Education Initiative (UNGEI), states that gender equity “means intervening more proactively to address the structural roots of gender inequalities” (p.3).Such intervention may require spending resources but it is the will and commitment to make changes in girls’ mathematics education that matters most than the mere spending of money.

Fennema and Meyer (1989) put forward three different views of equity: 1) equal opportunity to learn mathematics; 2) equal educational treatment; and 3) equal educational outcomes. In the case of equal opportunity to learn mathematics, students are not restricted on the basis of their gender from taking any courses in the high school mathematics curriculum. In spite of this freedom, fundamental differences exist in course enrolment statistics at the high school level (Devenport et al, 1998). As Devenport et al. (1998) report, there is about 25% probability that female high school students would enroll in advanced mathematics courses relative to 60% for males. Hence, equal opportunity does not necessarily translate into more female students taking advanced mathematics courses in high school or enrolling in mathematics-related careers programs.

Equal educational treatment has to do with the mathematical experiences of students in schools and in the mathematics classroom. In fact, mathematics teachers will not treat female students blatantly different for fear that it may elicit administrative sanctions from the school or protests from the student or their parents. However, as Meyer (1989) asserts “males experience in mathematics classroom is different from that experienced by females and that these differences in treatment appear to be related to differences in mathematical outcomes” (p.7). While equal opportunity to learn mathematics and equal treatment of the sexes are an important dimension of equity, they can not by themselves ensure that equal outcomes will be achieved for both male and female students. Hence, equal educational outcomes will be adopted as the conceptual lens for this paper. Equal educational outcomes concentrates on the outcomes of mathematical learning measured in terms of achievements, attitudes towards mathematics, mathematics course enrolment, and eventual participation in mathematically- related careers.

Equity as Equality of Educational Outcomes

King and Peart (1994) observe that generally Ontario female students obtain higher mathematics marks than males at all grades except in the Ontario Academic Courses (OAC) where the difference is only 0.6% (73.4% for females and 74.0% for males). Clegg (2001) found similar information in the 2000-2001 OAC calculus examination results with the average passing marks of 67.7% for females and 67.9% for males; a negligible difference of. 0.02%. This suggests that the mathematics achievement gap between males and females is closing up. Xin (1999) also used data from a sample of 52 middle and high schools in the Longitudinal Study of American Youth (LSAY) as input in sophisticated equation models. Her conclusion is that from grades 7 to 11, both male and female mathematics achievement grew at the same rate across three main domains—basic skills and knowledge, routine problem-solving, and complex problem-solving.

Further, Sanders and Peterson (1999) in reviewing the research regarding girls' mathematical achievement stated enthusiastically that, "what was once an alarming gender gap in math achievement and participation has been reduced to a few percentage points" (p.47). Lauzon (2001) adds that gender differences in mathematics achievement no longer exist but she concludes that gender achievement in mathematics is now a "monitoring" issue. Finally, Hanna (2003), using data from the Third International Mathematics and Science Study (TIMSS), argues that the achievement gap between female and male students has disappeared and that boys' achievement has now become a new equity issue. Does this suggest that gender equity in mathematics education is a resolved or monitoring issue? My response is an emphatic no!

Fennema (2000) recognizes that gender differences in mathematics achievement may be disappearing, but she points out to gender differences in mathematics that still exist in the enrolment in advanced-level mathematics, personal beliefs in mathematics, and career choice that involves mathematics. King and Peart (1994) make a similar observation. They note that despite the narrowing of the gap in gender mathematics achievement, female enrolment in the three OAC advanced mathematics courses falls far behind that of males. They computed the percentage of male enrolment in these advanced mathematics courses at one-third more than that of female students. Beyond high school mathematics, the percentage of males studying advanced-level mathematics and their achievements are far higher than that of females (Burton, 2004; Jones & Smart, 1995; Leder, 1992).

As a matter of fact, gender differences in mathematics educational outcomes appear more transparent when we use course enrolment in both secondary school and post-secondary institution, and career choices as our lever of equity. Benbow et al (2000) report a 20-year educational and career outcomes of gifted students (12-14 years old) in the US who, at age 33 completed and returned follow-up questionnaires. The 2,752 respondents were grouped into two cohorts. Cohort 1 consisted of individuals identified during 1972-1974, and cohort 2 consisted of individuals identified during 1976-1979. Eight hundred and forty males and 543 females returned the questionnaire from cohort 1 and 403 males and 189 females responded in cohort 2. According to the study 7.5% males and 6.3% females in cohort 1 obtained bachelor's degree in mathematics. In cohort 2, 10.3% males and 9.7% females obtained bachelor's degrees in math. Though over that period, the number of females with a bachelor's degree in math grew by 3.4%, males' numbers also grew by 2.8%. The outcome disparity, however, is more glaring in the comparative figures for bachelor's degree in engineering. For cohort 1, the figure is 22.9% for males and 8.1% for females. With regards to cohort 2, the numbers are 35% for males and 15.6% for females. Thus, the enrolment outcome for engineering degree, a mathematically-related career, is not the same for both females and males.

Gadalla's (n.d) study of the patterns of women's enrolment in university mathematics, engineering and computer science programs in Canada in the period 1972-1995 lends more support to the need to continue to research gender equity issues in mathematics education and to conceptualize equity in terms of mathematics course enrolment and mathematically-related career choices. Gadalla's (n.d) study shows that of the 6,020 students that enrolled in bachelor's degree in mathematics in 1972 / 73 in Canadian universities, only 30.2% were females. In the 1994/95 period, the number of females enrolled in full-time bachelor of mathematics degree program in Canada was 40.6% of the total of 8,022 students. So women enrolment in bachelor's degree in mathematics grew by approximately 10%. With regards to bachelor's degree in engineering enrolment, only 1.7% women out of the total of 19,337 students enrolled for 1972/73; the comparative figure for bachelor's degree in engineering enrolment for 1994/95 was18.8% women out of 40,613 students. The result is a net increase in enrolment of 17.10% for women. This suggests that while women's enrolment in undergraduate degree in engineering is increasing males preponderantly dominate the program.

Furthermore, enrolment in technology courses in Ontario secondary schools for 1997-98 demonstrates similar results. According to Bryson et al (2003), in grade 12 electronics, a mathematically-related career course, only 8.7% of the enrolment was females compared to 91.3% for males. In computer science at the same grade level, 14.1% female students enrolled relative to 85.96% males. They found that for the 1997-98 academic year, only 21% females enrolled in grade 12 information technology courses compared to 92% males. The course enrolment statistics in Ontario high schools show that males continue to dominate the mathematics-related technology courses. Therefore, gender equity in mathematics education is not merely a monitoring issue; it is indeed an issue that requires continuous research effort and a commitment to improve girls' mathematics outcomes.

Gender Inequity in Mathematics Classrooms

Wendel (2000) in his review of the literature in school effectiveness and improvement made a reference to classroom effects on students' learning. According to him researchers are now paying an increasing attention to classroom conditions that impact on students' academic achievements. Accordingly, to address gender disparity in mathematics educational outcomes, there is need to focus our attention on the classroom environment where females are taught and engage in interactions with teachers and their peers, and where they form their self-concepts in relation to mathematics learning. As Hanson (1992) has rightly observed,

> The question of girls and mathematics achievement continues to focus on the question why girls don't achieve rather than what is it in the classrooms or the culture that creates barriers to math success for girls; or how could school mathematics be changed in order to become more appealing to women and better accommodate their thinking and learning styles? (p.2).

Thus it is important to focus on classroom conditions, including the quality of interactions between female students and teachers, between female students and male students, the mode of instruction delivery, and discourse style that are critical to the process of developing mathematical understandings (Cassy, 2005; Kimball, 1989; Peterson & Fennema, 1985; Renne, 2001).

Mathematics teachers are the primary architects of the culture in mathematics classrooms—how mathematical concepts, principles, and theorems are delivered, how students are supposed to respond, and the protocols students have to observe in their interactions with the teacher. Dunne's (1999) research into the cultural politics of the mathematics classroom shows that the main classroom activities of teachers, such as maintaining order, teaching, and monitoring the performance of their students, involve social relations. In these social relations, teachers can not claim political neutrality or objectivity in how they structure these social relations for female participation in learning mathematics (Schwartz& Hanson, 1992; Levi, 2000).

Given that mathematics teachers establish the patterns of classroom discourse, they tend to concentrate or call more on boys who invariably are very competitive and aggressive in their demand for attention and in so doing the teacher alienates the girls from participating in the discourse (Hanson, 1992; Fennema, 2000; Lauzon, 2001). Even where a girl becomes assertive or aggressive as the boys, in order to participate in classroom discourses, her behaviour is deplored as unbecoming of a girl (Hanson, 1992; Dunne, 1999). And as most girls are shy, they choose to maintain their silences though they may have something important to contribute to the discourse (Bell & Golombisky, 2004). Hanson (1992) also goes on to assert that classroom interactions based on individual expertise, competition, and elaboration of abstract concepts are antithetical to female style of discourse which is more conversational based. Renne (2001) endorses this view by asserting that girls and women have a strong preference for a conversational form of interaction in which teachers and students collaboratively construct new understandings and negotiate resolutions to ambiguities and contradictions in learning.

Process questions give rich-context information about mathematics questions, compared to that of product questions which require simply answers or solutions. Process-questions help students to conceptualize the questions effectively, to find connections with prior experiences, and to propose or organize appropriate solutions. As Suurtamm (2004) rightly put it, “a process is seen as cutting across several content areas” (p.8). Renne (2001) also states that mathematics teacher interaction with girls centres on product questions, whereas the teacher interaction with boys focuses on process questions. And that this differential treatment contributes to girls’ poor mathematics outcomes. Schwartz and Hanson (1992) support this view, but they take the process-product dichotomy in a different direction. They argue that mathematics lessons that are structured around thinking processes required for arriving at answers or solutions help girls to learn mathematics much more effectively than those organized around answers or solutions.

Strategies for Gendering the Mathematics Classrooms

Several strategies may be used to resolve the problems identified above, to ensure that girls are provided ample opportunities for participation in classroom discourses and interaction without any gender biases. In this regard, Sanders (1997) has suggested that " teachers are almost always unaware of the biased behaviors they exhibit through verbal interactions, eye contact, and body language, which means they can not correct themselves" (p.2). One strategy is for a teacher to have a colleague to monitor his/her classroom interactions in order to assess if equal opportunities are created for girls to participate in classroom discourses. Videotaping teacher classroom interactions and reviewing them for gender differential treatments would be more effective, from my professional experience, than to do it manually. Again, from my professional experience, the videotaping will capture not only interactions but also the nature of the referents the teacher used in explaining mathematical concepts.

Another effective strategy is to arrange after-school one-on-one conferences with girl students, who in spite of opportunities the teacher has created in the classroom for their interaction, refuse to participate. I have used this strategy often in teaching high school mathematics and have found it more effective in assisting shy girls to ask questions and seek clarification of mathematics concepts they were taught in the classroom. As well, my strategy of allocating 70% of the discourse time in the classroom to girl students had helped countless number of them to excel in their grade twelve mathematics courses and to cultivate interest in mathematics. Moreover, I used some of the instruction time to narrate vignettes aimed at dispelling gender stereotypes and beliefs about mathematics disseminated by parents, teachers, students, guidance counselors, and society at large. I also used the time to tell the class about female mathematicians and inventors and all the careers for which mathematics was applicable. Thus my mathematics session was also a therapeutic session with the purpose to cultivate girl students' interest in mathematics.

A cooperative group approach has also been suggested as a strategy to increase girl participation in the mathematics classroom (Schwartz &Hanson, 1992; Perez, 2000; Renne 2001). According to Perez (2000), cooperative group gives girls a non-threatening environment to explore mathematics concepts and to build on their knowledge through discussion. Nevertheless, she cautions that cooperative group should be carefully balanced to prevent boys from dominating the groups. From my professional experience, teachers should know their students' characteristics very well in order to create effective cooperative groups to promote girls' mathematics interest and confidence. Schwartz and Hanson (1992) have also suggested that girls' exclusive cooperative groups would provide them more opportunities to interact as peers, and that this is likely to strengthen girls' interest and participation in mathematics education.

The literature on gender and mathematics education suggests that girls outperform boys in reading and writing at the high school-level and in the humanities at the university level (Benbow & Stanley, 1983; Burgess et al, 2004; Francis, 2000; Mittelberg &Lev-Ari, 1999). Consequently, writing to learn mathematics could be an effective strategy to assist girls to cultivate interest in mathematics at the high school level and to lay down a strong foundation for future post-secondary mathematics studies. From my professional experience, journal writing in the mathematics classroom provides girl students an alternative means of participating in verbal discourses. The mathematics journal then becomes a communication channel between the mathematics teacher and girl students who for some psychological or other reasons feel shy or uncomfortable to participate in verbal discourses in the classroom.

Regarding the efficacy of writing as a tool for mathematics learning, the National Council of Teachers of Mathematics (NCTM) (1989) states that, “the very act of communication clarifies thinking and forces students to engage in doing mathematics” (p.214). Pugalee (1997) also argues that writing can help students to “interpret unfamiliar texts, construct arguments, struggle to understand complex systems and develop new approaches to problem-solving” (p.308). Thus writing in the mathematics classroom is not only an alternative form of communication, but also a learning tool whose impact would be far-reaching beyond the walls of high school (Baxter et al, 2005). In fact, its use in early high school years is more likely to strengthen female student confidence in mathematics for eventual enrolment in advanced mathematics courses. As Jones & Smart (1995) have noted, “confidence can be considered to be a belief in one’s own ability…it is not a constant factor, but changes according to circumstances and situations” (p.164).

Teachers also benefit from using writing in the mathematics classroom. Drake and Amspaugh (1994) observe that teachers who add writing to their mathematics classes often find it easier to recognize and diagnose the nature of students’ conceptual problems and decide what can be done to resolve them. Similarly, Quinn and Wilson (1997) acknowledge that by incorporating writing in the mathematics classroom, teachers gain important information from student writing which can be used to improve instruction programming and strategies.

In the traditional mathematics classroom, mathematics concepts and principles are generally regarded as having the attributes of rationalism and objectivism (Bills, 1999). As such, they are not subject to critical interrogation and students are required to accept them as absolute truths. In such mathematics classrooms, the teacher is the central focus, in that he/she explains, demonstrates, assigns worksheets or questions students and evaluates their work. Accordingly, rote learning is likely to be the norm in such classrooms. Ridley and Novak (1983) have argued that rote learning of mathematics is responsible for the low participation of women in advanced-level mathematics. They state that,

> The integration of concepts into hierarchical frameworks of meaning, spanning the whole course and/ or linking with concepts in related courses or disciplines is rarely required at the secondary level. The consequence is that high achievement is possible or even favored with near rote-made learning strategies with the resultant failure to produce more concept integrative meaning learning strategies. The greater tendency of females to conform to expectations in such instructional practices will lead to progressively less capacity for building hierarchical meaning structures or less incentives to do so (p.314).

Certainly, females may not find a rote-learning environment to be intellectually challenging and emotionally stimulating. As Belenkey, et al. (1986) rightly put it, “educators can help girls and women develop their own authentic voices…if they emphasize connections over separation, understanding and acceptance over assessment and collaboration over debate” (p.229). Swain (2003) has also suggested a classroom environment dominated by discovery sessions rather information transmission as a remedy for gender equity in mathematics education. From my professional experience as a mathematics teacher, female students always prefer to talk and for that matter they want a classroom environment where they can ask any questions about mathematics such as these: “why do you always write the area of objects as square centimeters or meters or square this or that?”

Consequently, constructivist epistemology may be a viable alternative to rote-learning environment in which mathematical concepts are learned as discrete elements, without emphasizing their integrative characteristics. Griffin & Case (1997) have suggested that constructivist-based instruction is an effective tool for increasing student understanding of mathematics concepts. This is because learning activities in constructivist settings are characterized by active engagement, inquiry, problem-solving, problem-posing, and collaboration with others. Kroll & LaBosky (1996) state that in a constructivist setting the teacher is a guide, facilitator, and a co-explorer who encourages students to question, challenge, and formulate their own ideas, opinions, and conclusions. In such settings, multiple solutions and interpretations to mathematics problems/questions are encouraged, giving opportunities for discussions, dialogue, debate, and integration of mathematical ideas.

Furthermore, in a constructivist setting students construct their own understanding or knowledge through the interaction of what they know and believe and ideas, events and activities with which they come in contact with (Cannella & Reiff, 1994; Lambert, et al, 1995; Richardson, 1997). This way, students tend to have a positive mathematics learning experiences which would encourage them to enroll in advanced high school mathematics or a degree program in mathematics. For this reason, constructivist epistemology is most likely to build-up girls' confidence and interest in mathematics, so that they would be motivated to enroll in advanced mathematics courses in high school, pursue mathematics degree programs in post-secondary institutions, and take up mathematics-related careers (Belcheir, 1998).

To conclude this section of the paper, the suggested strategies are not likely to be put into use unless teachers are committed to gender equity in the classroom. This commitment requires an active intervention on the part of teachers to promote girl interest and confidence in mathematics (Levi, 2000), and an openness to change things in light of new information (Hayes et al, 2000). It also requires a caring ethic, by which mathematics teachers show a genuine interest in girls' mathematics educational outcomes; for teachers' caring attitudes and encouragement could make a tremendous difference in girls' mathematics educational outcomes (Campbell & Storo, n.d).

Conclusion

In the microenvironment of the classroom, teachers exercise leadership and are instrumental in affecting changes in order to bring about gender equity. Teachers as street-level bureaucrats have discretionary powers (See Lipsky, 1980; Marynard-Moody et al. 1990) in deciding how to implement gender equity policies in their classrooms. As Campbell (1990) has asserted, "teachers are part of the cause of the differential gender differences that exist… they have the power to contribute to helping to eliminate those practices" (p.227). This, from my perspective, requires teacher leadership to address gender disparity in mathematics learning outcomes, which implies teachers working together to attain a collective goal (Muijs & Harris, 2003). Thus, teacher leadership should be involved in any policy development and implementation designed to promote equal mathematical outcomes for high school girl students.

A committed teacher leadership can do the following to promote girls' interests in mathematics education: 1) teachers can exchange ideas on mathematics teaching that might increase girl students' participation and achievement; 2) organize workshops, seminars, and symposiums to promote girls' interest in mathematics education and mathematics-related careers. Jones and Smart (1995) report three major intervening strategies that teachers in England used to increase secondary school girls' confidence and interests in mathematics education--- mathematics conferences, using technology to learn mathematics, and involving girls in school-based research of gender issues in mathematics education. This example suggests that teachers can play an important role in promoting equal gender outcomes in mathematics education. However, this does not suggest that school principal leadership has no role to play in promoting gender equity. In fact, school principal leadership could coordinate activities of teachers engaged in reforming teaching practices to promote better female mathematics educational outcomes by providing them moral and material support. Alternatively, school principals could work with teachers, allowing them to take a leadership role, to develop a consensual policy to address gender mathematical outcomes in their classrooms.

Finally, researchers in the field of gender equity in mathematics education tend to homogenize girls into one gender category, without any references to race, ethnicity, or socio-economic status (SES). These social differences are important because as Wendel (2000) reports, socio-economic status (SES) of students accounts for almost 50% of the variance in student achievement. Consequently, secondary school girls from an economically disadvantaged background may not achieve the same mathematics educational outcomes as those from a privileged background. As well, gender differences in mathematics educational outcomes are not uniform among schools; some schools have less gender disparity in mathematics education outcomes than others (Glegg, 2001). Future research in gender equity in mathematics education needs to factor these social differences into the research design (Morin, 2003), in order to present a realistic picture of gender inequality in mathematics educational outcomes.

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