Gender Equity in Mathematics Education

Josie Catalano MacPherson

This paper will summarize research findings on gender differences in learning. It will examine a historical and current perspective of brain science and its' implications, as well as accommodations in the Mathematics classroom. It will attempt to answer the following questions: Why consider gender-based learning? What scientific base does this topic arise out of and what are its' implications? How can gender-informed teaching be used to enhance student learning?

Why Consider Gender-Based Learning?

Ontario educators have a professional responsibility to teach students to the best of their ability. This includes making data-informed decisions about their methodology based on current research and the individual needs of their students. Tomlinson (2003), a leading expert on differentiated instruction, states: "It is important to begin with the conviction that we are no longer teaching if what we teach is more important than who we teach or how we teach it." This includes acknowledging a students' gender as a criteria in their unique way of learning. According to Fullan, Rolheiser, Mascall and Edge (2001), if we want sustainable educational change to occur, it must be present at all levels of the system: the Ministry, the Board and the school. In Ontario this is evident in a number of policy documents.

The first goal of the YRDSB *Plan for Continuous Improvement* (2008-2009) as outlined on its' website is:

> "Delivering assessment-based instruction that is differentiated to intentionally support the strengths, needs and interests of each student to improve student achievement and success in all subjects and programs."

On the first page of Ontario's new Equity and Inclusive Education Strategy (2009) it defines the terms diversity and equity. Under diversity, it states: "The dimensions of diversity include … gender, gender identity…"   Under equity, it explains: "Equity does not mean treating people the same without regard for individual differences."

The Ontario Ministry of Education (2004) support guide for educators: *Me Read? No Way! – A practical guide to improving boys' literacy skills,* sights boys' underachievement in literacy as an educational concern. This resource, available to all stakeholders, lists the following recommendations for educators:

1. Choose appropriate classroom material.
2. Provide frequent opportunities to read and write.
3. Understand boys' learning styles.
4. Use the arts to bring literacy to life.
5. Appeal to boys' need for social interaction.
6. Influence boys' attitudes through the use of role models.
7. Bring critical-literacy skills into the classroom.
8. Make reading and writing relevant to boys.
9. Use technology to get boys interested.
10. Use appropriate assessment tools.
11. Be in their corner.
12. Engage parents in boys' literacy.
13. Build a school-wide focus.

These approaches are beneficial at tackling what Hirsch (2003) calls "the fourth grade slump in poor children's' reading comprehension". The term "slump" was originally coined by Chall (as quoted in Hirsch, 2003, p.p.10-16) to describe the apparent sudden drop off in test scores by low income children in grade four due, in part, to a limited vocabulary.

What historical scientific base does this topic arise out of and what are its' implications?

Gender-based learning is not a new concept. Throughout history gender specific roles have been socially assigned. This has impacted on familial and economic issues. During the nineteenth century some of the stereotypical roles were being challenged (Smith-Rosenberg and Rosenberg, 1972). Women sought expansion of their role as wives and mothers by demanding birth control, abortion rights, higher education and inclusion in a male-dominated workforce. This resulted in considerable backlash as quoted on page 333 of the Smith-Rosenberg and Rosenberg (1972) article:

> "…men hopeful of preserving existing social relationships, and in some cases threatened themselves both as individuals and as members of particular social groups, employed medical and biological arguments to rationalize traditional sex roles as rooted inevitably and irreversibly in the prescriptions of anatomy and physiology."

The use of craniometry, the measurement of human brains, in nineteenth century science, linked brain size to intelligence. Broca's data, which compared relative brain size of Parisian women versus men, through autopsies, showed that women were of inferior intelligence (along with Negros and senile whites). Carl Vogt, the German anatomist, wrote in 1864 (as quoted in Gould, 1981, p.103):

> "By its rounded apex and less developed posterior lobe the Negro brain resembles that of our children, and by the protuberance of the parietal lobe, that of our females … The grown-up Negro partakes, as regards his intellectual faculties, of the nature of the child, the female, and the senile white."

In 1879, Gustave Le Bon using Broca's craniometric data, published another attack on women (as quoted in Gould, 1981, p.p.104-105):

> "In the most intelligent races, as among the Parisians, there are a large number of women whose brains are closer in size to those of gorillas than

> to the most developed male brains. This inferiority is so obvious that on one can contest it for a moment, only its degree is worth discussion. All psychologists who have studied the intelligence of women, as well as poets and novelists, recognize today that they represent the most inferior forms of human evolution and that they are closer to children and savages than to an adult, civilized man."

Le Bon used his ideologies to oppose granting women higher education. Although Broca's data was later disputed due to scientific bias, (he did not consider overall body size as it related to brain size) it had a huge impact at the time.

In the pre-war years, Hoodless (as quoted in Lenskyj, 1990, p.206) advocated sex-differentiation in educational curriculum:

> "The 'dividing lines' which she suggested, after primary school, involved mathematics and science, which, for girls, should relate to 'home duties'. To learn 'the chemistry of food…cleanliness, cookery and needle work', she claimed, was more useful for girls than ' to wear out brain tissue in puzzling out a lot of abstract questions'."

A Galt teacher (as quoted in Lenskyj, 1990, p.207) stated at the 1881 Ontario Educational Association meeting:

> "and in a country like Canada, to stuff an ordinary girl's head with mathematics when she cannot by any written or unwritten formula whatsoever make her own garments, or initiate her into the mysteries of the corn laws when she cannot so much as bake a loaf of bread, is, I deem, an eternal unfitness ---'tis *wasteful and ridiculous excess* indeed."

In a patriarchal society, women's education had moral and intellectual restrictions. Early twentieth century educational leaders, comprised mainly of men with religious affiliations, preferred sex segregated schooling but understood that it could not become universal. In 1901, Silcox, a St. Thomas teacher, addressed the Ontario Educational Association's Training Department (as quoted in Lenskyj, 1990, p.209):

> "Silcox's attack on 'Sexless Schools'--- those which failed to take sex differences into account --- was based on the pseudo-scientific thesis that a high level of sexual differentiation characterized the higher forms of animal life. The preservation of humankind's 'highly developed state', he claimed, depended on the preservation and 'perfection' of these sex differences."

It was believed that the education of women and young boys should be conducted by women and that the education of older boys was the responsibility of men. Lenskyj (1990, p. 210) states: "the teaching of adolescent boys was both too important and too difficult to be entrusted to women … boys needed a man to show them."

What current scientific base does this topic arise out of and what are its' implications?

My secondary school experience took place in a gender segregated school in Northern Ontario. My parents are of European descent and value education. My siblings and I hold multiple university degrees. I graduated in 1980 with a combined honors degree in Mathematics and Psychology. By the late 1970's, "a very similar percentage of women were finishing degrees in mathematics as men" (Chipman as quoted in Gallagher and Kaufman, 2005, page 395). Thus I fit the profile of the time.

There exists today a societal concern in a lack of competent physical science and computer technology graduates to fill available positions. Three studies examine this dilemma. *Achievement in Math and Science: Do Mothers' Beliefs Matter 12 Years Later?* (Bleeker and Jacobs, 2004), *Important, but Not for Me: Parents and Students in Kansas and Missouri Talk About Math, Science and Technology Education* (Kadlec, Friedman, Ott, 2007) and *Math and Science Motivation: A Longitudinal Examination of the Links Between Choices and Beliefs* (Simpkins, Davis-Kean, Eccles, 2006).

The National Center for Education Statistics, 2001 (as quoted in Bleeker and Jacobs, 2004, p. 97) indicates that the percentage of women earning doctorate degrees in the United States, in the physical sciences is 23.4% and in engineering, 14.9%. In contrast, the number of women earning doctorate degrees in life sciences is 45% and in business, 50%. It is clear that women are on par when it comes to the "softer" math and science degrees but lag behind in the physical sciences and engineering areas. In the workplace, women make up only 23% of the science and engineering labor force, with 9% employed engineers and 10% employed physicists (NSF, 2000 as quoted in Bleeker and Jacobs, 2004, page 97). Recent studies show no gender differences in middle school students' math and science abilities as examined by science achievement exams, math test scores and grades (Catsambis, 1999; Hassan and Khalifa, 1999 as quoted in Bleeker and Jacobs, 2004, page 97). As students progress in secondary school, fewer and fewer of them select higher level math and science courses as options due to a lack of interest and confidence in their abilities to succeed. Of the group that selects higher level math and science courses, the majority are high performance males. The senior math and science courses are very abstract. Recent analysis of standards-based tests reveals that "there is a performance gap between males and females, particularly in the later years of education. However, if the tests themselves are scrutinized, the authors argue that standard assessment seeks to measure those abilities that men are best equipped to perform" (Gallagher and Kaufman, 2005, page 395). In other words, senior level standardized tests are male oriented assessments designed to elicit optimum results in males. Brain science research indicates that there are three types of brains: male, female and balanced. "The female brain is predominantly hard-wired for empathy, and the male brain is predominantly hard-wired for understanding and building systems" (Baron-Cohen, 2003). These differences describe general trends that are evident from early childhood on and should not be used to stereotype individuals since many other factors, including hormones, influence the brain orientation that a person has. The general trends are significant enough to warrant consideration. Senior level standards-based tests measure "understanding and building systems" not "empathy" or a balance between the two.

Senior level mathematics courses are pre-dominantly male-oriented with "understanding and building systems" as their primary composition.

According to Bleeker and Jacobs, consistent findings indicate the dominant role that parents' and students' attitudes play in this scenario. The current study found a strong correlation between mothers' gender stereotypes, perceptions of their children's abilities and their children's future self-perceptions of ability (Bleeker and Jacobs, 2004, page 98). Jacobs (1991, as quoted in Bleeker and Jacobs, 2004, p. 98) found that parents, who held traditional gender stereotypes favoring boys in mathematics, did so regardless of abilities. He also found "that parent gender-typed beliefs were indirectly related to children's self perceptions, so that boys had consistently higher mathematics ability beliefs and future expectancies than did girls, despite the fact that girls had higher grades in mathematics than boys" (Jacobs, 1991, as quoted in Bleeker and Jacobs, 2004, p. 98).

The number of parents who worry about whether schools are teaching enough math and science has declined since the mid-nineties. "In 1994, 52% of parents said that it was a *serious problem* that students weren't learning enough math and science, but by 2006, the number had dropped to 32% (Kadlec, Friedman and Ott, 2007, p.6). Parents do not see the need to improve math, science and technology education. It should be noted that 73% of parents say that advanced science courses should be expected only of students who show a special interest in the subjects (Kadlec, Friedman and Ott, 2007, p. 8).

The third study attempts to determine how engagement in out-of-school math and science enrichment activities relates to youths' subsequent self-beliefs, which predict enrolment in secondary school math and science courses (Simpkins, Davis-Kean, and Eccles, 2006, p.p. 70-71). According to Erikson (1982, as quoted in Simpkins, Davis-Kean, and Eccles, 2006, p. 71), middle school is a critical time for activities because this is when health and competence skills are established, which form the basis of self-esteem. Researchers have found that self-beliefs are refined during adolescence in response to performance feedback (Simpkins, Davis-Kean, and Eccles, 2006, p. 71). Students in secondary school make higher level math course selection choices based on their abilities. The article states: "A common influence on youths' beliefs and choices is their achievement. Research suggests that math and science achievement are positively associated with youths' values and self-concepts" (Casey, Nuttall and Pezaris, 1997; Frome and Eccles, 1998; Jacobs, 1991; Jacobs et al., 1998; Parsons [Eccles] et al., 1984, 1985; Updegraff et al., 1996; Wigfield, Eccles, Mac Iver, Reuman and Midgley, 1991 as quoted in Simpkins, Davis-Kean, and Eccles, 2006, p. 71). "There are marked gender differences in youths' math and science choices. Boys are more likely than girls to enroll in math courses during high school but are less likely to enroll in math activities outside of class" (Farmer et al., 1995; Parson [Eccles] et al., 1984; Updegraff et al., 1996, as quoted in Simpkins, Davis-Kean, and Eccles, 2006).

All three studies used a limited population in the United States. The first, sampled 143 sixth-grade math classrooms located in 12 school districts in primarily white middle and working class suburbs outside of Michigan. 80% of sixth grade teachers, 80% of students and 62% of mothers participated by completing questionnaires. The study included only those who remained in the eighth wave of the research, at age 24-25 years and whose mothers also participated when they were in sixth grade. Only 354 mothers and their children answered all of the items used in the current study (Bleeker and Jacobs, 2004, p. 99). The second used a random survey of 1,472 parents and 1,295 middle and high school students in Kansas and Missouri. The survey was preceded by 12 focus groups with parents, students and teachers in the Kansas City region and a series of interviews with local employers, leaders and experts. The population consisted of white, African-American and Hispanic parents and students. The third study sampled families with children in 12 public schools from three school districts in Michigan. Third grade children and their families were recruited and followed up in grade levels of interest in middle school and adolescence. Information from one child and both parents in each family were included. The sample size was 227. Ninety-seven percent of families had two parents, not representative of the population at large. Ninety-seven percent of mothers, 96% of fathers and 93% of children were European American and spoke English. Forty-two percent of mothers and 44% of fathers had a 4 – year college degree. Families' 1989 annual household income ranged between under $10,000 to over $80,000 (Simpkins, Davis-Kean and Eccles, 2006, p. 73). The longitudinal studies ended up with small sample sizes, which were not inclusive of other ethnic groups and not representative of the general population in the United States.

The results of the Kadlec, Friedman and Ott study (2007, p.10) show that parents are satisfied with the rigorous level of instruction in math and science because they see their children doing more challenging lessons than they did in school. Female adolescents, whose mothers reported low predictions of children's success in math careers were more likely to choose careers in non-science than in physical science - computing; however, mothers' perceptions had only a minimal effect on male adolescents' chances of choosing a non-science career, as opposed to a career in physical science – computing (Bleeker and Jacobs, 2004, p. 104). There is a direct relationship between 10th grade achievement (quantitative data) and math importance, math interest, math self-concept at the 10th grade. There is also a direct relationship between 10th grade achievement and number of math courses taken in high school. Gender differences were found in youths' math self-concept of abilities and out-of-school activity participation. Girls had lower math self-concepts even though they spent more time on math after school activities, which were generally considered to incorporate little physical activity and more feminine play themes, such as math puzzles, playing school and doing math problems (Simpkins, Davis-Kean and Eccles, 2006, p. 81).

Sax's Research on Gender Differences

In 1964, Lansdell (as quoted in Sax, 2005, p.11) reported anatomic sex differences in male and female brains. He found that the left side of the brain is specialized for language functions in males while asymmetry is much less noticeable in females. Male stroke victims, who suffered left hemisphere damage, showed a 20% drop in verbal I.Q while male stroke victims, who suffered right hemisphere damage, showed no drop in verbal I.Q. Female stroke victims, who suffered left hemisphere damage, showed a 9% drop in verbal I.Q while female stroke victims, who suffered right hemisphere damage, showed an 11% drop in verbal I.Q.

In 2004, scientists at U.C.L.A. (as quoted in Sax, 2005, p.13) examined a bird that was a lateral gynandromorphic hermaphrodite (half male, half female) and found dramatic differences in the left and right sides of the brain. In 2004, 14 neuroscientists from the University of California, University of Michigan and Stanford University (Sax, 2005) found a dramatic difference in proteins derived from the x chromosome and the y chromosome in human male and female brains. In men, the brain is protein-rich (y chromosome-coded); in females, the brain is protein-rich (x chromosome-coded).

In the 1980's Caine, a graduate student at Florida State University, studied the effects of music on newborn babies; her findings revealed gender hearing differences (as quoted in Sax, 2005, p.16). Cassidy, at Louisiana State University (as quoted in Sax, 2005, p.17), studied 350 newborn girls and boys and found that baby girls had substantially more sensitive hearing than boys, especially in the 1000 to 4000-Hz range, necessary for speech discrimination. Subsequent studies demonstrate that teenage girls hear better than boys and that the difference augments with age (Sax, 2005). Elliot (as quoted in Sax, 2005, p.18) demonstrated over 30 years ago that 11-yr old girls are distracted by noise levels ten times softer than noise levels that boys find distracting, such as a boy tapping his pencil on a desk. Researchers at Cambridge University (as quoted in Sax, 2005) studied newborns on their birthdates to detect whether they preferred a simple dangling moving mobile or a live woman's face. The boys were twice as likely to focus on the moving mobile (sex differences in social interest are hard-wired too?)

There are anatomical sex differences in the anatomy of the eye (Sax, 2005, p.18-22). The retina, comprised of rods and cones, send their signals to the next layer, ganglion cells (M and P ganglion cells); M cells are simple motion detectors while P cells comprise information about texture and colour; males have predominantly M cells while females have predominantly P cells. Young boys prefer to simulate motion in their drawings, such as action figures fighting, while girls prefer bright colours. Studies in young children demonstrate that girls are better at tasks involving object discrimination (What is it? Describe it?) Boys are better at tasks involving object discrimination (Where is it?)

Research indicates that gender is a significant factor in both choice of reading materials and reading achievement for boys and girls (Ontario Ministry of Education, Me Read? No Way! 2004). Boys typically score lower than girls on standards-based literacy tests and are more likely to be placed in special education programs. They have a higher drop out rate and are less likely to go to University.

How can gender-informed teaching be used to enhance student learning?

An awareness of brain orientation can facilitate a teachers' practice. Methodologies can be varied to include both "male" and "female" learning styles. Some of the strategies I have employed in my mathematics classroom include:

1. Move boys to the front, so they can hear my softer voice and I can better engage them.

2. Remove noise distractions from the class, such as boys tapping on the desks which are highly distractive to the girls with sensitive hearing.

3. Use a variety of problem-solving strategies that include object discrimination (what is it, describe it and where is it) – appealing to both genders.

4. Use mind maps, such as the Frayer model, placemats,…where students can describe in visual detail, mathematical definitions as well as explain concepts to each other (understanding and building systems).

5. Use Differentiated Instruction to accommodate individual needs, with choice on evaluations.

6. Maintain a tight, structured environment since adolescent boys need firm rules in order to succeed (Sax, 2005).

7. Provide ongoing individual support and verbal feedback (formative assessment).

8. Keep parents informed of classroom practices, assignments and student achievement.

9. Be sensitive to girl's feelings and aware of their need to please their teacher in order to succeed (Sax, 2005).

10. Provide a positive female role model to the girls in my mathematics classroom.

Conclusion

The historical overview describes inequitable belief systems that were grounded in scientific research which exploited minorities and women. The agenda of the day was to keep women in the home, prorogating the species and men in the workforce, making economic and policy decisions. There was an imbalance of power between the genders. Current research refocuses on some of the same themes, bringing boys once again to the forefront of educational concern. Gender-informed teaching must be carefully adapted to ensure that it does not exploit girls and limit their potential. In mathematics education, boys already have the edge. It is important that the classroom teacher provide inclusive strategies which benefit both genders to allow for maximum student learning.

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