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Impacting Middle School Girls' Interest and Achievement in Math:

Research on a Piloted Pre-engineering Program

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Abstract

A female's college and career goals may ultimately be restricted by declining interest and achievement in mathematics that originates during her pre-high school years. This researcher examined how a piloted pre-engineering program in one eighth grade middle school team impacted adolescent girls' interest and achievement in mathematics. The results suggest that Project Lead The Way (PLTW) impacted both boys' and girls' interest and achievement in mathematics. In five of seven attitude scales, PLTW had a positive effect on gender that was not paralleled in the control group. When achievement was considered, differences in growth levels between the two groups were statistically significant in six of the 11 standards in the experimental group. As this educational research was undertaken to assist local decision makers in supporting or opposing a district adoption of PLTW for all middle school students, effectively communicating the results to the various stakeholders in an engaging, useful manner was paramount.

Keywords: mathematics education, girls, pre-engineering

Impacting Middle School Girls' Interest and Achievement in Math:
Research on a Piloted Pre-engineering Program

Study Purpose

Lack of interest and low achievement in mathematics at the middle school level eventually results in a disparity in the number of females who pursue engineering and other STEM (Science, Technology, Engineering, and Mathematics) fields, ultimately impacting our society. Between 2004 and 2014, the percentage of females earning a Bachelor's Degree in Engineering has decreased (from 20% to 19%), as well as has the percentage of females in Computer Sciences (23% to 18%) and five related disciplines (National Student Clearinghouse Center, 2015).

In the document *2004 College-Bound Seniors: A Profile of SAT Test-Takers* (The College Board, 2004), 84,317 students (9% of all test-takers) stated that engineering was their intended college major. Of that population, however, 84% were males, leaving only 13,490 of the country's high school senior girls (16% of the population selecting engineering as their intended major) to potentially enter this field. By 2015, 150,874 (11% of all test-takers) stated that engineering was their intended college major (The College Board, 2015). Of all U.S. college undergraduates who chose a major in the Academic year 2011–12, 9.2% of males selected engineering, while only 0.9% of females did (National Science Foundation, 2016). Actual graduation rates from engineering programs show similar trends. A 2002 study by the American Association of Engineering Societies showed only 14,102 (20.54%) of the country's 68,648 engineering bachelor's degrees were awarded to women, and only 10.99% (15,097 of 77,701) of the engineering technology bachelor's degrees (Goodman & Cunningham, 2002). By 2004, 20%

of all engineering degrees were earned by women, but by 2014, that percentage had dipped to 19% (National Student Clearinghouse Research Center, 2015). Research additionally shows that, while 62% of men in college engineering programs earn their degree, only 42% of women do (Goodman & Cunningham, 2002). It also indicates that retention of females in college engineering programs is at least partially impacted by a lack of pre-college experience and knowledge in engineering.

Is achievement in mathematics at least partially to blame for this gender-linked imbalance in enrollment and retention in engineering programs? Interestingly, while 54% of 2015 SAT participants indicating they have taken more than four years of math in high school are females, their mean mathematics score is 496, compared to 527 for males (The College Board, 2015). This data is both puzzling and concerning.

Why is it so important that we increase the number of women in STEM, particularly engineering, fields? "One's creativity is bounded by one's life experiences," according to William A. Wulf, president of the National Academy of Engineering (Wulf, 1998, para. 26). As females bring different life experiences to the table by virtue of their gender, the field of engineering, as well as other male-dominated domains, suffers in the end from opportunities lost when women are not part of the innovation teams. The nation's schools, ultimately, have both the opportunity and capability to improve this unacceptable situation. Moreover, as organizations that purport to serve all students, they have an obligation to attend to our girls and meet their educational needs. Finally, school leaders, as change agents, have a moral responsibility to implement innovative programs that will address the inequities inherent in the mathematics education of females in the United States that persist into the 21st century.

The White House is assisting in this endeavor. In the *Federal Science, Technology, Engineering, and Mathematics (STEM) Education 5-year Strategic Plan*, it states that it:

...sets out ambitious national goals to drive Federal investment in five priority STEM education investment areas: 1. Improve STEM Instruction: Prepare 100,000 excellent new K-12 STEM teachers by 2020, and support the existing STEM teacher workforce; 2. Increase and Sustain Youth and Public Engagement in STEM: Support a 50 percent increase in the number of U.S. youth who have an authentic STEM experience each year prior to completing high school; 3. Enhance STEM Experience of Undergraduate Students: Graduate one million additional students with degrees in STEM fields over the next 10 years; 4. Better Serve Groups Historically Under-represented in STEM Fields: Increase the number of students from groups that have been underrepresented in STEM fields that graduate with STEM degrees in the next 10 years and improve women's participation in areas of STEM where they are significantly underrepresented; and, 5. Design Graduate Education for Tomorrow's STEM Workforce: Provide graduate-trained STEM professionals with basic and applied research expertise, options to acquire specialized skills in areas of national importance, mission-critical workforce needs for the CoSTEM agencies, and ancillary skills needed for success in a broad range of careers.

(STEM Education National Science and Technology Council, 2013, p. viii)

Science, Technology, Engineering, and Mathematics (STEM) education has been shown to positively impact student learning. A recent meta-analysis of 28 studies, including this researcher's, reveal that integrative approaches among STEM subjects have positive effects on the students' learning, due to the "student-centered learning context provided by integrative approaches" (Becker & Park, 2011, p. 31).

The primary purpose of this mixed-methods study was to determine if the pre-engineering program Project Lead The Way (PLTW) could positively impact adolescent females' attitudes towards mathematics, as well as achievement in mathematics, at one suburban New England middle school. During a pilot, a triangulation of data was collected through student surveys, student assessments, student and teacher interviews, and classroom observation results.

A secondary purpose for this this educational research was to assist local decision makers in supporting or opposing a district adoption of PLTW for all middle school students, as eighth grade CMT math scores were both dismal and reflective of national trends regarding math achievement and gender. For this reason, effectively communicating the results to the various stakeholders in an engaging, useful manner was paramount.

The empirical research outcomes of this and other action research must be communicated to the research community, as well as shared with educational leaders and stakeholders, in multiple formats, including engaging visual representations, so that decisions regarding program adoption, funding, and support may be justified.

Theoretical Framework

Professional literature recognizes the role of both nature and nurture in math achievement.

Biological theoretical perspectives suggest that math achievement is tied to the gender one is assigned at birth. Sex-linked causes of lower levels of success in the area of math by females include iron deficiency (Iron Deficiency, 2010), spatial visualization (Adams, 1998), speed of math fact retrieval (Royer & Wing, 2002), and brain structure (Gurian & Stevens, 2004).

Social theoretical perspectives state otherwise. These propose that attitudes impact achievement, as confidence, expectations, and attributing success to ability rather than effort are factors that contribute to discrepancies in boys' and girls' math abilities and scores (Ai, 2002; Atweh, Forgasz, & Nebres, 2001; Stipek & Gralinski, 1991). Math anxiety is considered to be “the key social attitudinal variable that might account for sex differences in achievement and enrollment in mathematics courses” (Eccles & Jacobs, 1986, p. 375). Stereotype threat has been cited as one influencer of female students' attitudes towards mathematics. It has been learned that the type of information girls received prior to participating in a math test, regarding their gender-related inaptitude, had a significant effect on both expectancy and performance in a series of experiments (Cadinu, Maass, Frigerio, Impagliazzo, & Latinotti, 2003, p. 275).

Engaging in gender-neutral programs that encourage a growth mindset (Dweck, 2006, 2008) can serve to eliminate these barriers to a female's success in mathematics classrooms. These include STEM programs that contain these female-selected features: “hands-on experiences, project-based curriculum, curriculum with real-life applications, and opportunities to work together” (Boaler, 2016, p. 103).

Literature Review

At ages 9 and 13, the achievement levels of girls are “higher in reading, similar in mathematics, and lower in science than those of males” (U.S Department of Education, 1995, para. 1). These differences, unfortunately, persist into the high school years, eventually causing the gap to widen even more. The 1992 National Assessment of Educational Progress (NAEP) scores show females' reading proficiency 12 scale points (about one and one-half years of schooling) higher than for males, while in mathematics and science, males outperform females by 4 scale points (about half a year of schooling) and 10 scale points (one year's worth),

respectively. On the 2003 NAEP, males surpassed females in mathematics by 3 scale points at grade 4 and 2 scale points at grade 8: a gap that was not found to be statistically different from the gap in any of the previous assessment years (National Center for Education Statistics, 2005). By 2015, males surpassed females in mathematics by 2 scale points at grade 4 but 0 scale points at grade 8. However, students scoring in the advanced range (9% of grade 4 males versus 6% of grade 4 females; 9% of grade 8 males versus 8% of grade 8 females) and proficient range (42% of grade 4 males versus 38% of grade 4 females; 34% of grade 8 males versus 33% of grade 8 females) mirror these traditional differences (National Center for Education Statistics, 2015).

The aforementioned discrepancy in 2015 SAT scores, in which boys outperformed girls on the math component of the test by 31 points (the amount was 36 in 2004), is not a new phenomenon. Since the test was first introduced and normed as the Scholastic Aptitude Test in 1941, males' scores have surpassed females' (Frisch-Kowalski, 2003, p. 2). Grade 12 NAEP scores similarly show this inconsistency, with 26% of males and 23% of females scoring at or above proficient, and 3 points (153 versus 150) separating their average scale scores (National Center for Education Statistics, 2015).

What could possibly be a reason for these incongruities?

Biological Factors Impacting Math Achievement

Gender has long been cited as a plausible reason for the reported discrepancies in math abilities and scores among boys and girls. Indeed, many studies have focused on the role gender plays in perceptions of confidence, expectations for success, and the attribution of success to effort over ability in math classes, with females exhibiting less confidence and lower expectations, and attributing failure to low ability (Ai, 2002; Atweh et al, 2001; Stipek & Gralinski, 1991). Gender, however, as the sole factor in this enigma surrounding girls and

mathematics is disputable, with relatively few studies suggesting that sex alone is responsible for the math achievement gap between boys and girls. In fact,

In 1989, the National Research Council of the United States dismissed the “biological determinism” of sex differences in mathematics, citing evidence from the vast majority of studies finding “almost no differences in performance among male and female students who have taken equal advantage of similar opportunities to study mathematics.”

(Campbell, n.d., para. 1)

Three years earlier, the British Royal Society (1986) expressed similar sentiments when it announced, “There is no convincing evidence of innate gender differences in mathematical ability” (para. 1).

The problem with research in this area surrounds the area of semantics. *Sex* and *gender*, according to Fennema (2000), are not the same thing.

While the meaning and use of words is a murky area, when I use the word *sex*, I am referring to biologically determined behaviors. When I use the word *gender* I am inferring social or environmentally causation of behaviors that differ for females and males. Of course, it is impossible to totally separate social and biological influences and perhaps it isn't always necessary. However, I shall try to be consistent even though I am sure that my mixing of the two words will reflect the complexity of sorting out of learning differences between males and females. (para. 3)

Differences, then, attributed to gender are not the same as differences attributed to sex.

An example of research concentrating on sex-related, or biologically-determined, differences in math ability or achievement between boys and girls can illustrate this distinction. A study of 5,398 children, aged 6 to 16, at the University of Rochester School of Medicine and

Dentistry found that children with an iron deficiency were more than twice as likely to score below average on a standardized math test as those who were not. Not surprisingly, iron deficiency is more prevalent among girls (8.7% of the girls in the study, compared to only 3% of the boys), as adolescent girls' poor dietary intake, menstrual blood loss, and high iron requirements make them more susceptible (Iron Deficiency, 2001). While this study suggests that, in this case, math ability and achievement may be sex-related, the evidence supports the case that sex alone is rarely accountable for discrepancies between boys' and girls' achievement in mathematics. Additionally, if iron alone is responsible for this anomaly, iron supplements can easily be prescribed to alleviate the effects that a deficiency initiates.

Spatial visualization, the mental manipulation of three-dimensional objects, is a cognitive variable that may affect gender-related differences in mathematical ability. While researchers have, for years, attempted to attribute the discrepancy to biological makeup, it is actually a skill that can be developed through exercise and practice (Adams, 1998). Researchers believe that types of play to which boys are "naturally" drawn - blocks, etc. - may actually assist the development of spatial ability (Adams, 1998; Gurian & Stevens, 2004; Whyte, 1986). Girls, then, can improve in this skill area by engaging in games and play that support it.

Another interesting study suggests that it is the speed of math-fact retrieval that contributes to sex differences in math test performance in select populations (Royer & Wing, 2002). "The variance distributions for students in grades 4 through 8 indicated that select males (those from the top half of the distribution) were faster at math fact retrieval than select females" (para. 12). Royer traced the sex differences in these select males back to grade 4 and hypothesized that the differences "must come from boys (but not girls) engaging in some out of school activity that provided practice on the retrieval of math facts" (para. 16), as well as from

boys entering first grade with a preference for retrieving math facts from memory. The speed of math fact retrieval ultimately may impact on math test performance, as most math achievement tests are timed. Additionally, high-level math reasoning

places great demands on working memory while holding together a problem representation during the problem solving process. Slow and effortful math-fact retrieval could stress the cognitive system even more, creating a situation where the problem representation falls apart and has to be reinstated, thereby losing valuable time during the testing process. (Royer & Wing, 2002, para. 14-15)

In other studies, positron emission tomography (PET) and MRI technologies have found structural and functional differences in the brains of males and females that may help explain their documented differences in their math-learning ability, as well as other subjects. Girls' corpus callosums, for example, are up to 25% larger than boys by adolescence, enabling more "cross talk" between hemispheres. They have stronger neural connectors in their temporal lobes than boys, leading to "more sensually detailed memory storage, better listening skills, and better discrimination among the various tones of voice" (Gurian & Stevens, 2004, p. 22), resulting in greater use of detail in writing assignments. Girls also use more cortical areas of their brain for verbal and emotive functioning. Boys use more cortical areas of their brain for spatial and mechanical functioning. They have less serotonin and oxytocin, the human bonding chemical, making it "more likely that they will be physically impulsive and less likely that they will neurally combat their natural impulsiveness to sit still and emphatically talk with a friend" (p. 23). Additionally, "the male brain is better suited for symbols, abstractions, diagrams, pictures, and objects moving through space than for the monotony of words" (their brains enter frequent neural rest states to recover from the latter), thus helping illustrate why boys learn math and

physics better when taught abstractly on a chalkboard, among other things (p. 23). As in the other sex-related reasons for females' diminished mathematical ability already mentioned, this research depicts differences for which specific supports may be prescribed.

While all these studies suggest biological reasons for the reported discrepancies in math abilities among boys and girls (which can rather easily, as described above, be remedied through external interventions), it is currently widely believed that social and attitudinal factors impact on junior and senior high school students' grades and enrollment in mathematics courses (Eccles & Jacobs, 1986).

Social Factors Impacting Math Achievement

Math anxiety has been cited as “the key social attitudinal variable that might account for sex differences in achievement and enrollment in mathematics courses” (Eccles & Jacobs, 1986, p. 375). This anxiety stems from internal belief systems relating to confidence, perception of the usefulness of mathematics, fear of success, and attributional style (Fennema & Leder, 1990). Girls in seventh through ninth grade express more anxiety about math than boys, while boys have been found to have higher expectancies for success in math and stronger intentions to keep taking math when they no longer have to (Heller & Parsons, 1981; Meece, Wigfield, & Eccles, 1988). These internal belief systems also lead high-ability girls to perceive that they receive more support and encouragement than lower-ability girls, resulting in greater self-confidence and achievement (Love & McVey, 2001).

Some research suggests that the difference in math anxiety between males and females is close to zero, and that the widely accepted belief that females have more negative attitudes towards mathematics than males is a manifestation of the stereotypical belief that women are more emotional than men (Hyde, Fennema, Ryan, Frost, & Hopp, 1990). Indeed, in a recent

study of first grade children in Italy (Galdi, Cadinu, & Tomasetto, 2014), students colored a picture (boy correctly does math, girl correctly does math, or landscape), played a computer game, performed eight math calculations, and finally looked at a picture of a boy and girl. They were then asked, "These are a boy and a girl. They are 6-year-olds and they are good at school. Is the boy better at math, the girl better at math, or are they the same at math?" The outcome was that the majority of children across conditions indicated their gender as superior in math, indicating that there were no stereotypical automatic associations yet.

However, while research suggests "there is no difference in girls' and boys' self confidence in their mathematical ability in the primary grades,...by grade six, boys have more confidence, even though their math test scores and grades are not any higher than those of girls" (Research and Educational Planning Center, 1990, p. 3). Sherman (1983) maintains that "it is neither anxiety nor lack of ability that keeps women from mathematics" but rather "a network of sex-role influences which makes mathematics, and the careers mathematics are needed in, appear incongruent with the female role, especially with motherhood" (p. 342). Despite the cause, the negative attitudes are very real and debilitating.

Convincing students that math ability is not a gift, but something that can be nurtured, was the focus of a study completed by growth mindset guru, Dr. Carol Dweck.

In our [8-week] intervention [for junior high students] (based on one by Joshua Aronson: Aronson, Fried, & Good, 2002), we taught students about the brain, how it forms new connections every time they learn, and how over time this can lead to increased intellectual skills. We also taught them how to apply this lesson to their schoolwork. Students in the control group received an eight-session intervention, as well, replete with high-quality instruction in useful skills, but they did not learn about the expandable

nature of intellectual skills. (Dweck, in S.J. Ceci & W. Williams (Eds.) (2006), page numbers not given)

The role of the teacher in affecting attitudinal factors in girls is paramount. "Teachers' attitudes, expectations, and treatment of students definitely affect students' confidence, aspirations, and other mathematics-related attitudes" (Research and Educational Planning Center, 1990, p. 144). Differential treatment of boys and girls in mathematics classes factor highly in girls' success (or lack of it) in math (Fennema & Leder, 1990). This differential treatment may include such behaviors as teachers' patterns of questioning in urban fourth grade classrooms (Wimer, Ridenour, Thomas, & Place, 2001), teachers' failure to alter girls' patterns of engagement by encouraging them to diversify their self-selected roles when working collaboratively with boys in seventh grade classrooms (Atweh et al., 2001), and teachers' encouragement of girls in seventh through tenth grade classrooms (Ai, 2002). While, according to one study, sex differences in evaluative feedback do not appear to exist in junior high school mathematics classes (Heller & Parsons, 1981), feedback must be considered when examining the "whole teacher" and his/her behaviors as they are perceived by girls. This perception may even extend to the role teacher gender plays in affecting girls' interest in mathematics (Stone, n.d.). Additionally, seventh and eighth grade students of both genders who are either cognitively or socially unsure of themselves may avoid seeking help in math class (Ryan & Pintrich, 1997): a research finding that must be addressed when teachers reflect on the behaviors they employ to encourage students in math classes.

Stereotype threat, especially the effect of expectancy on performance, is another "potential mediator of performance deficits" (Cadinu, Maass, Frigerio, Impagliazzo, & Latinotti, 2003, p. 267). This group found that, for women who considered logical mathematical abilities

important (i.e., greater than social ability or creative ability), the type of information they received prior to participating in a math test had a significant effect on both expectancy and performance in a series of experiments. In the negative information condition, on tasks that evaluate logical-mathematical abilities, women were told that gender studies show that females obtain lower scores than males. In this case, female participants “showed a sharp decrease in performance compared to the positive and control conditions” (pp. 275-276). In a different study, researchers studying stereotype threat found that women did not score as high as men on a word problem test, as stereotype threat interfered with “women’s ability to strategize and convert the problems” into their numerical mathematical equivalents (Quinn & Spenser, 2001, p. 62). When tested on the word problems’ numerical mathematical equivalents, however, women and men performed equally well.

A study of situational factors that influence females’ math performance concluded that “the presence of males constitutes a threatening intellectual environment for females performing a math task, and specifically that women experience a greater deficit in their math performance the more males there are in the environment” (Inzlicht & Ben-Zeev, 2000, p. 370). Women completing a difficult verbal test performed equally as well in three-person groups consisting of themselves and two males, themselves and two females, and themselves and one other female and a male. When the task was a difficult math test, however, females’ test performance became a function of the number of males present, with performance deteriorating as the number of males increased.

Parents, teachers, boys, and girls unconsciously succeed in sustaining the view that technology, too, is a male domain (American Association of University Women, 2000). Sanders (1995) suggests that it is an accumulation of subtle differences, “powerful and at the same time

so often unrecognized” (p. 149), including male-oriented computer language (boot, hard-drive, crash), parental factors (more computer purchases for male children than female, greater access to summer computer camps for males), curriculum factors (biased software, computer programming devoid of application to life), biased teacher behaviors (calling on boys more than girls, verified by this researcher), and peer attitudes (sexist jokes, female need for same-sex peers in their setting), that lead to the absence of females in computing environments.

Despite the overwhelming evidence that females are at a distinct disadvantage in mathematics, whether due to biology or societal/environmental factors, they are not destined to failure. All of the cited research shows that females can overcome these obstacles.

STEM programs which engage females may serve to foster both achievement in, and positive attitudes towards, mathematics. The National Girls Collaborative Project (NGCP) advocates for the adoption of programs that are accessible, research based, show evidence of success, and are girl centered (Engaging Girls in STEM, 2016).

It is alarmingly apparent that school leaders must “challenge the math process,” a la Kouzes and Posner (2002), if the two critical problems discussed above – gender and mathematics achievement and gender and mathematics attitudes - are to be successfully addressed. Principals and superintendents must demand that STEM programs in general, and mathematics programs in particular, be developed or redesigned to provide girls with the appropriate opportunities and experiences they need to develop positive attitudes towards and high levels of successful achievement in math.

Methodology

This quasi-experimental study utilized a mixed-methods approach using data collected from a convenience sample of non-equivalent groups that included all of the students on two of

the three eighth grade teams in the middle school. A treatment, Gateway To Technology, or GTT (the middle school component of the pre-engineering program Project Lead The Way, PLTW), was provided to the students on one of the teams. This study focused on how participating girls' attitudes towards and achievement in mathematics changed during the course of the school year, as compared to girls who were not program participants. The study was conducted within a single school year.

The research design initially involved the use of the pre-test/post-test control group design. All 299 eighth graders at Wildcat Middle School (WMS) were given a pre-test (Test 1 of the mathematics component of the Blue Ribbon Testing© program) to determine their current level of mathematics achievement by standard. At the time the research was conducted, Blue Ribbon Testing© was Connecticut Mastery Test (CMT) Diagnostic software built from the Connecticut Framework that could be used throughout the school year to assess students' readiness for the CMT. All eighth graders also participated in an administration of seven of the Fennema-Sherman Mathematics Attitude Scales.

Focus groups and classroom observations were conducted by the researcher at the end of the school year to provide the qualitative data that were juxtaposed with the quantitative data, necessary for triangulation.

Treatment (Program)

An experimental group (one of the three eighth grade teams) received the treatment, which consisted of the Project Lead The Way's Gateway to Technology middle school curriculum (which will simply be called PTLW from this point forward) added to its daily schedule as a fifth academic class for the entire school year (four marking periods). PLTW began at a Clifton, NY high school in New York in 1986 as a pre-engineering program. It spread to 12

NY high schools by 1997, was field tested in 3 middle schools in 1998, and was utilized in 671 schools in 31 states by May 2003. It is currently available, and used in varying amounts, in all 50 states, D.C., and U.S. territories, in 9000+ schools, and has impacted 2.4 million students and 35,000+ teachers (PLTW, State by State, 2016). It should be noted that one of the goals of PLTW has been “to increase interest and awareness of females and minority students in technology and related careers” (National Alliance For Pre-Engineering Programs: Project Lead The Way, 2003, p. 4).

Two complete modules were delivered by the Technology Education teacher during the course of the school year: Design and Modeling and The Science of Technology. While more had been planned - The Magic of Electrons and Automation and Robotics – the Technology Education teacher’s extended illness prevented their delivery.

The control group (one of the other two eighth grade teams, consisting of 99 students) took the school district’s traditional middle school “success area” classes as its fifth class: two marking periods of art, one marking period of computers, and one marking period of family and consumer science. The sixth and seventh periods of the day contain physical education, health, music, and foreign language or reading classes. At the end of the school year, all students took the post-test (Test 3 of the mathematics component of the Blue Ribbon Testing© program) to determine level of mathematics achievement by standard. They also all participated in a second administration of the Fennema-Sherman Mathematics Attitude Scales.

Throughout the 2004-05 school year, all 179 eighth grade students in the study continued to receive the supplementary services to which they were entitled. Title I tutors, afterschool math help (AfterMath Program), special education services, 504 plans, and so on were available to

students whose special education or regular education individualized instructional plans (IEPs) required them. A proportionate number of students received these services on each of the teams.

Sample and Participant Selection

As PLTW was piloted by an eighth grade team that contained three “flex” (heterogeneous) classes, one eighth grade ALP (Advanced Learning Program) class, and one seventh grade ALP class, the seventh grade class was excluded from the analysis. In addition, girls and boys from one of the other eighth grade teams, which had a total of four flex classes and one homogeneous class grouped by Algebra aptitude (based on the successful completion of Pre-Algebra in grade 7) were included in a comparison of attitudes. (Note: all seven of the eighth grade flex classes in the study followed the same mathematics curriculum.) As all eighth graders were randomly placed on their teams by guidance counselors the spring preceding the school year, the average ability levels of the girls on the team piloting PLTW were the same as on the other two teams in the school. This was checked at the beginning of the study, using seventh grade “off-year CMT” scores and report card grades. In all, 179 of the school’s 299 eighth grade students (two eighth grade teams) were initially involved in the study. By June, 156 pre- and post-scores on the Fennema-Sherman Mathematics Attitude Scales and 134 pre- and post-scores on the mathematics component of the Blue Ribbon Testing© program had been obtained for analysis.

Data Collection

Data were collected in several ways. Mathematics achievement was determined through Blue Ribbon Testing© test results, which were obtained from the reports generated by this CMT diagnostic computer software program that is tightly correlated to Connecticut state standards. Areas tested were: number sense, operations, estimation and approximation, measurements,

spatial relationships and geometry, probability and statistics, patterns, discrete mathematics, and integrated understandings. An initial administration to students during the first week of school, based upon availability of the computer lab and/or wireless computer lab, generated baseline student data. A second testing occurred in January, while a final administration of the test was scheduled in early June (between June 1 and 9), again based upon computer lab and wireless availability. Only scores generated from the first administration (pre-test) and final administration (post-test) of Blue Ribbon Testing© were considered in this study. Scoring reports can be generated by individual student, by individual classrooms or by entire teams. For this study, however, team scores were used, as fluidity in classroom assignments of students had resulted in changes from the original groupings.

Student attitudes towards, and subsequent interest in, mathematics were measured through the use of Fennema-Sherman Mathematics Attitude Scales (FSMAS) and student focus groups. The initial rigorously standardized administration of the FSMAS was conducted by homeroom/advisory period teachers on the same day (September 14), at the same time (8:30a.m., during the advisory period) for all eighth grade students, prior to the September implementation of the CMT math subtests as well as to the commencement of the piloting of PLTW. The second administration of the FSMAS occurred at the end of the school year under the same rigorously standardized conditions. The researcher organized the collected data in a spreadsheet.

Eight focus groups (four per team, two per classroom) were conducted by the researcher over three days in June to determine students' attitudes towards mathematics, as well as their views on what contributed to those attitudes. These sessions were approximately 25 minutes in duration and were tape-recorded. PLTW was discussed in those focus groups containing the girls or boys who had piloted it. While interviews were considered as a possible means of collecting

these data, the potential for students to hesitate in providing information to their principal (the researcher) in a one-on-one setting was carefully considered. In agreement with research, which mandates qualitative research to concentrate “on words and observations to express reality and attempts to describe people in natural situations. where their disclosures are encouraged in a nurturing environment” (Lewis, 1998, para. 6), the focus group interviews were held in the main office conference room, as many groups of WMS students have participated in problem-solving meetings with the researcher in that setting. The number of students per focus group ranged from 1 to 11, with the original goal of each of the 8 focus group interviews conducted to contain alternately the entire population of either girls or boys from 2 established classes per team: one flex class and the Geometry class from the experimental group (the team piloting PLTW), and one flex class and the Algebra class from the control group. These groups, then, were “naturally occurring,” rather than drawn together specifically for research; thus, the members could relate to or even challenge each other’s comments (Kitzinger, 1995, para. 15).

Two classroom observations were conducted (on May 31 and June 1) of each team’s mathematics classes (the Algebra class in the control group, the Geometry class in the experimental group, and one flex class from each group), totaling four classroom observations, in order to collect data on the types of questioning the teachers utilized (i.e., higher-order or lower-order), the gender of the respondent, the seating of the respondent, and whether the respondent was called upon by the teacher or had volunteered an answer. Seating charts were also sketched by the researcher during the class period. With these data, it was determined whether student gender plays a role in the determination of teacher questioning, teacher selection of the respondent, and student seating. While the researcher attempted to collect these data, via note-taking and scripting, as a complete observer from the rear of the classroom, there was sensitivity

to the fact that the mere presence of the researcher in the classroom, as the school's principal, relegated her role to being observer-participant.

A teacher focus group interview using semi-structured questions was conducted on June 13 after all other data had been collected. This interview with two participants (the two eighth grade mathematics teachers), which was tape recorded, generated data on teachers' reflections of their instructional practices, as related to student gender. Again, while individual interviews were considered by the researcher, a focus group interview was selected as the method of data collection since it is "popular with those conducting action research and those concerned to 'empower' research participants because the participants can become an active part of the process of analysis" (Kitzinger, 1995, para. 10). In this way, participants could share experiences and anecdotes, identify and define problems in conducting gender-neutral classrooms, and assist with interpretation of quantitative findings (Mahoney, 1997, chap. 3). While the inclusion of the Project Lead The Way teacher in the focus group would have been optimum, he was absent due to an extended illness during that time.

Instrumentation

The researcher used several data collection instruments to identify student interest and achievement in mathematics. They included:

- seven of the nine Fennema-Sherman Mathematics Attitude Scales;
- student focus groups;
- Blue Ribbon Testing© scores in mathematics (teachers administered one test in September, 2004, during the first two weeks of school, to all eighth graders, and issued subsequent tests in the winter and spring; only fall and spring scores were examined);
- classroom observations; and

- teacher focus groups.

Seven of the nine Fennema-Sherman Mathematics Attitude Scales were used to determine girls' attitudes toward mathematics, both over time within the PLTW classroom and as compared to girls not participating in the program. These scales were developed by Elizabeth Fennema and Julia A. Sherman in 1976. The scales, each of which contains positive and negative statements on a five-point, Likert-type scale that ranges from "strongly agree" to "strongly disagree," provided information about girls' attitudes towards mathematics in the following categories: personal confidence about learning mathematics, success in mathematics, perception of teachers' attitudes towards the respondent in the subject, perception of the subject as a male domain, perception of the usefulness of the subject matter, anxiety towards mathematics, and motivation in mathematics. Split-half reliabilities for the scales, which were not renormed, ranged from .86 and .93. Construct validity was determined at the time of scale construction and validated by factor analysis. Intercorrelations among eight of the nine scales by sex "indicated that while the scales are interrelated, each scale measures a somewhat different construct... [and] appeared to be approximately the same for both sexes with all differences between the sexes nonsignificant" (Fennema & Sherman, 1976, p. 9). These correlations ranged from .17 to .66. The ninth scale (the Anxiety Scale), however, correlated .89 with the Confidence Scale. By using this instrument with both boys and girls in mathematics classrooms, the researcher was able to ascertain whether the female students at the middle school mirrored universal attitudes towards mathematics, which tend to be more negative than those of males.

These attitudes were further explored in semi-structured student focus groups, conducted by the researcher, during which a focus on interest in mathematics and the mathematical concepts addressed in the PLTW middle school units was stressed. In addition, students' views

towards mathematics achievement, as well as their views on what has contributed to changes in achievement, were investigated.

Blue Ribbon Testing© scores were utilized to determine growth in achievement in mathematics, as indicated by mastery levels of the 11 standards assessed over the 8 months between the first and third administrations of the test. The 11 standards tested are: number sense; operations; estimation and approximation; ratio, proportion, and percent; measurement; spatial relationships and geometry; probability and statistics; patterns; algebra and functions; discrete mathematics; and integrated understandings. Each test consists of 40 questions, with results also reported by question breakdown. Validity was established and published in a report:

No system can forecast the exact performance of students on a test. However, by taking a similar test of varying question types, it is possible to get a good indication of their placement. This analysis has shown that Blue Ribbon, with a level of confidence, determined the weakest skills, forecast the weak strands, and forecast the level breakdown on the actual CMT at the school level. (Blue Ribbon LLC, 2004, p. 11)

Within the eighth grade mathematics classrooms, student participation was charted by gender and organized by whether a student:

- initiated a question,
- volunteered to answer a question,
- was called upon to answer a question and did
- was called upon to answer and did not.

During the four classroom observations at the end of the school year, seating charts were sketched, indicating the positioning of male and female students in the classroom. This indicated whether females were clustered by gender or whether they were interspersed throughout the

classroom. In addition, the type of questioning the teachers utilized (i.e., higher-order or lower-order) was collected in the researcher-generated data collection chart. All observations were conducted by the principal/researcher, whose presence in mathematics classrooms is not unusual.

The researcher shared the results with teachers in a focus group interview in June, prompting a discussion on the context in which mathematics concepts were introduced along with corresponding interest levels of students. These interviews were semi-structured, and questions were developed by the researcher.

Data Analysis and Results

Mathematics attitudes data collected from the two administrations (pre- and post-) of the seven Fennema-Sherman Mathematics Attitude Scales was analyzed. Male and female students' scores on the various scales were initially compared to normed scores using *t* tests, to test for the typicality of Wildcat Middle School students. Next, the adjusted scores of the students piloting PLTW were compared to those that were not through the use of a MANCOVA (multivariate analysis of covariance), in order to equalize the groups that, through randomization of assignment, were similar but not equal. Interactions and main effects were noted at that time. Analyses of covariances (ANCOVA) on each dependent variable (univariate analyses) were conducted as follow-up tests to the MANCOVA. Using the Bonferroni method, each ANCOVA was tested at .05. Significant differences in any of the seven attitudes scales demonstrated by the females piloting PLTW were noted. Trends emerging from the data were examined. Student focus group interviews were conducted, with collected data organized, coded, and analyzed by themes. Classroom observations were analyzed through the use of a verbal flow chart and classroom seating chart. Data from teacher focus groups were organized by categories and

themes, and finally coded for analysis. The results of the initial and final Blue Ribbon Testing[®] were also analyzed.

As with the attitude scales, male and female students' scores on the various achievement subtests were initially compared to normed scores using *t* tests, to test for the typicality of Wildcat Middle School students. Next, the adjusted scores of the students piloting PLTW were compared to those that were not through the use of a MANCOVA (multivariate analysis of covariance), in order to equalize the groups that, through randomization of assignment, were similar but not equal. Interactions and main effects were noted at that time. Analyses of covariances (ANCOVA) on each dependent variable (univariate analyses) were conducted as follow-up tests to the MANCOVA. Using the Bonferroni method, each ANCOVA was tested at .05. Significant differences in any of the eleven achievement subtests, or strands, demonstrated by the females piloting PLTW were noted. Trends emerging from the data were examined.

In all, a total of four eighth grade classes comprised the experimental group (three flex and one ALP Geometry), grouped by gender, and five eighth grade classes (four flex and one Algebra) comprised the control group, also grouped by gender.

Holistic scores were not used as certain subscores may be more sensitive to the implementation of PLTW than others.

The statistical unit normally used in a study of this type would be the mean of each class (X), as each unit of large group instruction is unique in its interactions. However, in this limited study in which only four classes were piloting Project Lead The Way, the use of the classroom as the instructional unit was not feasible. Therefore, the constraint of research dictated the use of the mean of each group, by gender, as the statistical unit.

The results of data analysis indicated that curriculum does significantly impact students' achievement in mathematics. Students collectively exposed to the pilot curriculum, PLTW, showed improvement in achievement as compared to students who were not exposed to PLTW.

Impact of Curriculum on Achievement

A MANCOVA was first implemented to determine main effects and interactions. This enabled the researcher to look at the effect of the program on students' achievement across all the different components of "achievement in mathematics." Analyses of covariances (ANCOVA) on each dependent variable were then conducted as follow-up tests to the MANCOVA. Using this step-down method, the researcher could look at the effect of the program within each of the components of "achievement in mathematics." An examination of general trends next followed to further explore relationships among variables. Finally, focus group interviews, classroom observations, and a teacher focus group afforded additional data, as well as insights into behaviors, opinions, and perceptions.

The results of data analysis indicated that curriculum did significantly impact students' achievement in mathematics. In other words, students collectively exposed to the pilot curriculum, PLTW, showed improvement in achievement, as compared to students who were not exposed to PLTW. The results showed significant differences between achievement of students exposed to PLTW and achievement of students exposed to the traditional curriculum on the dependent measure, the Blue Ribbon Testing© results, Wilks's $\Lambda = .80$, $F(11, 105) = 2.26$, $p = .02$. The multivariate r^2 based on Wilks's Λ was strong at .19. This indicated 19% of the variance in the dependent variables was associated with the curriculum.

Trends in Achievement within the Experimental and Control Groups

Trends in the quantitative data showed that the Project Lead The Way curriculum positively impacted student achievement in mathematics. An inspection of differences in pre- and post-Blue Ribbon Testing© scores indicated that students in the experimental group exhibited an improvement in mathematics achievement over the course of the school year.

While statistical data may (and should) be displayed in various tables to describe the results to the research community (and may be viewed in the dissertation on which this paper is based), the intent of this paper was to effectively communicate the outcomes of a study to various school district stakeholders in an engaging, useful manner, per the theme of this NERA conference: "Making an Impact – Effectively Communicating the Results of Educational Research." In an effort to assist local decision makers in supporting or opposing a district adoption of PLTW for all middle school students, this author's potential utilization of appealing yet illuminating visual displays to more fully involve the community at large in digestion-friendly data consumption was contemplated and selected. These appear throughout this section of the paper.

An examination of trends revealed a positive change in the configuration of female achievement. Eleven strands were included as subtests in the Blue Ribbon Testing© program. During the September administration of the pre-test, prior to the piloting of Project Lead The Way, Wildcat Middle School males in the experimental group scored higher than the group's females on all 11 of the subtests: "Number Sense," "Operations," "Estimation and Approximation," "Ratio, Proportion, and Percent," "Measurement," "Spatial Relationships and Geometry," "Probability and Statistics," "Patterns," "Algebra and Functions," "Discrete Mathematics," and "Integrated Understandings." By the end of the school year, the females

outperformed the males in four of the subtests: “Patterns,” “Algebra and Functions,” “Discrete Mathematics,” and “Integrated Understandings” (Figure 1).

	BEGINNING OF SCHOOL YEAR	END OF SCHOOL YEAR
STANDARD	WHICH GENDER SCORED HIGHER?	WHICH GENDER SCORED HIGHER?
Number Sense	M	M
Operations	M	M
Estimation and Approximation	M	M
Ratio, Proportion, and Percent	M	M
Measurement	M	M
Spatial Relationships and Geometry	M	M
Probability and Statistics	M	F
Patterns	M	M
Algebra and Functions	M	F
Discrete Mathematics	M	F
Integrated Understandings	M	F

Figure 1. Gender of experimental group students whose mean average in each standard of Blue Ribbon Testing was higher.

When considering growth in mathematics achievement by individual student, rather than growth in the collective entity (team), the researcher determined that both the experimental group females and males had more students demonstrating improvement than did the females and males in the control group (Figure 2). Over 77% of the experimental group females improved or maintained scores in over half (six or more) standards from the September Blue Ribbon Testing© pre-test to the June post-test, compared to only 45% of the control group’s females. Additionally, the experimental group’s males showed similar results, with 75% of its males improving or maintaining scores in six or more standards, while only 51.3% of the control group’s males did. This corroborates the ultimate finding that PLTW is related to the significant

difference that exists in achievement between those girls exposed to the PLTW curriculum and those girls who were not.

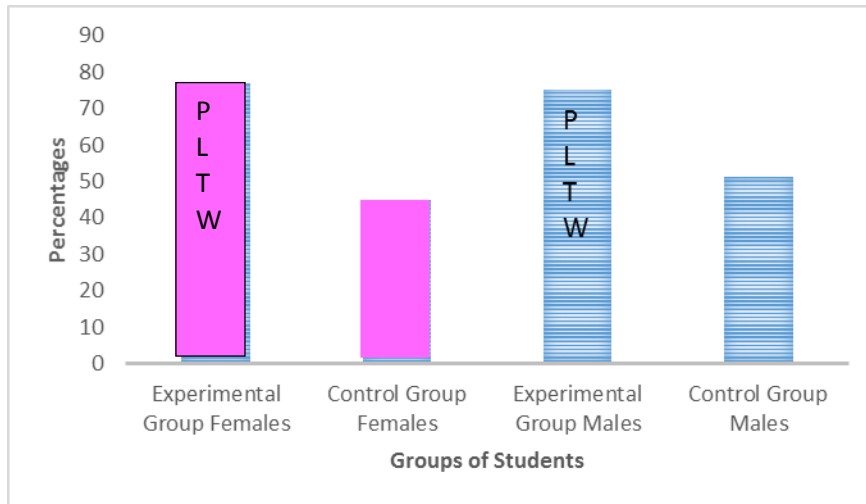


Figure 2. Percentage of students improving or maintaining scores on six or more standards of Blue Ribbon Testing by group and gender.

Impact of Curriculum on Attitudes

The results of data analysis of attitude scales, in which students self-reported their attitudes, indicated that curriculum did not significantly impact students' attitudes towards mathematics when data were aggregated to include males and females ($p > .05$). In other words, self-reporting students collectively exposed to the pilot curriculum, PLTW, did not show any improvement in attitude, as compared to students who were not exposed to PLTW.

The gender-disaggregated data revealed a significant interaction between student gender and curriculum in influencing females' perceptions of their teacher's attitude towards them as learners of mathematics ("teacher") within the experimental group ($F = 6.87$, $p = .01$, $\eta^2 = .045$). Interestingly, these females experienced a significant decline in this attitude over the course of the school year.

Trends in Attitudes within the Experimental and Control Groups

Patterns of increases or decreases in mean attitudes indicated that students in the experimental group experienced improved attitudes towards mathematics over the course of the school year. Males demonstrated higher mean scores in four attitude scales, and females in one attitude scale.

Student focus group interviews supported this finding. Proportionately, the females in the experimental group indicated either a like or love of mathematics (55%) at a two-to-one ratio over the students in the control group (27%) at the end of the school year (Figure 3): a proportion that was also observed in the experimental group males.

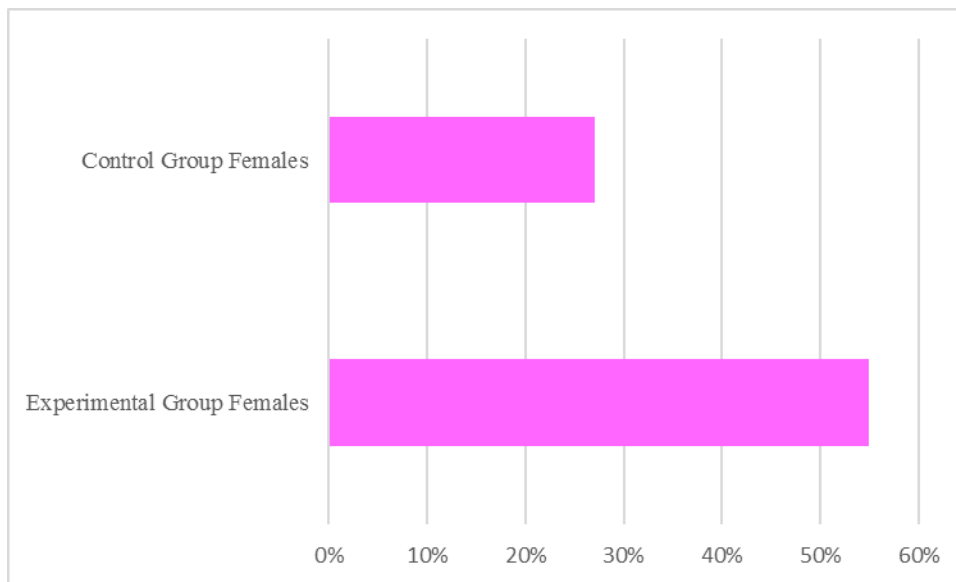


Figure 3. Percentage of females indicating a like or love of mathematics at the end of the school year by group.

The researcher learned what students thought teachers did in their classes to make math either interesting or uninteresting during focus group interviews. The most frequent response for female students was the use of manipulatives, the use of real-world examples, and open-ended

problem-solving. Like the females, the males indicated the use of manipulatives and the use of real-world examples as their primary reasons, but indicated their third highest factor to be playing games: the fourth highest response for females. Other popular responses for the females included projects, the use of contests/competitions, creating/building things, offering different strategies, and allowing students to working groups. Males included creating/building things, projects, and using computer technology (Box 1; Figure 4).

Box 1 – What Do Teachers Do in Classes to Make Math Interesting?

“Projects, *Project Lead The Way*, a page out of Mrs. O’s [4th-6th grade math teacher] book, tie-in activities, like the trip to the Final Four thing – that was cool!”

Experimental Group Student #6 (male)

“Usually teachers try to, in other classes, like social studies and stuff like that, they usually try to put it to a story or something, or try to involve something fun.”

“In social studies we did the Stock Market. That was about selling, buying, adding up all your stocks, stuff like that. That was pretty cool.”

“And awesome.”

Control Group Students #7, 8, 9 (males)

“And a lot of things in elementary school would be, like, hands-on, and we could see it, it would be right in front of us and we’d know what to do with it. But like now we’re just learning off the board and we can’t really take it all in... because it’s not in front of us...”

Experimental Group Student #10 (female)



Figure 4. Frequency of words used by students to describe what they thought teachers did in their classes to make math interesting, with the size of each word indicating its frequency or importance.

Finally, classroom observations indicated that females in the experimental group volunteered to answer questions posed by the teacher in their math classes four times as often (68%) as females in the control group volunteered to answer questions (17%). This corroborated the ultimate finding that PLTW contributed to the significant difference that existed in attitudes between those girls exposed to the PLTW curriculum and those girls who were not (Figure 5).

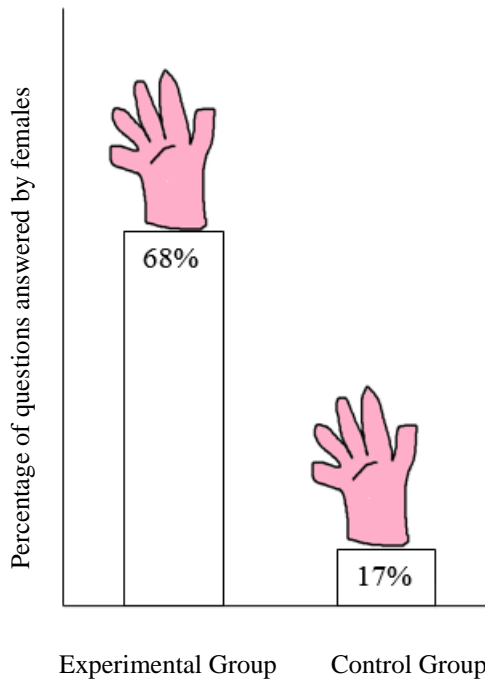


Figure 5. Percentage of questions posed in mathematics classes answered by females at the end of the school year, by group.

Discussion/Conclusions

The Impact of Curriculum on Girls' Achievement in Mathematics

The change in mathematics achievement among the students on the team that piloted Project Lead The Way indicates that the Gateway To Technology curriculum, even when not delivered in its entirety, had a positive impact on achievement in several mathematics standard areas. This growth was not limited to one gender, but evidenced by both males and females piloting the program. Addressing middle school mathematics achievement, then, when there is no gap (as illustrated in national and local data), by nurturing positive attitudes towards it, may be the best way to prevent the attitude and achievement gap that clearly still exists at the high school level.

Spatial visualization is a factor in achievement. “Many [scientists] now believe that traits that seem intrinsic - meaning those grounded in the brain or shaped by a gene - are subject to cultural and social forces, and that these forces determine how a biological trait actually manifests itself in a person’s behavior or abilities” (Whalen & Begley, 2005, para. 6). Spatial visualization, a cognitive variable that may affect gender-related differences in mathematical ability, is a skill that can be developed through exercise and practice (Adams, 1998). Indeed, WISE (Women Into Science and Engineering) suggests that parents buy their daughters scientific and construction toys which “can be just as much fun and have the added benefit of equipping girls for the ever-growing technological demands of today’s classrooms and of modern life” (Toys for the Boys Are Good for Girls, 1998, p. 4). It is plausible that the females in the school district that houses Wildcat Middle school have already been afforded a variety of experiences that assist in the development of spatial visualization: a notion that is supported by some responses provided during the focus group interviews, as well as in the equity of score distribution on CMTs by gender.

The Project Lead The Way Gateway To Technology curriculum offers additional opportunities for the development of spatial visualization. Autodesk Inventor® software, a component of the program, allows students to use solid modeling in the design process (Project Lead The Way Middle School Program, 2005). The Autodesk website states, “With automatic drawing views, you can create front, side, detail, isometric, section, and auxiliary views of your 3D model and then quickly dimension and annotate them” (Autodesk Inventor Series: Overview, 2006).

Observations of students in PLTW indicated an overwhelmingly positive response to Autodesk software. Students are eager to demonstrate their abilities to create detailed drawings

to visitors to the program, as well as explain the various commands necessary to accomplish this. Females, especially, appear proud of their proficiency in this program and of their role as “engineer.”

Brain differences can be overcome. Positron emission tomography (PET) and MRI technologies have found structural and functional differences in the brains of males and females that may help explain their documented differences in their math-learning ability, as well as in other subjects. Boys use more cortical areas of their brain for spatial and mechanical functioning. Additionally, “the male brain is better suited for symbols, abstractions, diagrams, pictures, and objects moving through space than for the monotony of words” (their brains enter frequent neural rest states to recover from the latter), thus helping illustrate why boys learn math and physics better when taught abstractly on a chalkboard, among other things (Gurian & Stevens, 2004, p. 23). Being afforded opportunities to support these brain differences while learning mathematics should be a component of all instructional programs.

The impact of Project Lead The Way on females' ability to learn mathematics is typical of classes that include CAD design instruction. “Learning to design on a CAD system teaches students to think creatively, to ask questions, and to find answers to their own questions” (Thilmany, 2003, para. 6). This was evidenced by the fact that more experimental group females demonstrated improvement than did females in the control group. Over 77% of the experimental group females improved or maintained scores in over half (six or more) standards from the September Blue Ribbon Testing© pre-test to the June post-test, compared to only 45% of the control group females. The males in the experimental group echoed this trend.

The Impact of Curriculum on Girls' Attitudes towards Mathematics

Professional literature related to this topic recognizes the role of attitudes in math achievement. Attitudes certainly impact achievement, as confidence, expectations, and attributing success to ability rather than effort are factors that contribute to discrepancies in boys' and girls' math abilities and scores (Ai, 2002; Atweh et al, 2001; Stipek & Gralinski, 1991). A discussion of math anxiety, confidence, the role of teachers, stereotype threat, male proximity, and other factors contributing to girls' attitudes follows.

Math anxiety is still related to gender at Wildcat Middle School. Math anxiety is considered to be “the key social attitudinal variable that might account for sex differences in achievement and enrollment in mathematics courses” (Eccles & Jacobs, 1986, p. 375). This anxiety stems from internal belief systems relating to confidence, perception of the usefulness of mathematics, fear of success, and attributional style (Fennema & Leder, 1990). Girls in seventh through ninth grade express more anxiety about math than boys, while boys have been found to have higher expectations of success in math and stronger intentions to keep taking math when they no longer have to (Heller & Parsons, 1981; Meece et al, 1988).

Some research suggests that the difference in math anxiety between males and females is close to zero, and that the widely accepted belief that females have more negative attitudes towards mathematics than males is a manifestation of the stereotypical belief that women are more emotional than men (Hyde et al, 1990). Sherman (1983) maintains that “it is neither anxiety nor lack of ability that keeps women from mathematics,” but rather “a network of sex-role influences which makes mathematics, and the careers mathematics are needed in, appear incongruent with the female role, especially with motherhood” (p. 342). Despite the cause, the negative attitudes are very real and debilitating.

The Fennema-Sherman Mathematics Attitude Scales (FSMAS) include anxiety towards mathematics as a subscale. While all girls experienced an elevation in anxiety levels, the females in the experimental group showed only a nonsignificant increase, compared to a greater increase for girls in the control group. Males in the experimental group showed a decrease in anxiety, while those in the control group showed an increase. One cause of these lower levels of anxiety in the experimental group may be that, through their successful participation in PLTW, those females (and males) who had previously felt anxious towards mathematics did not continue to build upon those feelings/attitudes during the school year.

Confidence is also related to gender at Wildcat Middle School. While early gender differences in confidence are nil, “by grade six, boys have more confidence, even though their math test scores and grades are not any higher than those of girls” (Research and Educational Planning Center, 1990, p. 3). Many “add-on” math programs for girls purport to build up their confidence levels. These programs that concentrate on the mathematics, science, and technology achievement and attitudes of girls have several common traits/components. They include focusing on real-world examples, establishing a comfortable, supportive climate, fostering collaborative learning, and establishing connections among topics (DeHaven & Wiest, 2003; Freehill, Benton-Speyers, & Cannavale, 2004; House, Johnson, & Borthwick, 2003; Thom, 2002).

While the confidence subscale scores on the FSMAS administered in this study showed all Wildcat Middle School girls lagging behind in confidence compared to the boys, as well as dipping over the course of the school year (pre-test $M = 3.24$, $SD = .92$; post-test $M = 3.09$, $SD = .92$), it is significant that the confidence levels of the females on the team that piloted PLTW (the experimental group) showed a much lower rate of decrease than those females in the control

group (pre-test $M = 3.62$, $SD = .90$; post-test $M = 3.12$, $SD = .97$): 0.15 points (statistically nonsignificant) versus 0.50 points (statistically significant). Additionally, the males in the experimental group showed an increase in confidence (up 0.20 points) over the course of the school year (pre-test $M = 3.69$, $SD = .87$; post-test $M = 3.89$, $SD = .88$), while those in the control group showed a decrease of 0.16 points (pre-test $M = 3.75$, $SD = .77$; post-test $M = 3.59$, $SD = .85$), both of which were, however, nonsignificant.

It may be concluded that those girls who participated in PLTW experienced a less than-expected dip in confidence because of the extra time they spent daily completing tasks that demanded a level of comfort with mathematical concepts. Additionally, there are confidence-builders intrinsic to PLTW that can be attributed to greater self-assurance. The Gateway To Technology program “promotes communication and collaboration by emphasizing a teaming approach in the instructional units. This approach utilizes the strengths of each team member to accomplish the goals of the project, while offering students learning challenges at all ability levels” (PLTW Programs, 2003, p. 5). Also, because it was a component of their academic program, rather than an after-school, summer or weekend program, the girls did not have to demonstrate that initial level of confidence to seek it out.

Teachers influence girls' attitudes towards mathematics. The role of teachers in affecting girls' attitudes towards mathematics has been recognized as a significant one. “Teachers' attitudes, expectations, and treatment of students definitely affect students' confidence, aspirations, and other mathematics-related attitudes” (Research and Educational Planning Center, 1990, p. 144). Differential treatment of boys and girls in mathematics classes factor highly in girls' success (or lack of it) in math (Fennema &

Leder, 1990). While, according to one study, sex differences in evaluative feedback do not appear to exist in junior high school mathematics classes (Heller & Parsons, 1981), feedback must be considered when examining the “whole teacher” and his/her behaviors as they are perceived by girls. This perception may even extend to the role teacher gender plays in affecting girls' interest in mathematics (Stone, n.d.). Additionally, seventh and eighth grade students of both genders who are either cognitively or socially unsure of themselves may avoid seeking help in math class (Ryan & Pintrich, 1997); this research finding must be addressed when teachers reflect on the behaviors they employ to encourage students in math classes. Internal belief systems also lead high-ability girls to perceive that they receive more support and encouragement than lower-ability girls, resulting in greater self-confidence and achievement (Love & McVey, 2001).

At Wildcat Middle School, students indicated, through the use of the FSMAS and student focus group interviews, that they found definite activities and actions initiated by the math teacher to be interesting, uninteresting, encouraging, and discouraging. Those that students perceived as fostering interest included such activities as using manipulatives, creating or building things, using computer technology, and using real world examples (Box 1). Interestingly, all of the activities and actions that both groups of students, as well as both genders of students, cited as promoting interest were those that the experimental group students indicated were present in their Project Lead The Way class.

It should be noted that in the 12 FSMAS questions that referred to student perceptions of teachers' attitudes towards the respondent in the subject, math teachers were referred to in a very general manner, without referencing the present math teacher. All students, then, had an opportunity to focus on their past as well as their current experiences in mathematics classrooms.

Curiously, all students at Wildcat Middle School, regardless of their inclusion in the experimental or control group, indicated that their math teachers' attitudes towards them appeared to worsen over the course of the school year. Perhaps if math teacher was not specified, but rather teachers in general in whose classes math is learned, then those girls participating in PLTW would have indicated that they felt a more positive attitude from their teacher than they otherwise indicated on the FSMAS. Nevertheless, the girls did express their appreciation of their PLTW teacher in focus group interviews. Classroom observations, at the end of the school year, revealed a difference in response patterns and teacher feedback to questions in the experimental group math classrooms when compared to the control group classes. Females in the experimental group math classes volunteered more than their control group counterparts, indicating a different level of comfort with math questions. Teacher-generated seating plans were equitable in all classrooms, with the experimental group's accelerated math class accommodating most of its females in the front of the class. This was explained by the teacher as a way he encouraged girls: "The ones who seem to really like it, I try to put them up close so they're not in back with a lot of people around them."

It is of interest that, of the seven girls interviewed in this accelerated class, five remarked that they merely tolerated math, one stated that she liked it, and only one indicated that she loved it. This contrasted with the four interviewed females from the experimental group's flex class who all declared they loved math. This demonstrates that, through their involvement with the PLTW curriculum, the females who were of average mathematics ability felt more comfort with, and experienced more success in, mathematics than they previously had experienced.

Stereotype threat and the impact of curriculum. Stereotype threat has been cited as another influencer of female students' attitudes towards mathematics. It has been learned that the

type of information girls received prior to participating in a math test, regarding their gender-related inaptitude, had a significant effect on both expectancy and performance in a series of experiments (Cadinu et al, 2003, p. 275).

Students at Wildcat Middle School said that they were not verbally subjected to any negative messages prior to any administrations of the Blue Ribbon Testing©. In the focus groups, these same students indicated that they did not always feel capable in mathematics. Almost all students indicated, however, through the FSMAS, that their perceptions of math as a male domain changed during the school year. According to Fennema and Sherman (1976), “the less a person stereotyped mathematics, the higher the score” (p. 7), so Wildcat Middle School’s students’ higher scores were indicative of a decrease in the stereotypical belief/notion that math was primarily for boys. The most dramatic positive change was found in the males who piloted PLTW (pre-test $M = 3.82$, $SD = .87$; post-test $M = 4.09$, $SD = .86$), as compared to no change in that of the females in the experimental group, and slight increases in the males and females in the control group. This may be due to the males in the experimental group working side by side with females in a pre-engineering program, observing the females competently operating computers, building race cars, manipulating data and diagrams, and successfully completing other tasks and activities formerly considered to be typically male-oriented. It is important to understand that, as evidenced in focus group interviews, most of the males in this group believed that the females were capable, but simply did not like math or the math teacher.

Male proximity does not negatively impact females piloting PLTW. It has been concluded that “the presence of males constitutes a threatening intellectual environment for females performing a math task, and specifically that women experience a greater deficit in their

math performance the more males there are in the environment” (Inzlicht & Ben-Zeev, 2000, p. 370).

Data obtained from the FSMAS contradicted this finding. For the same reasons cited in the section on stereotype threat, the females who piloted PLTW may have been spared this intimidation because they worked side by side with males in a pre-engineering curriculum on a daily basis, rather than in an after-school, weekend or summer program.

Components of programs contributing to girls' positive attitudes. Programs that concentrate on the mathematics, science, and technology achievement and attitudes of girls have several common traits/components. They include focusing on real-world examples, establishing a comfortable, supportive climate, fostering collaborative learning, and establishing connections among topics (DeHaven & Wiest, 2003; Freehill et al, 2004; House et al, 2003; Thom, 2002; Boaler, 2016). Students in PLTW reported experiencing the components listed in the literature in this matter. In focus group interviews, they cited using hands-on activities and projects, creating/building things, and using real-world examples as contributing to their interest in mathematics. This suggests that any program including such components would see an increase in positive math attitudes, as well as in achievement, among its students.

This was the first study on the impact of PLTW at the middle school level. However, a review of several middle school add-on programs in existence indicated such results as increased confidence scores on the Modified Fennema-Sherman Mathematics Attitude Scale at a statistically significant level (DeHaven & Wiest, 2003, pp. 32-33). For example, 1) a “48% increase in the percentage of the girls who said Girlstart increased their interest in math, science, and technology” (Comparison of program results from 1999 to 2000, 2000, para. 1); 2) significant condition effect for future computer usage and technology involvement (Gilbert,

Bravo, & Kearney, 2004, p. 192); 3) increased student achievement, as test scores jumped 212 % (Green, 2001, p. 23); 4) a significant change in 4 of 12 areas assessed, including confidence in engineering skills (House et al, 2003, p. 89); and 5) attitudes positively altered (House et al, 2003).

Previous research suggests that programs such as Project Lead The Way contain the rudiments that contribute to female students' sustained interest in mathematics. Moreover, unlike the "add-on" programs, PLTW is offered within the school day, making it easy, even necessary, for females to access it.

Implications for Educational Leadership

At the local school district level, STEM programs can be adopted or created to provide all students with engaging, gender-neutral experiences that naturally embed mathematics across multiple disciplines. PLTW has been used in varying amounts, in all 50 states, D.C., and U.S. territories, in 9000+ schools, and has impacted 2.4 million students and 35,000+ teachers (PLTW, State by State, 2016). School district budgets must be reviewed and adjusted to ensure a strong STEM program is in place.

Additionally, districts can furnish professional development in strategies that inspire math confidence in female students, including that of nurturing a growth mindset. Indeed, instructor behavior influences a middle school girl's interest in mathematics in subtle ways. Girls report to feel less confident in math, and harbor less than amicable feelings towards math. Yet they also earned high grades in math and realize its usefulness in the present and in their futures. Perhaps it is the less overt teacher behaviors – questioning patterns and conscious planning to encourage girls – that subtly impact on girls' psyches and shatter their confidence. Through visitations of math classrooms, school administrators can observe verbal flow patterns,

complexity of questions and responses, and encouraging words/behaviors, for gender inequities. This data must be shared with teachers in post-observation conferences so that they may appropriately modify their classroom practices.

At the college/university level, teacher preparation programs can offer STEM materials and methods courses, while administrator preparation programs can encourage research in STEM education and its impact on females.

In the research arena, investigators (including this one) must survey and interview females currently enrolled in engineering programs at the post high school level to determine what adult actions at the K-12 (pre-college) level influenced their selection of a major in engineering. The knowledge gained may be applied in public schools across the U.S. as a means of encouraging females to pursue a career in the STEM areas.

To improve education, monitoring the impact of programs and classroom strategies on teaching and learning is necessary. Effectively communicating the results of all education research to constituents is crucial. Per this conference theme, school leaders must “disseminate findings that are accessible, engaging, discursive, and useful for various stakeholders” (NERA, 2016). This will enable informed decision-making so that program adoption, funding, and support may be justified.

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