Gender and Mathematics: How to Control an Uncontrollable Variable

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Many education researchers have pursued the topic of gender, especially in the field of mathematics. Gender is one of the few variables policy-makers, schools and teachers cannot control or change. However, as analyzing standardized test results has repeatedly shown, not only do boys and girls perform differently when completing mathematical questions but most boys continue to outperform girls in a variety of mathematical areas (Aunola et al 2004; Carr et al 2008; Council of Ministers of Education, Canada [CMEC] 2012; Preckel et al 2008).

As I contemplated gender in mathematics and reflected on the research studies and assessment results, I began to wonder why girls get lower marks in mathematics than boys do. I thought about my Grade 3 class, and I considered the possibility that researchers would find similar results with my students. As quickly as I conceived the thought, I felt appalled. Because I strongly believe that boys and girls are equal in their ability to learn any given subject, the only explanation for such assessment results would therefore be that I do not support my female students and my male students equally in their quest to discover the world of mathematics. Since I am passionate about learning and teaching mathematics, this thought saddened me. Unfortunately, many young girls across the country seem to be receiving insufficient support from their math teachers, as the latest results of the Programme for International Student Assessment (PISA) indicate (CMEC 2012). As an education professional, I find this situation unacceptable. For the sake of not only the girls in my classroom but also my own two daughters, I have undertaken a journey of inquiry into the issue.

In my quest, I found that education researchers have revealed four possible reasons for gender differences in mathematics performance in the elementary years:

- Gender-specific learning approaches and strategy preferences
- Gender differences related to motivation and competence belief
- Gender-biased assessment procedures and tools
- Gender-biased teacher beliefs and conduct

These factors may at first glance appear to be separate and unrelated, but they are in fact closely linked, and they create a complex and compelling argument for why gender is such a powerful variable affecting students' ability to learn mathematics, from as early as Grade 1. Here, I examine these underlying causes of gender differences in mathematics performance while exploring practical classroom strategies for limiting or avoiding the impact of gender, specifically in the elementary mathematics classroom.

Gender-Specific Learning Approaches and Strategy Preferences

Educators, regardless of which age group they work with, have long known that boys and girls learn and play differently (Cherney and London 2006; Gurian 2011; Gurian and Stevens 2006; James 2009). Generally, boys tend to thrive in a competitive environment in which their peer group drives them to do their best, whereas girls are much more interested in taking a cooperative approach and are often more concerned about the well-being and success of others (Bonomo 2010). In their review of the assessment data, literature and research done on gender differences in mathematics, Geist and King (2008, 46) point out that "girls use cooperation more than a competitive approach and are less concerned with being 'first' or 'best' and more with being sure the needs of their close friends are met as well as their own," whereas boys "function better in a competitive environment (such as number grades on worksheets and tests and teacher recognition)" and therefore "have the advantage in a traditional classroom."

However, the differences between boys and girls do not end there. An overwhelming amount of evidence points to a clear distinction between boys' and girls' preferred use of strategies when completing mathematical tasks (Bailey, Littlefield and Geary 2012; Hickendorff et al 2010; Imbo and Vandierendonck 2007). For example, Carr et al (2008) discovered that girls favour the use of manipulatives when

solving arithmetic problems, and this hands-on strategy choice "may eventually constrain [their] development of mathematical knowledge and skills" (p 72). In contrast, the researchers showed that although boys prefer the use of cognitive strategies and retrieval, they are equally capable of reverting to the use of manipulatives when needed. Therefore, boys can switch from using retrieval to using manipulatives when dealing with more difficult problems, while the mathematical approach of girls is much more restricted (Carr and Davis 2001).

This gender-specific strategy choice is not limited to arithmetic problems. Fennema et al (1998) had previously shown that boys and girls also differ in their approaches to problem solving. In their study, the researchers established that girls tend to use modelling and counting strategies, while boys prefer more abstract strategies (such as derived facts and invented algorithms). Although researchers have been unable to establish why girls do not use invented algorithms as often as boys do, as educators we should be concerned that, without attempting to extend their knowledge through the invention of new arithmetic strategies, girls are limiting the extent of their mathematical learning to the simple recall of procedures and algorithms.

At this point in my quest, I began to wonder how I could assist young girls with learning mathematical concepts and skills in my classroom when their approaches to learning and their strategy preferences are clearly so different and distinct. After considering the research, I came to realize that many traditional classroom activities and instructional approaches create a clear disadvantage for the female mathematicians in our classrooms. However, in my effort to find concrete examples of how to adjust instructional strategies and create activities that support girls and boys equally in their mathematical learning, I found only a handful of articles (Gavin and Reis 2003; Karp et al 1998; King and Gurian 2006; Levi 2000).

As the research indicates, the traditional classroom environment, where students work individually and where competition is frequently used as a motivational strategy, is not conducive to girls' way of learning mathematics. Instead, as Gavin and Reis (2003, 38) point out, mathematics teachers should strive for a more balanced instructional approach in which they "provide some competitive, some cooperative, and some individual learning situations and allow choice whenever possible." Additionally, teachers should provide opportunities for students to work in same-sex groups, allowing girls to discover mathematics without the competitive edge boys might bring to such activities. Furthermore, to promote the use of a variety of mathematical strategies, teachers should carefully observe their students in order to determine when they are developmentally ready to move beyond using only manipulatives to including cognitive strategies and retrieval in their mathematical repertoire. At the appropriate time, elementary teachers can then offer many opportunities for students to solve mathematical problems without the use of manipulatives. In this way, teachers will encourage the use of cognitive strategies and retrieval, which is essential for the successful mathematical learning of female students in particular.

Gender Differences Related to Motivation and Competence Belief

The emotional and psychological state of mind of students greatly affects their ability to successfully complete tasks or solve problems. Educators know that students whose emotional needs are not being met, students who lack confidence or students who are unmotivated will experience more difficulties in learning and understanding new skills and concepts. This also holds true when students are completing mathematical tasks (Bouffard et al 2003; Gottfried 1990; Wigfield and Eccles 2000). Studies have consistently supported the idea that boys and girls develop different beliefs about their confidence and competence in the area of mathematics, and that they do not experience the same level of motivation when engaged in mathematical tasks.

Eccles et al (1993) showed that not only do boys value mathematical activities more than girls do and, therefore, are more motivated to engage in such activities but boys also consistently report higher levels of confidence than girls of their age when considering their mathematical abilities. Additionally, Lindberg et al (2013) observed an increasing gap between the math self-concept of male students and that of female students during the early elementary years. They point out that "this increasing gender gap in math self-concept may later on lead to actual gender differences in math achievement" (p 4). Unfortunately, even when academic grades indicated that girls had performed as well as their male counterparts had, girls reportedly experienced significantly less enjoyment and pride (Frenzel, Pekrun and Goetz 2007). Additionally, as the researchers point out, this low competence belief not only negatively influences girls' perception of the value and enjoyment of learning mathematics but will once again negatively affect their motivation to engage in mathematical activities in the future. This

research indicates that limited motivation, low confidence, and inadequate experience of enjoyment and pride even when successful create a vicious cycle that hinders girls in learning mathematical concepts as easily as boys.

Most elementary mathematics teachers face this challenge when trying to encourage their female students to embrace the world of mathematics. As classroom teachers, we might feel overwhelmed when trying to come up with creative solutions to counteract the negative emotions girls have toward the value of mathematics and their engagement with the subject. Once again, the existing literature offers little guidance and few suggestions for elementary teachers about how to adjust current classroom strategies in order to sufficiently support girls in their mathematical learning. Yet, the solution might be easier than we expect.

To help female students gain confidence and take more pride in their mathematical accomplishments, our classrooms need to become safe, caring and supportive learning environments. Teachers should be a source of encouragement and support for all students, but particularly for female students. Above all, letting our female students know that all great mathematicians struggle and encounter difficulties is essential when trying to help them deal with the discomfort associated with such experiences (Gavin and Reis 2003). Furthermore, allowing students to share their mathematical ideas in a variety of ways will allow even the most self-conscious students to receive positive feedback. Classroom displays, journal writing, and the discussion of mathematical ideas with a partner or in small groups allow students to experience the mathematical world in a nonthreatening way.

To help girls recognize the value of mathematics and motivate them to participate, ask students to work on real-life math problems that touch on the interests of girls as well as those of boys. Whenever possible, give students a choice about what they will work on and what mathematical questions they will pursue in order to motivate all students to be actively engaged in the lesson. As most girls are not aware of the significant contributions women have made to mathematics and science, elementary teachers should present such information in the form of classroom discussions and displays. As Gilbert and Gilbert (2002, 526) point out, "Few students anticipate excelling in a field in which they think no one who looks like them has excelled before." This particularly holds true for our female mathematics students. The National Women's History Project website (www.nwhp.org) contains resources for classroom teachers who want to encourage female students in this way.

Gender-Biased Assessment Procedures and Tools

As previously indicated, existing large-scale assessment results consistently point toward gender-specific differences in mathematical ability as early as ages five and six (Voyer, Voyer and Bryden 1995). This trend continues today as boys consistently outperform girls on standardized achievement tests (CMEC 2012; Kenney-Benson et al 2006). However, as accountability in education continues to gain importance and the use of standardized assessment tools becomes inevitable, educators must take a closer look at the assessment procedures and tools they rely on, particularly if the results are used as evidence that girls are less capable in mathematics.

As previously established, girls prefer playing and learning cooperatively (Barnes 2011; Diamond 1994; Schwartz and Hanson 1992). Therefore, standardized assessment tools, regardless of whether the emphasis is on competition or on students' individual achievements, do not support girls' way of learning. Additionally, if such assessment tools include timed tests, girls will, more often than boys, experience unnecessary stress and, consequently, will be unable to do their best mathematical thinking (Gavin and Reis 2003).

As researchers have established, the problems do not end there. Procedural factors can also greatly influence students' performance results. As Voyer, Voyer and Bryden (1995, 263) point out,

> Larger [differences in achievement results] were obtained when the test was administered individually than when it was given in a group. This would suggest that there are meaningful sex differences in the way [participants] respond to the differences between these two testing situations.

The researchers explain that scoring procedures also appear to have an impact on the magnitude of gender differences in test results. Finally, the test questions themselves can give boys an unfair advantage, particularly if the questions are based on prior knowledge that girls might not have, such as knowledge of sports (Duffy, Gunther and Walters 1997; Zumbo and Gelin 2005).

Even though the use of standardized assessment tools is problematic, especially when considering gender-specific learning styles and psychological factors, this form of assessment has become an integral part of today's educational world, even during the elementary years. Therefore, our challenge is to find new and innovative ways to carefully incorporate such mandatory standardized assessment tools in

order to minimize their negative effects on female students. It is critical here to note the distinction between incorporating standardized assessment and relying on it. Informal assessment, such as observing students while they are engaged in mathematical tasks or asking them to share their thoughts as they attempt to problem solve, not only allows students to reveal their learning in a nonthreatening way but also provides teachers with a rich source of information to gauge the quality of their instruction. Allowing students to demonstrate their knowledge and skills through mathematics portfolios, creative projects or small group assignments, for example, will nurture creative thinking and encourage risk taking, and will therefore elicit a more accurate picture of girls' mathematical abilities (Gavin and Reis 2003).

Gender-Biased Teacher Beliefs and Conduct

While problems with test questions, assessment procedures and scoring practices may explain existing differences between the test results of boys and girls in mathematics, my inquiry indicates that teacher–student interaction and, more specifically, teacher conduct may also affect students' mathematical performance. After careful review of the literature on the topic, I noted that teachers can negatively affect girls' mathematical learning in three ways:

- Through gender-biased beliefs and the application of gender stereotypes (Garrahy 2001; Gilbert and Gilbert 2002; Tiedemann 2002)
- Through the use of gendered language (Damarin 1990; Gavin and Reis 2003; Gilbert and Gilbert 2002)
- By focusing on boys more than girls during instructional time and classroom discourse (Wimer et al 2001)

As I contemplated the powerful implications of these disturbing research results, I came to realize the importance of unravelling my own beliefs about gender and understanding how those views affect my interactions with students. It worried me that "the magnitude of gender imbalance and gender bias [in classrooms] could be enormous and . . . detrimental to the education of girls and boys" (Garrahy 2001, 93). Once again I felt compelled to continue my quest to find solutions to eliminate this problem in elementary mathematics.

Classroom teachers frequently hold on to a desire to see all their students as the same and remain blind to obvious differences between boys and girls. However, as Garrahy (2001) points out, this view gives teachers a false sense of objectivity and impartiality, because the generic child does not exist. In reality, teachers often "unconsciously [apply] gender stereotypes by assuming that girls should use their abilities to help and empower other students, whereas boys should use their abilities to further excel in mathematics and empower themselves" (Gilbert and Gilbert 2002, 526), thus threatening gender equity in the classroom. Instead, as Levi (2000) establishes, teachers can take on one of three roles in order to address gender differences:

- Focus on providing equal opportunities, and respect the gender differences between their students
- Ensure that girls and boys have the same experiences
- Attempt to compensate for gender differences in society

Unfortunately, research does not offer a conclusive answer as to which role would address students' gender differences most efficiently. Therefore, educators should make pedagogical decisions grounded in the particularities of each class and each student in order to adequately support the mathematical learning of boys and girls (Levi 2000).

The language that teachers use can greatly hinder efforts toward gender equity in the classroom. Gilbert and Gilbert (2002) indicate that teachers' repeated use of the generic *he*, as well as addressing the entire class as *guys*, is both ambiguous and discriminatory toward female students. Additionally, teachers usually assume that it is a student's mother who should be contacted when issues arise. The repeated use of "I guess I will have to call your mother" sends a strong message to students about expected gender roles and fosters a gender-biased classroom environment. Gavin and Reis (2003) point to an analysis by Damarin (1990) of the traditional vocabulary used in mathematics that indicated a strong male influence on the type of words that are part of the daily instructional discourse. The goals of *mastery* and mathematical *power*, the strategy of *attacking* problems, and the use of *drills* and *competitions* may support boys' way of learning while leaving girls struggling in a seemingly male-dominated mathematical world. Therefore, the use and modelling of nongendered language should be essential to teachers' efforts to combat gender stereotypes in the mathematics classroom.

The prevalence of gender-biased beliefs among teachers and the use of sexist language during mathematical discourse are not the only ways teachers inhibit gender equity in their classrooms. In their study on teachers' questioning in elementary mathematics, Wimer et al (2001) discovered that although teachers

directed their questions equally toward girls and boys, they would call on boys more frequently than girls when no student volunteered an answer. This observation is supported by Gavin and Reis (2003), who point out that in order to promote girls' mathematical learning, teachers need to give equal attention to their female students. The researchers go on to suggest that peer observation between colleagues can help teachers establish whether they are, in fact, dividing their attention equally among their students. Additionally, shifting classroom discourse away from an argumentative approach to a much more supportive learning activity in which students discuss concepts and practise their reasoning skills to help each other gain mathematical understanding might very well encourage girls to participate in discussions more easily (Morrow 1996), as well as increase the amount of teacher attention they receive. Additionally, educators should consider reducing the amount of teacher talk and instead offer students more time to engage in class discussion and work cooperatively (Becker 2003), while supporting their efforts to develop and share their mathematical thinking.

Conclusion

My inquiry made it clear to me that if I wanted to change the mathematical fate of my current and future female students, I needed to make a variety of critical changes to my professional practice. Consequently, I began to carefully reflect on and change the daily activities I planned for my class, the assessment procedures and tools I had been confidently relying upon, and the language I used when interacting with my students. I now give my students more opportunities to work cooperatively and support each other in their mathematical learning. Additionally, I have found a new appreciation for the use of a broad spectrum of assessment tools, and I now more frequently incorporate informal assessment during instructional time. Finally, when talking to my class or to individual students, I select my words more carefully and strive to avoid the use of gender-biased language. While I cannot claim to have completely levelled the mathematical playing field for my female students, I continue to adjust my professional practice according to the information I have discovered through my research.

As my journey of inquiry has revealed, elementary school girls face a great many disadvantages in their quest to acquire mathematical skills and knowledge. Not only do traditional teaching approaches and classroom activities often fail to support girls' ways of learning, but teachers' gender-biased beliefs and conduct continue to undermine the motivation and confidence of their female students. Therefore, I no longer find it surprising that many girls do not perform as well as their male classmates on large-scale standardized assessments. However, after carefully reviewing the existing literature on this topic, identifying the causes of the existing gender gap in mathematical achievements, and exploring classroom strategies for limiting the impact of gender, I am convinced that the goal of gender equity in the elementary mathematics classroom is attainable and, therefore, can be incorporated into our professional practice—not just for the sake of our students but also for our daughters.

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