Research-Informed Practices for Inclusive Science, Technology, Engineering, and Math (STEM) Classrooms: Strategies for Educators to Close the Gender Gap

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Abstract

The underrepresentation and attrition of women students in science, technology, engineering, and math (STEM) fields is a widely acknowledged, complex problem for which solutions will be multi-faceted. However, while a large body of research examines factors that influence girls' and women's experiences in these fields, many STEM educators at the K-12 level may be unfamiliar with the most recent research on gender's relation to STEM classes. This paper aims to bridge research to practice by identifying strategies for educators as they work to capture students' interest in STEM and retain students who are already interested. Seven "key practices" for creating gender-inclusive STEM classrooms were identified through a comprehensive literature review of social science research in gender and education. This research indicates, moreover, that the benefits of most practices can be broadened to all STEM students.

The paper begins with an overview of the conceptual and methodological approach to the literature review process, and then presents and discusses the seven practices and supporting research. We then turn to recommending implementation strategies for educators to make courses more inclusive. The strategies are followed by a brief outline of suggested directions for future research.

Introduction and Background

According to the United States Department of Commerce, "Although women fill close to half of all jobs in the U.S. economy, they hold less than 25 percent of STEM jobs. This has been the case throughout the past decade, even as college-educated women have increased their share of the overall workforce"[1]. The gender gap in STEM employment is not an anomaly; it reflects the disparity in the relative numbers of men and women pursuing STEM education, of which the K-12 years, particularly high school, are this paper's focus.

Female high-school students are more likely to aspire to attend college than are their male counterparts, and young women enroll in college, persist, and graduate from it at higher rates as well[2]. So why does this STEM-specific gap exist? This paper employs the tools of "gender analysis" to address this question.

Gender analysis provides a framework for thorough analysis of the differences between women's and men's "gender roles, activities, needs, and opportunities in a given context"[3] to eliminate the role of false assumptions and stereotypes. Gender analysis seeks to achieve equity rather than equality in that gender equity accounts for the differences in women's and men's "life experiences, needs, issues, and priorities"[4].

Gender analysis in STEM education allows us to more deeply understand the effects of existing STEM programs and new STEM initiatives: whom they are most affecting and in precisely what ways. This knowledge provides policymakers, educators, parents, and students with the tools necessary to determine how to, for example, allocate limited funding, write a successful curriculum, or avoid reinforcing counterproductive stereotypes in the home or classroom. All of this contributes to the ultimate goal of creating classrooms that better support the growth of young women engineers and scientists, and leads to three major societal benefits. The first benefit is about sheer numbers: retaining more women in STEM while maintaining the numbers of men results in more engineers and scientists for the future. This is important for the U.S. to maintain competitiveness in the global economy that is becoming increasingly technology-driven. The second major benefit is that a more diverse set of scientists and engineers can better represent the population and bring new perspectives on identifying problems and designing solutions. This diversity of ideas is crucial to innovation and to equitable consideration of the needs of women and men[5]. A third benefit is greater satisfaction and fulfillment for some individuals because without the negative effect of social norms or stereotypes, some students may be more inclined to study what truly interests them.

There are three concepts that are fundamental to our use of gender analysis in this paper. The first is the distinction between the terms “sex” and “gender”. Sex refers to biological and physical characteristics and is associated with the words “male” and “female”. Meanwhile, gender refers to socially constructed roles, norms, and attributes, and is associated with “masculine” and “feminine”[5]. In much of the research discussed in this paper, study participants are classified by sex but differences in the dependent variable (achievement, self-efficacy, etc.) are attributed to gender, that is, to social and cultural forces that differentially shape women’s and men’s behaviors and attitudes.

While this may seem like a subtlety, clarity in attributions of differences between men and women students has huge implications regarding the solutions to motivating students and eliminating the gender gap. If it is not made clear to educators, parents, and students that differences in educational settings tend to be gender-, not sex-based, then the differences are likely to perpetuate themselves through the belief that the differences are natural and inherent. However, if the emphasis is placed on the role of social and cultural factors (“gender-based”) then the attitude shifts to one of empowerment and transformation in the education system and society.

The second fundamental concept is the importance of considering both how the environment creates and affects gender differences and how it may affect men and women differently. In *The Gender Gap in College*, Linda Sax notes a tendency that affects our understanding of gender differences[6].

> The inclination is to focus on descriptive comparisons of women and men, rather than to focus on the environmental forces producing gender differences. That is, studies tend to compare college men and women in terms of their characteristics and abilities, such as assertiveness or mathematical competence, but pay little attention to the ways in which various experiences may contribute to those gender differences. This practice… falls short of documenting the biological, cultural, or sociological factors that may explain the observed dissimilarity.

Selected research in this paper presents not only how students' educational experiences vary by gender, but also how the impact of a single educational experience differs for women and men. This is known as a "conditional" or "interaction" effect, which occurs when the influence of an environment or experience differs for different groups of people. Understanding these interactions helps in identifying the origins and perpetuation of the gender gap as well as in designing solutions. For example, Sax found that although "majoring in math-intensive fields strengthens men's and women's belief in their mathematical aptitude", "the influence of these majors is stronger for women than men, suggesting that continued exposure to mathematics is particularly important for female students"[6]. This indicates that there is an interaction between an individual's gender and a math-intensive major. With this finding, we can glean new insights into particularly effective or important environments for women that may be less salient otherwise.

The final point that must preface the study of gender differences is the importance of avoiding over-generalization because neither men nor women can be treated as one homogeneous group. Gender differences in STEM education cannot be fully understood without attention to race, ethnicity[i], and family income level or socioeconomic status. Moreover, we cannot overemphasize gender differences in light of other variables. Ohland et al. note that at the post-secondary level, gender differences are only one factor in engineering persistence, among institutional and racial differences[7]. This paper focuses on inclusive STEM education with regard to gender but future research will probe differences by other variables more deeply.

Methodology

Drawing from gender analysis and its supporting concepts, data for this paper pull from a comprehensive literature review conducted in 2012. This literature review began with a focus on classroom environments, teaching practices, and learning experiences that influence women's and men's success and retention in STEM disciplines. Specific attention was given to research on gender in high school physics, chemistry, biology, and math; however, research on pre-engineering and undergraduate engineering education was included as well. We further focused our search (with some exceptions) to papers that: sampled students between 7th grade and college sophomores; discussed the conditional effects of gender; and were published within the last twelve years (since 2000).

Once several clear themes (e.g., the importance of spatial skills) emerged from this targeted literature search, further research review was tailored to those theme areas. We used the American Association of University Women Educational Foundation's publications *Why So Few?*[8] and *Where the Girls Are*[9] as a springboard into further research. The *Journal of Engineering Education* and the *Journal of Research in Science Teaching* were particularly relevant; sources also included journals such as *Science, American Journal of Sociology,* and *Journal of Personality and Social Psychology,* books, commentaries, and technical reports. A strength of this review is its cross-disciplinary nature; it unites findings from various fields such as interpersonal communication, curricular research, and sociology to reflect the multi-faceted nature of the gender underrepresentation problem in STEM. In total, this paper cites 21 journal articles or books from 10 different journals. For each journal article cited, approximately four others were reviewed but not cited. Those were excluded because they were not immediately relevant to the seven key practices or they were not published within the last twelve years.

Table 1 summarizes three core constructs that this body of work focuses on: identity, self-concept, and self-efficacy. These constructs are measures of a sense of belonging, enjoyment, and/or competency, and have been found to play a highly influential role in men's and women's achievement and persistence in STEM fields. We return to these constructs throughout this paper in developing strategies for educators to create more inclusive STEM classrooms.

Table 1: Defining Common Metrics

Term	**Functional definition**	**Notes**
Identity	For a given subject, identity is a compilation of level of interest, self-assessment of competency, and how much recognition one feels with regard to it[10].	"Science career aspirations in eighth grade (i.e., early *identification*) strongly predicted physical science bachelor's degree attainment several years later"[10].
Self-concept	A student's perceptions about their ability in a certain area (such as science) and the feelings of self-worth they associate with this ability[11].	
Self-efficacy	Self-efficacy, part of Bandura's Social Cognitive Theory[12], is an individual's level of confidence in their ability to act effectively to perform a specific task. For example, science self-efficacy is "students' belief in their ability to succeed in science tasks, courses, or activities"[11].	Affects a student's persistence and performance. Four sources of self-efficacy: mastery experience, vicarious experience, social persuasion, and physiological states[12].

From the literature selected, seven key practices were identified as having impact on women student's interest and retention in STEM fields. They are unified by several characteristics: ease of implementation (notably, none of the suggested practices require new infrastructure or staff), novelty, and potential to not just retain more scientists and engineers, but to create *better* scientists and engineers. In addition, each practice can be applied to improve a single course or more broadly implemented over several courses to further the benefits. Also, while the focus of these practices is on high school education, the contexts of middle school, high school, undergraduate, and graduate school are comparable in many ways (e.g., classroom settings, underrepresentation of women, engagement with multiple teachers). Therefore most of these practices can be applied directly or only slightly altered to fit the entire education trajectory.

Seven Key Practices

The seven key practices are organized into two clusters: "Skills to Emphasize" and "Scaffolding to Implement". After a description of all the practices for a given cluster, implications for practice and new research questions are presented for that cluster.

Cluster One: Skills to Emphasize

The "Skills to Emphasize" cluster encourages educators to instill the importance of calculus, spatial reasoning, communication abilities, and resilience in their students because reinforcing these areas may benefit women students in particular.

1. A Foundation in Calculus

It is hard to overstate the importance of a solid foundation in mathematics for all potential STEM students, but more specifically, calculus has been shown to be an especially important step in increasing the likelihood of girls to pursue STEM.

Sadler and Tai's "Two High School Pillars Supporting College Science" examined the correlation between varying amounts of high school biology, chemistry, physics, and math preparation, and grades in introductory college science classes[13]. This study found that the two best foundations for college science courses were study in the same science subject and advanced study of mathematics in high school. Biology, chemistry, and physics "were only significant as predictors within their respective disciplines" and "no significant cross-disciplinary effect was found"[13]. For example, taking high school biology only had a significant effect on college biology grades. However, one subject transcended disciplinary boundaries in its positive effect: mathematics. "Years of mathematics instruction was a significant predictor of performance across all college science subjects"[13]. In fact, taking more years of math in high school increased the average college grade in biology and chemistry more than taking high school biology and high school chemistry did, respectively. This study highlights advanced math's critical role in preparing students for college, particularly the study of STEM in college.

While Sadler and Tai used the progression through years of math instruction as a variable, Correll used calculus, the pinnacle of high school math, to examine effects of advanced math instruction on choice of a quantitative major. Correll defined quantitative majors as "all engineering majors, chemistry, physics, other physical sciences, computer programming, statistics, and mathematics"[14]. In this study, taking calculus in high school had a conditional effect on choosing a quantitative (STEM) major through an interaction with sex. Specifically, "females who enrolled in high school calculus are 3.22 times more likely to choose a quantitative major than females who did not take calculus" [14]. In contrast, males who take calculus are only 2.27 times more likely to choose a quantitative major than males who did not take calculus[14]. Thus, the positive effect of taking calculus on choice of a quantitative major was greater for girls than for boys. This research indicates that encouraging girls to take calculus in high school may be a vital step in closing the gender gap in STEM participation.

2. Develop Spatial Skills

Albeit a vague definition, spatial skill is the ability to recognize or solve problems associated with relationships between objects or figures, including position, direction, size, form, and distance. It encompasses "mental rotation, spatial perception, and spatial visualization"[15]. Spatial skills are involved in engineering in, for example, visualizing and sketching three-dimensional components and systems to build models. It is a pervasive stereotype that women have poor spatial skills and therefore this stereotype may be contributing to the gender imbalance in STEM. However, spatial skill development is entirely possible because spatial skills are malleable through practice and, contrary to the aforementioned stereotype, no scientific support has been found for genetic or hormonal differences being the cause of gender differences[15]. Spatial skill development should be targeted as an area for instruction because improving spatial skills improves retention of engineering students[16] and therefore can help to narrow the gender gap in STEM.

Although research is inconsistent as to the relation between actual engineering performance and spatial skills test scores[ii,15], in a six-year longitudinal assessment, Sorby found that first-year "female engineering students with poorly developed spatial skills who receive spatial visualization training are more likely to stay in engineering than are their peers who do not receive training"[8]. Among undergraduate women who failed a spatial skills initial assessment test, 77 percent of those who took a spatial-visualization course were still enrolled in or had graduated from the school of engineering[iii],[16]. In contrast, only 48 percent of those women who failed but did not take the spatial-visualization course were still enrolled in or had graduated from the school of engineering[16]. Of the men who failed the initial assessment, 61 percent of those who took a spatial-visualization course were still enrolled in or had graduated from the school of engineering and 52 percent of those who did not take the course were still enrolled in or had graduated from the school of engineering, however this difference in retention rates for men was not statistically significant[16]. Therefore the spatial-visualization course had a conditional effect by gender on students' retention in the school of engineering. While the spatial-visualization course did not raise women's scores above those of men's, (i.e., there were no gender differences in pre- or post-test scores among those taking the course), this intervention holds promise for women because it closed the score gender gap and a much larger fraction of women had failed the initial assessment test[16].

Another example of a successful intervention is that a three-hour workshop provided "for low scoring students in their introductory engineering graphics course at the University of California at Berkeley… effectively eliminated previously established gender differences in spatial reasoning task scores"[17].

Although much of Sorby's research has focused on undergraduates, "Sorby recommends that this training happen by middle school or earlier to make a difference in girls' choices"[8]. Early training is beneficial because spatial skills help students interpret diagrams in math and science tests and textbooks. In fact, in one study, "when mental rotation ability was statistically adjusted for, the significant gender difference in [SAT-Math] was eliminated for the college sample and the high-ability college-bound students. This suggests that spatial ability may be responsible in part for mediating gender differences in math aptitude among these groups"[18]. Spatial skills may be a keystone in the math gender gap as well as a key part of the broader STEM gender gap.

This research implies that for both genders, spatial skills can be improved dramatically with relatively minimal coursework. Although ties of spatial skills to engineering performance are not yet established, the tie between improving spatial skills and increasing retention of women engineers is not to be ignored.

3. Emphasize Communication

Emphasizing the importance of communication skills in the practice of science and engineering and changing the perception that individuals cannot be gifted or skilled in both math and language can help girls feel that they can succeed in STEM.

Although popular conceptions of engineering and some sciences remain heavily math-focused, strong communication skills allow engineers and scientists to use their technical skills most effectively. The vast majority of STEM jobs involve teamwork, which necessitates communication skills. Twenty-first century engineers and scientists "must be team members who thrive while working with a variety of people having differing social, educational, and technical skills"[19]. Communication can play a major role in career advancement as well. One study, which interviewed practicing engineers on the importance of oral communication, found that "seventy percent of the responses indicated that effective oral communication was essential for promotion in the organization"[20].

The same study examined how oral communication is important to engineers in their work. Fifty percent of the responses named some form of public speaking as most important, thirty-two percent indicated meetings, nine percent suggested informal or interpersonal situations, and eight percent of the responses indicated that some form of instructional skills were important [20]. These data imply that engineering practice is "an intensely oral culture and while formal presentations are important to practicing engineers, daily work is characterized more by interpersonal and small group experiences"[20]. Notably, this work culture is contrary to the stereotype of the isolated engineering profession and is potentially appealing to many young students.

In explaining the importance of communication skills in engineering and science to students, it is helpful to explain what aspects of communication are key for success. For engineering specifically, "communication skills such as translation, clarity, negotiation, and listening are vital"[20]. A study that observed formal and informal teaching of communication in a capstone design sequence found "five important features of speaking in engineering: simplicity, persuasiveness, results-oriented, numerically rich and visually sophisticated"[21]. This study also identified a common thread: "The key speaking competency in engineering was translation—whether it was translation of technical material for lay audiences, translation of design results into a visual, translation of numbers into a results-oriented structure, or translation of design results into a 'sales pitch'"[21].

Despite the importance of communication to engineering, interpersonal communication and collaboration skills are generally portrayed as the opposite of math and science skills, implying that people are almost always more skilled in one at the expense of the other. Portraying math skills and language skills as mutually exclusive is potentially damaging because students make relative comparisons of the feedback they receive in various subjects. In a longitudinal study of students in eighth grade through two years out of high school, Correll observes that "higher English grades and test scores actually lead to lower levels of mathematical self-assessment for both males and females"[14]. More specifically, when students score highly on English, they tend to rate their math skills lower than if they based their self-assessments solely on their mathematical performance.

Moreover, this negative effect of good English grades on mathematical self-assessments is stronger for females than for males[14], therefore it is a conditional effect. Mathematical self-assessments are important because "self-assessments of task competence are shown to have an effect on career-relevant decisions over and above actual ability"[14]. Correll found that "the effect of gender on calculus enrollment is, at least partially, the result of gender differences in perceptions of mathematical competence"[14]. In other words, when girls and boys perceive themselves to be equally mathematically competent, they are equally likely to enroll in calculus.

Taken together, this knowledge provides compelling evidence of the importance of communication skills in engineering, and suggests that emphasis on the integration of math and communication skills in engineering would benefit women students in particular.

4. Demonstrate and Encourage Resilience

This practice is about helping students learn to embrace challenges and setbacks by teaching them that their academic skills are malleable. In addition to combatting the negative stereotypes of their technical abilities that girls and women face, this practice is an important life lesson for all students.

Using spatial skills as an example of a broader phenomenon, the Assessing Women in Engineering project suggests that "score differences are accepted (by female students and those around them) as an unchangeable phenomenon of natural ability, a phenomenon permanently disabling female students and providing evidence that women just do not belong in engineering classrooms. Such interpretations may result in a downward spiral of lost self-confidence, lowered test scores, and a decrease in sense of belonging for female students"[15]. Closely related to this phenomenon is *stereotype threat*. Stereotype threat is a psychological threat that occurs when an individual is doing a particular activity for which a negative stereotype about their group (sex, race/ethnicity, age, socioeconomic status) applies. For example, a woman may feel apprehensive about performing on a spatial skills task because she fears that performing poorly would confirm the existing negative stereotype. Stereotype threat may actually cause her to perform worse than she would have otherwise and therefore the danger lies in this phenomenon's nature as a self-fulfilling prophecy.

However, a mindset shift can have measureable positive consequences to combat this downward spiral. One study investigated how women's math performance is affected by whether they are considering genetic or experiential accounts for the stereotype of women's underachievement in math. The results were that "stereotype threat in women's math performance can be reduced, if not eliminated, when women are presented with experiential accounts of the origins of stereotypes"[22].

Several studies by Carol Dweck have provided similar findings in that focusing on the power of practice rather than inborn talent is a key motivator for students. This becomes especially important for students who are under negative stereotypes. Dweck calls the message of innate ability and natural talent a *fixed-mindset* message whereas the message of interest, commitment, and hard work is a *growth-mindset* message. A longitudinal study of college calculus students found that “students’ perceptions of two factors in their math environment—the message that math ability is a fixed trait and the stereotype that women have less of this ability than men—worked together to erode women’s, but not men’s, sense of belonging in math”[23]. The fixed mindset has a conditional effect in that the fixed mindset is particularly damaging to women, likely due to the negative stereotype about their natural ability. However, “the more women perceived malleable-ability environments, the more they maintained a sense of belonging to math, even when they perceived their environments as highly gender-stereotypical”[23]. Teaching the power of a growth mindset allows women to thrive, even when they understand the stereotypes against them.

Perhaps this mindset concept explains one study’s findings that “having female scientist guest speakers” and “discussion of women scientists’ work” were not effective in increasing students’ physics identity[10]. This implies the possibility that young women do not necessarily connect the success of others to their own potential. However, this type of self-deprecating thinking is more likely to prevail if one has a fixed mindset rather than a growth mindset, because with a fixed mindset, one sees those role models as born with talent that they either do or don’t have, rather than seeing those role models as passionate and hard-working.

Stereotype threat can particularly manifest itself when stigmatized individuals are outnumbered in a test setting. Being outnumbered triggers awareness of the negative stereotypes about their group and the individuals perform worse as a result. A strategy to gain insight into keys to success is to examine those students who experience success and achievement in minority situations, indicating that they are not succumbing to stereotype threat. One experimental study explored this type of resiliency among high self-monitors (people who are self-monitors are concerned with and able to monitor and control their behaviors) by testing women’s self-monitoring levels and math scores on a shortened sample GRE test under same-sex conditions and under numerical minority conditions (i.e., one woman was outnumbered by men two to one)[24]. The study found that the high self-monitors tested in a numerical minority situation performed better than low-self monitors tested in a numerical minority situation. Thus, women high self-monitors were cognizant of the stereotypes, but “they appeared undaunted by them… We suspect that high self-monitors construe public minority situations as challenges rather than threats because their coping resources are likely to exceed their perceptions of stress”[24]. While teaching self-monitoring is outside the scope of typical classroom, teaching the value of resilience and a love of challenges is within the realm of all teachers and may help girls to be less intimidated by their STEM classes.

Cluster One Interpretation

These four “Skills to Emphasize” have been selected because the research has demonstrated their potential for considerable positive impact, even with minimal resources. Below are several suggestions for implementation of this research in the classroom.

Teachers of advanced algebra or pre-calculus classes should take a moment to encourage individual students, particularly girls, to continue their math sequence through calculus. It may be worth sharing with students Sadler and Tai's finding that advanced high school math was the best indicator of high grades in introductory college science classes. Along these lines, taking a moment to identify girls who are succeeding in both math/science and reading/writing classes or tests and assuring them that their math/science skills are indeed as strong as they have demonstrated may be impactful. This is a chance to teach that what a student is good at is not so much about inborn ability, but rather about what a student sets their mind to and works hard to practice – in essence, the growth mindset. In order to instill the importance of resilience, when talking to students about their progress, is important to praise effort rather than talent. Educators can share stories of others' failures, persistence, and success – or even better, their own stories of struggle.

Several workshops and interventions for improving spatial skills have already been designed. Incorporating one into, for example, a geometry class, can provide girls with the spatial tools they need to do better in math class, on standardized math tests, or hands-on activities.[iv] Research suggests that significant improvements can be reached in just three hours[17]. With such a minimal time demand, there is no reason not to implement a spatial skills workshop. Since there are several types of spatial skills, choosing one that is especially relevant to a class activity or concept and giving students a chance to practice that skill is a way to gradually build spatial skills.

Regarding the emphasis on communication skills, using the typical communication or writing exercises but situating them in the context of a science or math activity can introduce the idea that these so-called "soft" skills are necessary in the hard sciences. In fact, with the nature of both topics, a spatial skills exercise could be combined with a communication skills exercise.

Further development of these four "Skills to Emphasize" also lies in research. A potential direction for further research is conducting gender analysis on Sadler and Tai's data or developing a similar study that breaks down results by gender. This would help to determine if the high school classes of biology, chemistry, physics, and advanced mathematics have a conditional effect with gender for their influence on grades in introductory college science courses. Another possibility is investigating students' perceptions of mathematics, specifically whether they see math as a possible obstacle to their success as engineers, as a necessary tool, or as fun along the way (intrinsic interest in math itself). This analysis should be broken down by gender as well as the strength of each student's present identification with STEM.

With regard to spatial skills, further research should investigate the effects of spatial skills interventions on K-12 students. Ideally this would be a longitudinal study using gender analysis and perhaps looking at correlations with standardized test scores in math as well as high school course selection. The same applies to communication skills interventions. Finally, much remains to be learned about teaching resilience since it is much harder to quantify than academic subject knowledge.

Cluster Two: Scaffolding to Implement

The "Scaffolding to Implement" cluster emphasizes the importance of active expert roles, clear feedback in grading, and re-evaluation of group work in the classroom.

5. Active Expert Roles

Adopting an active expert role means "answering questions, making comments, teaching others," and "allowing students the opportunity to express their own voice through presentations"[10]. Students who reported teaching their classmates more frequently had stronger physics identity (see Table 1 for definition). "Specifically, taking on the role of an expert through teaching others might make students feel like they belong to the expert group"[10]. Since this feeling of belonging is what girls often lack in STEM fields, active expert roles may help girls in particular to enhance their sense of belonging to their classmates and to the material they engage with.

The importance of active expert roles lies in their equivalence to mastery experiences, which is one of the four sources of self-efficacy according to Bandura's Social Cognitive Theory[12] (see Table 1). A mastery experience is success in a given activity and it can increase self-efficacy. In one study on sources of science self-efficacy in middle school students, of the four sources of self-efficacy, "only mastery experience significantly predicted science self-efficacy," and "boys reported stronger mastery experiences than did girls"[11]. Moreover, mastery experiences were a slightly stronger predictor of science self-efficacy for girls than for boys. Providing more opportunities for active expert roles in STEM classes can potentially increase a student's science self-efficacy[11].

Another study surveyed first-year engineering students to discover which pre-collegiate experiences influenced their self-efficacy. The 53 pre-collegiate experiences examined in the study included "pre-engineering classes, multi-day programs, engineering hobbies, working in an engineering environment, extra-curricular engineering programs, and single-day field trips"[25]. This study compared the engineering self-efficacy of first-year students with the above experiences to those without. Seven of the 53 engineering experiences were correlated with engineering self-efficacy: programming, electronics, video games, robotics, model rockets, technology classes, and engineering classes.

The important takeaway from this study is that the effective experiences share the elements of "hands-on experiences, self-motivated learning, real life application, immediate feedback, …and problem-based projects"[25]. Replicating similar experiences in the classroom could correct the mastery experience gender imbalance reported by Britner and Pajares and could therefore help correct the STEM self-efficacy gender imbalance.

6. Clarity in Grading Policies

Girls may underestimate their performance in math classes in part due to gendered expectations of their competencies. Thus, clear grading policies and constructive feedback would help them to properly gauge their success based on their performance alone.

Based on a comparison of math and verbal self-assessments among students from eighth grade through two years beyond high school, males do not seem to assess their competence more favorably than do women at *all* tasks, regardless of the gender association of a task. However, "males are more likely than females to believe they are competent in *math*. This pattern emerges even though math grades and math test scores are very similar for males and females"[14]. Correll also found that females rely more on performance feedback (in this case, math grades) in making self-assessments of their mathematical competency[v]. Correll hypothesizes this is because "they must contend with lower societal expectations of their mathematical competency"[14]. The implication is that when females cannot form a firm sense of their ability, they fill in the gap with societal expectations.

A similar incongruity between girls' actual performance and perceived performance is found in middle school science classes. A study investigating whether the sources of science self-efficacy in middle school students differ as a function of gender found that despite girls earning higher final grades in middle school science classes (after controlling for prior achievement), girls reported equal science self-efficacy as boys and lower science self-concept than boys[11]. In other words, there was a disconnect between self-assessments, self-efficacy, and actual performance.

Girls need a better picture of where they stand in math and science classes because otherwise they will use their biased self-assessment. The implications of these two studies are that grades and test scores in math and science must be better explained to students. This strategy is completely within educators' power to implement once they are aware of the need.

7. Re-evaluate Group Work Practices

While group work has often been encouraged as an exercise to build teamwork and communication skills, recent research indicates that there may be subtle, unintended consequences which may be cause to reconsider the way group work is approached in the classroom.

One study on interpersonal communication with a focus on gender and engineers versus non-engineers found that "engineering males were more likely than other groups to draw negative conclusions about speakers who engaged in self-belittlement by admitting to difficulties or mistakes - particularly with technological issues"[26]. According to Wolfe and Powell, this speech tendency of self-belittlement is more commonly exhibited by women. The engineering men were more likely than others (non-engineering men, engineering women, and non-engineering women) "to perceive such speakers as incapable, whiny, and insecure"[26]. However, male engineers were intolerant of the female-typical speech style regardless of the speaker's sex. This means that they were averse to the speech style itself and not biased toward the female employees themselves.

The trend was most pronounced among students in mechanical and computer engineering and least present in bioengineering and industrial engineering. Perhaps not coincidentally, women comprise a smaller percentage of the workforce in mechanical and computer engineering than in bioengineering and industrial engineering[8].

It is likely that this situation of self-belittlement and undue negative assumptions occurs during group work. While the study suggests women should focus on eliminating self-effacing speech, perhaps a better strategy is for educators to reconsider how they structure group work. Further reason to be wary and critical of how group work is set-up is that in a study examining factors affecting a student's physics identity, it was found that the frequency of group work was not effective in increasing students' physics identity[10].

Debbie Chachra, in an editorial titled "The Perils of Teamwork", discusses how requiring first-year students in engineering classes to work in teams may not be having the desired supportive effect[27]. Since first-year students come in at various levels of experience, they divide based on skill sets and self-efficacy, so therefore women and URM are often given less technical and more managerial tasks. This can perpetuate a vicious cycle to make women feel that they do not belong[27].

Cluster Two Interpretation

These three "Scaffolding to Implement" were chosen because educators should be aware of the new insights into how seemingly straightforward classroom practices, such as grades or group work, may be having unforeseen effects.

One idea for restructuring group work is to focus on individual work early in the course in order to essentially level the playing field by allowing each student to fill in the gaps in their own skill set[27]. Another strategy is to have group members share their personal learning objectives with their teammates before beginning a project so that the project roles can be divided more fairly[27]. A third option is to clearly define roles which each group must select a teammate to fulfill. This can balance the distribution of types of work among group members.

There are two main avenues for building mastery experiences into a curriculum. The first is by hands-on activities, which traditionally require more time and resources. The second is to assign projects in such a way that a student gets to take ownership of a topic. This is especially effective if the student gets to choose a topic that interests them. Additionally, problem-based projects facilitate creativity and the satisfaction of finding a solution.

Further research is needed on the best strategies for giving honest and constructive grading/performance feedback, with gender analysis included. This could investigate the effects of reporting ranks, averages, and percentiles on student motivation. In the meantime, as suggested in cluster one, speaking to students individually about their grades can send a clearer message than a written note. The research also suggests that girls who are succeeding may be underestimating themselves so it is important to encourage girls at all levels, not just those below average.

Future research could build on Wolfe and Powell's finding that engineering women were less tolerant of male-typical discourse styles than non-engineering women and males. This finding is counter-intuitive and could be a key piece to understanding how interpersonal interactions shape career choices.

Finally, since the cause of the disparity in frequency of reported mastery experiences between girls and boys remains unknown, research could build on the conditional effect of mastery experiences in shaping self-efficacy by gender. Additionally, doing gender analysis in Fantz, Siller, and DeMiranda's study on pre-collegiate experiences could reveal clues as to how self-efficacy is built differently between boys and girls prior to their entrance to college.

Closing Words

It is of vital importance to analyze gender as a variable in STEM education research. Analyzing gender is critical to understanding the reasons for the gender imbalance at many levels of STEM employment as well. However, we must not overemphasize the differences found, if any, nor attribute gender differences to sex without further research. The underlying reason is that we must avoid causing exactly what we are trying to avoid. In finding and addressing gender differences in STEM education, we cannot afford to let gender differences reinforce themselves through mechanisms such as stereotype threat.

Researchers also must not let gender differences overshadow more significant effects. It is important to place gender differences in the larger context of other factors affecting an outcome. For example, concerning gender differences in motivation in science, we also see that "it is the environment of the science class, arranged by the science teacher, that delivers a large effect on self-reported student effort"[28]. As researchers and educators, we must seek to understand and address the underrepresented, underperforming, and underserved students but not lose sight of the common threads between all students and the power of a well-designed classroom to support them.

The goal of this paper is to share recent research findings about gender's relation to STEM classes so that educators can take the first step to improving their classroom practices. We want educators to be aware of the ways in which their students may be affected differently and the simple steps to provide a more inclusive classroom. This paper is a first step; still needed is research into and development of optimal methods of implementation.

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[i] Underrepresented minorities in STEM fields in the United States include Black/African-American, American Indian/Alaska Native, Hispanic, and Native Hawaiian/Pacific Islander.

[ii] It is important to keep in mind that there are many types of spatial skills and therefore the type of spatial skill(s) tested in a given study may be responsible for the difficulty in drawing general conclusions from a body of spatial skills research.

[iii] Therefore this study involved self-selected students since their increased motivation that led them to take the spatial skills class. Their increased motivation may also be a factor in their retention so further research is needed with a random sample.

[iv] This paper is not intended to evaluate specific spatial skills development programs but it is worth noting that current work is underway by ENGAGE, an Extension Services Project funded by the National Science Foundation, that compiles spatial skills teaching resources and includes sample communication for discussing spatial skills training with students and/or parents.

[v] Recall (from section 1) Sadler and Tai's result that taking advanced math in high school positively affected grades in introductory college physics, biology, and chemistry. Although no gender analysis was done in their study, when combined with learnings from Correll[14], implications for gender analysis arise. The dependent variable of Sadler and Tai's study, grades in introductory science courses, may have a greater effect on self-concept and self-efficacy for women students. Since girls rely more on performance feedback in forming their self-assessments, the better they do in introductory STEM courses, the more likely they are to believe they can be competent in STEM and will choose to pursue STEM. This can be all influenced by electing to take advanced math in high school.