# AC 2007-317: HIGH SCHOOL MATH AND SCIENCE TEACHERS' AWARENESS OF GENDER-EQUITY ISSUES FROM A RESEARCH-BASED WORKSHOP

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# High School Math and Science Teachers' Awareness of Gender and Equity Issues from a Research-Based Workshop


## Abstract

Over the past decade the first-time enrollment of females in undergraduate engineering has not increased and remains at about 20%, in spite of ongoing K-12 engineering gender diversity programs. The underlying cause for the decline is not cognitive ability or academic performance. Instead, the cause has sociocultural roots that create barriers to female participation in science and engineering education and careers. The research literature shows that some of the most important STEM (science, technology, engineering and math) participation barriers along the educational pathway from K-12 to undergraduate engineering include: "chilly climate" in science classrooms; lack of tinkering self efficacy; lack of technical self efficacy; lack of societal relevance of STEM careers; and lack of female and minority STEM role models. This work presents the results of a research-based workshop on issues that inhibit females from enrolling in college curricula that lead to STEM degrees and careers. The workshop was presented to 48 high school math and science teachers (80% female and 20% male) from four school districts who were participating in a four-course sequence of math, science, and engineering classes as part of a National Science Foundation sponsored Math Science Partnership project entitled, Project Pathways. The workshop was conducted with an active learning approach that included frequent breaks for reflection, discussion and recording of facts, ideas, experiences, strategies and possible actions. The results showed that all teachers were aware that gender-equity issues existed in K-12 science and math classrooms. However, they were less frequently aware of underlying causes or of possible approaches to address the causes. The teachers were aware of some of the types of findings in the research literature such as gender and minority stereotypes, the "chilly climate" in some math and science classrooms, and the lack of female and minority role models. However, many were unaware of other types of findings in the literature which were composed of more subtle forms of bias, such as lack of activities to develop tinkering self-efficacy and more frequent control of classroom labs and projects by more aggressive males than less aggressive females. Based on the their own experience and their informed knowledge of research-based gender and equity issues, the teachers proposed strategies to address the issues. The most frequently cited strategy for addressing the STEM gender barrier was improving tinkering self-efficacy. Suggestions included participation in hands-on activities at home, parental involvement, starting early in elementary school, and structuring laboratories and projects for equal female and male participation. Specific responses and analysis, as well as other less frequently cited issues and strategies, are presented in more detail in body of the paper.


## Introduction

Although the nation's workforce is composed of 46% women, only 23% of scientists and engineers are women[1]. Engineering is on of the least equitable professions with 9% women, while the physical sciences have 22% women and, surprisingly, even the life sciences, have only 36% women. In contrast, female lawyers and doctors are approaching a level of 50% in their professions overall[1], while math, seen in the past as a male domain, is now perceived by students to be a female or gender-neutral domain[2]. Students begin to make critical decisions about future course selection and possible career paths in middle school through early high school, where adolescents' individual identity begins to emerge[3]. Yet, it is also in middle school that a gender gap begins to emerge for interest in science, a foundational subject for engineering education[4]. Although enrollment in high school science classes (biology, chemistry, and physics) is roughly gender neutral, greater loss of interest in science by females is reflected by their reduced participation in advanced-placement science classes, such as physics, which was 32% in 1984 and 36% in 1994[1]. A consequence of females' losing interest in middle and high school science is a corresponding lack of interest in pursuing science and engineering education and careers. While there are many reasons for this gender gap, there are important environmental and affective factors that have a negative impact on science and engineering interest and persistence. They include: gender stereotypes; the "chilly climate in science classrooms; technical self-efficacy; tinkering self-efficacy; and the perceived societal relevance of science and engineering.

Both affective and cognitive issues are being addressed in a NSF-funded, five-year Math Science Partnership program at Arizona State University which is entitled, *Project Pathways: Opening Routes to Math & Science Success for All Students.* This project has been designed to address the issues of teacher preparation, underperforming students, and underrepresented populations in STEM (science, technology, engineering, and math) disciplines. It is based on an in-service teacher enhancement model for improving mathematics and science learning and achievement for students in grades 9–12. Research shows that improvements in student learning begin with new models of content-specific, professional development (PD) for teachers. Thus, the broad goal of the *Pathways* project is to produce a model of a more effective PD delivery system for supporting secondary STEM teachers' continued professional growth, including a reduction in the gender and minority gap in participation in STEM disciplines. The model is creating experiences and tools that are shifting the instructional approach in secondary STEM classrooms in order to provide students with the STEM content understanding and process behaviors that will enhance opportunities for success in university STEM courses or majors.

The goal of this work is to answer the question of: considering math and science teachers' own experience, and as augmented by an informed knowledge literature findings on gender STEM issues, what approaches would they select to address the issues and why.

## Background

*Project Pathways Structure and Courses.* The project model is a school/university/community partnership. Core partners are four school districts whose demographics mirror those of Arizona (Chandler, Mesa, Tempe, and Tolleson) and the Center for Research on Education in Science, Mathematics, Engineering, and Technology (CRESMET) at Arizona State University. The supporting partners are the Intel Corporation and Maricopa Community College faculty. The project is being implemented through a sequence of four module-based graduate courses coordinated with school-based professional learning communities (PLCs). The on-site activities promote same-school teacher communication, which can enhance pedagogical content knowledge and sustainability of classroom-based reflection. It is also provides teachers with the opportunity to earn a Master's degree of Natural Science (MNS) in content at ASU. The four courses taught include: 1) *Functions and Modeling* (Spring 2005 and 2006); 2) *Connecting Chemistry, Physics and Mathematics* (Fall 2005 and 2006); 3) *Connecting Biology, Geology and Mathematics* (Spring 2006 and 2007); and 4) *Integrating Mathematics, Science and Engineering* (Fall 2006 and 2007). Each course is being taught to high school science and math teachers from the four school districts with classes of 8 to 25 participants. Courses are taught on-site in each district once a week for 3 hours in late afternoon. The composition of teachers is about 55% mathematics, 25% biology and the remaining 20% chemistry and physics. The modules for each course have been developed by teams of 4 to 6 university and community college faculty. In each classroom there are two instructors and two teaching assistants. The instructors may be university or community college faculty or high school master teachers. The professional learning communities have four to six teachers and are held once a week for one hour and are overseen by a facilitator who is a usually a teacher at the school where it is held.

*Project Pathways Engineering Design Capstone Course.* In the engineering design process, the goal is to solve a technological problem or create a technological process, artifact or system. In the design cycle there is a series of steps employed, which are usually iterated as cycles, to achieve the end result[16]. Briefly, the design process may consist of the following steps: define a problem or need; specify the functional requirements and constraints to be fulfilled; brainstorm alternative solutions; evaluate solutions based on the criteria in requirements and constraints; use the proposed solution to fabricate a prototype and create an associated mathematical model; test and evaluate the prototype and model; and iterate to refine or modify the solution or, select another solution. In order to fully implement the design process, the concept of function and covariation must be used in conjunction with the scientific principles that describe the physical phenomena associated with the proposed design solution. Thus, in the *Pathways* project, the first course in Functions and Modeling, and the second and third courses in science, provide a critically necessary foundation for the activities and design projects in the capstone engineering course. As part of the project, a gender workshop was conducted to take advantage of the teachers' experience, in conjunction with findings in the literature, help teachers identify, discuss, and strategize about possible ways to address classroom gender and equity issues. As a result, teachers would be able to propose possible activities for their own classrooms.

*Female and Minority Interest, Achievement, and Persistence in STEM Education* - It is a challenge to show that mathematics and science have societal value and relevance in undergraduate engineering education[5]. This lack of connecting science to context and relevant experience in students' lives is a concern about the way it is taught in K-12[6]. A curriculum that links socially relevant content to science and STEM careers[7] and learning would also enhance linking abstract ideas in science to real-world contexts. Thus, both college and pre-college instructors should be concerned about students' understanding of the societal relevance of science and engineering.

The differences in way that males and females view the societal relevance of engineering are based in differences in the way men and women view knowledge and learning. Women are "connected knowers" who understand through context and relationships among people[9]. Men base their knowledge on logic[10]. These differences need to be accommodated in science and engineering curricula in the K-12 and the university or lower populations of females in STEM education and careers will persist. Women interested in science will more likely to enter people-related fields such as psychology or the biological sciences[11]. Even in first grade boys has more of an interest in physical science and girls have an interest in the biological and social sciences[12]. Girls in the K-12 system want to help people, the earth, and animals, all domains of which are linked to biological but not physical sciences[13].

Recent enrollment figures for high school mathematics (geometry, algebra II, trigonometry, pre-calculus, calculus) and science (biology, chemistry, physics, engineering) courses indicate that the gap between the number of males and females taking these courses is minimal. But, despite taking more high school courses in science and mathematics, the percentage of women interested in majoring in science and engineering in college has risen only slightly since 1977[14].

One reason for differences is in perceived competency. Girls in grades K-3 feel less competent in physical science than boys[15]. Another reason is that some females see science and mathematics as a means to an end -- a pathway to college entrance[16]. Another reason is that gender stereotypes still exist, which was pointed out in the workshop The science and mathematics professions are still perceived as for men by students as young as age five[15]. Negative experiences in science classrooms can degrade self-efficacy, as found when gender inequities in physics made girls' afraid of participating group discussions and activities[17]. One or more reasons may contribute to lower female participation.

*Bandura's Social Learning Theory.* According to Bandura[18], "... self-efficacy refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments". Bandura's social learning theory[19] finds that self-efficacy in learning is fostered by mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states. Self-efficacy influences how much effort is worthwhile to achieve an outcome[18,20,21]. Self-efficacy is also context specific in referring to an individual's belief to control a *given attainment*, such as learning a foreign language or running a race. Self-belief is a motivator of behaviors for attaining a goal, such as climbing a mountain[18]. Higher self-efficacy to do school-related tasks is related to higher academic persistence, particularly among minorities[22,23].

*Stereotypes of Scientists and Engineers and the Chilly Climate in Classrooms.* The image of the stereotypical white male scientist or engineer is a broadly held stereotype. People holding these stereotypes are usually male and may include: parents; school counselors; science and math teachers; and students in math, science, and engineering courses. Interactions of females with such individuals can have negative impact due to verbal persuasion, especially if they are significant individuals in students' lives. It can also create negative affective states in which females can't see the possibility of positive outcomes of classes or their relevance and value to their future. In math, science, or engineering classrooms with male teachers, they and/or their students holding such attitudes can create a "chilly climate" in the classroom.

*Tinkering Self-Efficacy.* A person's experience, competence, and comfort with manual activities are the basis for tinkering self-efficacy[24]. This reflects a person's confidence in conducting activities such as manipulating, assembling, disassembling, constructing, and modifying components and systems, (e.g. assembling a toy). Common hands-on activities are related to science and engineering education and careers, as well as laboratory-based and physical science careers, which females generally avoid. Women's lack of experience in tool and machinery use and assembling and disassembling devices contributes to low tinkering self-efficacy. An improvement could result better science and engineering achievement and career interest.

*Technical Self-Efficacy.* A person's confidence and belief in their competence to learn, regulate, master, and apply technical academic subject matter underlies their technical self-efficacy. Male engineering students who drop out of engineering have greater technical self-efficacy than females who graduate as engineers[25]. Women's self-assessment as problem solvers and as future engineers is lower than men's[26]. Although all girls experience declines in self-efficacy as they go through school[27], this is more so for Latinas than for Euro-American girls. Some studies report that even Latinas who excel in science receive messages of low expectations that contribute to their lower self-efficacy[28].

*Societal Relevance of Technology/Engineering*. This refers to the relationship of the science and engineering products and services and how they benefit individual lives, society and the environment (e.g. the science and engineering behind prosthetic devices for amputees or energy efficient appliances that conserve resources). Women usually do not consider science and engineering as a viable career choice because they are not aware of the societal relevance or the compatibility with their interests and values[29]. Women who consider STEM careers are often concerned about societal relevance and leave STEM majors for more personally fulfilling careers[30]. Thus, the evidence indicates that women's low levels of participation in STEM education and careers is due not to their cognitive ability or academic performance, but by affective factors that draw them to careers outside STEM[31, 32].

*The Role of K-12 Educators.* K-12 science educators and school counselors play a significant role in students' interest in science and engineering education and careers. They can influence their attitudes and perceptions through effective instructional strategies. Well-designed curricula can improve interest and achievement with instruction that uses important aspects of the sources of self-efficacy of mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states[18].

## Results and Discussion

## Methodology

The high school workshop was conducted during a three-hour class in an interactive format in which projected slides from a gender-equity learning module were also installed on teachers' computers. The general procedure for the workshop's four school district sections was: 1) a brief 5-minute warm-up discussion by the teachers on a given topic; 2) a short 5 – 10 minute presentation of research literature on the topic; 3) a think, pair, share activity for individuals at each table on a question pertaining to the topic; 4) a report out in a community discussion of the one most relevant or revealing example from each of 5 or 6 tables; and 5) recording by each individual on their computer their own or a shared story and brief reflection on personal insights on the topic. When the workshop was finished the teachers all turned in their recorded reflections with memory sticks to the instructor.

The workshop module was entitled "Can All Students Participate and be Served by the STEM Professions?" The first topic presented was on "Minority and Female Science and Engineering College Enrollment, Degrees, and Career Participation". There was a warm-up discussion on minorities in science and engineering followed by the presentation of literature findings. The teachers were then posed the question, Can you think of an example of a math or science "turnoff" incident or example for a female or a minority in a classroom, school, or daily life?" The teachers then conducted the think, pair, community share, and reflective recording activities.

The second topic was, “Some Barriers along the Educational Pathway form High School to the STEM Professions.” Before the presentation of literature findings, the teachers started with the warm-up discussion on what they might think are possible barriers or hindrances to STEM participation by females and minorities. Literature findings were then presented on each of the following subtopics: 1) societal relevance and impact of engineering; 2) tinkering self-efficacy; 3) technical self-efficacy; 4) “chilly” STEM learning climates; and 5) too technically oriented workshops. The teachers were then asked to think, pair, and community share on an incident related to one of the barriers. This topic was completed by reflective recording.

The next topic discussed was, “General Strategies to Promote STEM Participation.” The teachers had their warm up discussion with the activity of picking a “participation barrier factor” and possible strategies to address it. Literature findings on possible strategies were next presented. This was followed by now readdressing the original warm-up discussion activity on barrier strategies with the think, pair, community share, and reflectively recorded activities.

The fourth topic was, “Strategy-based Gender/Ethnic Sensitive STEM Activities for Knowledge, Awareness, and Career Guidance.” The warm up discussion considered what activities might develop students’ awareness, knowledge, and career possibilities linked to gender/minority issues. General strategies for such activities were discussed, in think, pair, community share, and reflectively record activities.

The fifth and final topic, which was abbreviated due to time limitations, was on “Some Gender/Ethnic Sensitive Engineering Activities and Career Guidance.” Just a single component of the usual five-component topic format was used. This was the presentation of literature findings on possible types of classroom engineering activities with gender/minority sensitivity for awareness of future courses and careers related to engineering disciplines. Such suggested activities included: 1) take apart (and maybe rebuild) items such as appliances, cell phones, and computers; 2) learn about the engineering design process in terms of how a component(s) of a familiar system, such as a bicycle or running shoe, are engineered from concept to manufacturing; 3) redesign common household objects to meet the needs of children, women /minorities, and the elderly; 4) image technical products and /or systems 10, 20, 50, or 100 years into the future; 5) research women’s / minorities’ engineering and science contributions over time through discoveries, inventions, and patents.

## Results and Discussion

The workshop addressed a variety of gender gap issues and associated barriers by showing the research of underlying causes of the barriers. Bandura’s’ social learning theory (SLT) was often applied in the analysis and interpretation of many of the responses in order to provide a theoretical grounding for understanding the responses. Examples of various types of barriers described by written responses will now be presented.

*Stereotypes of Scientists and Engineers and the “Chilly Climate” in the Classroom.* The image of the stereotypical white male scientist or engineer is manifest through many different types of people, settings and ways. People that this might hold these stereotypes are usually male and often include: parents; school counselors; science and math teachers; students in math, science, and engineering courses. From Bandura's SLT self-efficacy perspective, interactions of females with these individuals could have negative impact from the viewpoint of verbal persuasion, especially significant individuals in students' lives, as well as affective states in which female students could not see potential for positive outcomes of classes or relevance and value to their future. When male math, science, or engineering teachers and/or their students hold these attitudes they may result in the so-called "chilly climate" in the classroom. Frequently occurring incidents in the teachers' lives captured male stereotype images and how they often contribute to the "chilly climate" in science and engineering classrooms. The teachers expressed this in the following ways.

Beth experienced this attitude in her college classes in saying:

> I had a professor who constantly stated his belief that women should not be engineers.

Kelly also described a similar attitude in the following:

> *When the instructor is a male chauvinistic pig.* I had an instructor at the private college I attended he would always put down females any chance he had the opportunity. When you are in a neg. surrounding it affects the out come.

Sue related her own experience in saying:

> Males dismiss females doing science or going into science. The typical reaction I have seen with males addressing females is that males wonder why a female would care about science. Sometimes because a female can look nice she can't think.

Rita described a high school teacher's attitude when she related the following:

> *Male teachers in past dismissed possibility of women in science or engineering.* When I was in high school, I wanted to take an electronics class. My advisor told me that I was not allowed to take it since I was a girl. That was my first experience with academic prejudice that I encountered. I think that we have made great strides in promoting women, but we still have this stigma.

Sally felt that the negative consequences of stereotyped images extended beyond females and also included minorities and also included possible parental stereotypes:

> Another turn-off is feeling like you are constantly swimming upstream. When a girl has an interest in science or engineering and *everyone tells that girl that she "can't" do something*, that classes are not "for girls," eventually the girl may be discouraged. I imagine there are similar stories for minority students.
>
> *What parents have done may influence what their children do.* Since engineering has traditionally been a white male dominated field, and few women and minorities have gone into engineering, there may be little encouragement for women and minorities to enter the field.

Beth also extended her concerns about negative effects of stereotypes to minorities and also included possible parental stereotypes:

> Incident: I had a professor who constantly stated his belief that women should not be engineers.
> Lack of role models within the minority community.
> Lack of parental support/confidence.

Kelly felt that, for a female, joining the STEM workforce was a decision that had to be justified throughout a person's life:

> It is acceptable in our culture for a white male to go into and succeed in engineering and when asked as a child, teen or 20's something, stating engineering is acceptable. However, if *a girl or minority is asked what do they want to be when they grow up, stating a less expected/accepted answer like "engineering*" probably causes the person asking to follow-up with "why? " This leads to the kid always defending a choice of career and wonder why am I in this position? If I change my choice, then I am not on the defense all the time.

As part of the workshop teachers were also asked to pick a barrier issue and propose means to address it. Two of the teachers had suggestions about ways to address the issues of stereotypes and the "chilly climate". Rita said:

> *"Chilly" STEM environment:*
> One way would be some sort of sensitivity training for educators of STEM courses. Make sure that you weed out individuals who are not being receptive to encouraging women in the profession.

All of these female teachers have described how some male teachers' attitudes of science and engineering stereotype professionals emerge in the classroom. The impact and power of negative verbal persuasion can certainly discourage or even defeat possible interest in STEM education and careers. For Sue, the stereotypical image extended beyond the issue of who should be a scientist or engineer, and felt that some males could even dismiss the intellectual capabilities and potential of females in general. Kelly went beyond a single incident and felt that going into a STEM career was a decision that a female had to defend her entire life. In spite these teachers' experiences with stereotypical opinions and negative verbal persuasion, they had the fortitude and persistence to continue on their STEM educational pathways and become high school math and science teachers. Now that these females have succeeded in their STEM careers, they have the opportunity to act as change agents and role models.

*STEM Role Models to Address the "Chilly Climate"* Successful female STEM teachers, such as those in the Pathways courses, can act as role models of STEM professional success. They have the ability to create positive classroom climates and enhance vicarious experiences with team based learning, and give encouraging verbal persuasion, all of which can lead to positive affective states for female students in their science and math classrooms.

Fred felt that negative stereotypes of minorities as scientists or engineers and the negative persuasion were associated with lack of positive role models for underrepresented populations.

> One factor that might "turnoff" minority students in a math or science classroom is a *misbelief that minorities are not as capable of technical professions as their Caucasian counterparts.* The stereotype that minorities are best taught a trade or profession. This must be frustrating as a young minority to believe that the adults in your life believe that you are only capable of trade or labor professions. If a student does not believe he/she can pursue a technical career this is obviously a huge barrier to a STEM profession. Having a lack of confidence or role models is a barrier to participating in a STEM profession.

Mary also saw the issue of negative stereotypes tied to the issue of the lack of positive gender and minority role models.

> Time commitment, male dominated profession, lack of interest, no feeling of accomplishment, not getting job satisfaction, minority are too busy trying to catch up with culture as well as curriculum, level of math, *need a role model, and a few bad men Professors*.

Beth had suggested that one approach to address the issue of chilly climate was for emphasis to be placed on the positive impact of role models:

> *Role models, Non-traditional engineering, research technology*
> More exposure to female and minority engineers.

Although Dick was unaware of any particular incidents he had observed, he commented on the lack of role models and possible ways to address that issue.

> I do not know of a specific event that took place for a student to be turned off from engineering. However, I would imagine that if there are no *role models in engineering*, some will believe that maybe it is not for them (that particular minority). The Participation Barrier Factor is to have different *minority role model*s come into my class and talk about their experience in engineering. Hopefully, this will encourage others of a particular minority to think about possibly going into engineering. Class activity – Meet an Engineer Day.

*Tinkering and Technical Self-Efficacy.* Females may lack tinkering self efficacy because of fewer, if any, hands-on and related activities while growing up. This lack of mastery and vicarious experiences produces negative affective states in science and engineering laboratory and design experiences. This, in turn, drives females toward disciplines that create more positive states, such as the biological sciences, where there are more positive role models and stronger correlations to helping society. Although technical self-efficacy refers to problem solving ability the teachers have combined it together with tinkering self-efficacy. Some examples of issues and approaches to address tinkering self-efficacy are described here.

Sue suggests that tinkering self-efficacy could be enhanced with approaches such as structuring team-based activities so that females had opportunities to play the role the hands-on person and organizing summer activities for females that focused on tinkering activities.

> *Tinkering and technical self-efficacy – assign switching in roles when working in teams*
> To address tinkering and technical could form groups with girls as leaders and the tinkers. Assign specific roles that the boys naturally take and assign them to the girls. And make the boys the writers or observers or timekeepers. Also before school starts have classes where students can take introduction to tinkering. Like going from elementary school to high school they have summer school programs about going to junior high and high school. The classes are designed to alleviate stress for the new student.

Mona makes a similar suggestion while emphasizing that such programs should start when children are younger.

> *Tinkering…*
> if you start young with your own kids and show them how to work through. In a classroom teachers could encourage minority or girls in groups work through a task of tinkering. One suggestion was even keeping girls or minorities in a group so they are forced to do it and not wait for a guy to take control of the task. Assign roles so that they cannot be overlooked. Other groups said; engineer day for women or minorities, summer school programs to get started,

Don also suggests starting tinkering activities when females and minorities are younger with the best place being at home with everyday tasks with encouragement from parents.

> *Tinkering* – I think one of the best ways to break this barrier is to start early. Parents need to make a concerned effort to expose young girls to the tinkering process. Everyday household jobs can provide the types of experiences needed to accomplish the task. For example, changing then oil, backwashing the pool, putting together furniture, using power tools….

Frieda also suggests enhancing tinkering skills at home that promoted by children's parents.

> *Tinkering self-efficacy*
> a. let a daughter work side by side with her dad changing the oil, etc.
> b. allow girls to fix 'things' around the house
> c. buy girls tinkering toys like legos, bionicles, tool sets. . .

Fred also suggests a similar approach for parents to provide opportunities to tinker with toys and everyday tasks.

> *Tinkering self-efficacy-*
> We must provide opportunities to our children from a very early age to "tinker". Children need to opportunities to take things apart and put them together. This can be done a regular basis. If you change a tire on the car or bike, let your children help. If you are fixing the sink, the disposal, the frig., etc. let the children help. Include your children in daily activities. Yes, it will take you longer but it will provide them unique and valuable opportunities.
> Provide your children with toys that promote mechanical thinking. Tinker Toy's, Linkin Log's, erector sets, connects, lego's, etc. These toys help develop fine motor skills, mechanical thinking, and spatial relationships.

Sophie says that females should not be excluded from hands-on activities.

> *Tinkering self-efficacy:*
> All students need to be encouraged to tinker and work with their hands. Labs or assignments could be done individually so everyone has a chance to do the hands-on work without allowing someone else to stand in and take over.

Kelly is a science teacher who is already addressing the issue of tinkering self-efficacy in her own classroom.

> *Tinkering self-efficacy.*
> As it was stated in class, by giving children the opportunity to build and manipulate objects. It gives the child the confidence that they can achieve if they put their minds to it. Also by giving the girls a non-traditional toys and letting them play and manipulate the objects.

Trudy finds that if laboratory activities are not structured males will take over and exclude females from participation. She also comments that childhood activities for males are directed toward building and putting together whereas for females the activities are not. She suggests that the problem could be helped by starting females with hand-on activities in elementary school.

> When my students are in physics, the *boys tend to overpower the girls in performing the lab*, meaning they take over. Unless the girl feels very comfortable, she will not push the male student aside to participate. Most boys are raised to "build" by giving them Legos, K'Nex, Erector sets. Whereas female sets of Legos are of houses with furniture to build.
>
> Tinkering and Technical Self-Efficacy
> Starting in Elementary Schools, the students should be *exposed to labs with equipment and group the students as all girls* or all boys so that the girls have access to the equipment. This gives the girls the opportunity to tinker and become technically knowledgeable.

Mary talks about improving tinkering self-efficacy both at home and at school as well as talking about female role models as inventors and engineers.

> *Tinkering self-efficacy.*
> Women need to have the opportunities to "tinker" with things. Include more building activities, talk about things that women have engineered, talk about all different types of engineered artifacts that would interest male and female (toys and humanity saving), engineering barbies and other toys, lessons on fixing things around the house, research projects on the different engineering items.

Sandra also talks about activities at home and schools and compares activities for boys and girls.

> I think that *females tend not be engaged in "tinkering"* activities when young. There are different roles that parents assume of their children based on gender. Boys are typically thought of wanting to do more mechanical things whereas girls might want to play family roles. My son liked to take apart toasters, old radios anything that he could mess around with. He was easy to buy for. Buy a remote controlled toy and the remote would be broken within a few hours. We tend to buy different toys for girls. We don't promote fixing things and engaging in wondering why things work or don't work.
>
> In class, it would be fun to create a problem to solve and separate girls and boys into groups. This would force the girls to problem solve and not rely on any male influence. When told to participate, girls will perform. Given a choice, they would sit back and let others perform tasks.

*Perceived Societal Relevance of STEM Courses and Careers*. As previously stated, most women do not consider science and engineering as a viable career choice because they do not see the societal relevance and, consequently, believe that they are not compatible with their interests and values. Some of the teachers offered their own approaches for addressing this issue as described here.

Joan talks about changing impressions of the cold nature of engineering by having female role models discuss their jobs and also discuss engineering disciplines and activities that play "helping" roles for society.

> Many females may be turned off by the idea that engineering is a cold science field, creating bigger, better, mechanical devices. We could have female engineers visit school and tell students about what they do. Also, focus on engineering that "helps" society instead of building mechanical devices. Sharing more ideas about the nurturing and helping fields in engineering that may be more suited to women.

Sally suggests societal relevance could be enhanced by highlighting aspects of engineering and its disciplines that help society.

> As educators, we could encourage girls, who may be turned off by their perception of the things engineers do, to pursue engineering by highlighting work engineers do to "make the world a better place." For example, we could talk about engineering advances in the world of agriculture or the environment, in the area of prosthetics, in medical or biomedical engineering, etc.
>
> If girls perceive that engineering is all about designing machinery, it may encourage girls' interest in engineering to *bring up engineering machinery associated with industries that appeal to girls*.

Ellen suggests emphasizing aspects of engineering that are cool, such as design, innovation, and the positive impact that engineering has had on society in the past.

> *Societal relevance and impact of engineering:*
>
> - Try to show all the *cool things that engineers do, especially "helping" innovations like solar power*, biomedical engineering, etc. Have students do a short research assignment about a design innovation in engineering.
> - Highlight an *innovation like the printing press*, and have students brainstorm all the effects on society. How did it change our world?

Frieda suggests that both counselors and teachers could present opportunities for invention and innovation in engineering, as well as having guest speakers talk and offering high school engineering courses.

> *Societal Relevance*
>
> 1. teachers and counselors educate students about the engineering profession – they show all the possibilities in the field and neat inventions
> 2. guest speakers from the work field present in the school classroom
> 3. offer engineering courses in the high school

**Summary, Conclusions, and Implications**

Teachers in the Project Pathways capstone-engineering course first described their own experiences with gender-equity barriers in STEM education and then found out about the research-based issues that inhibited females and minorities from pursuing STEM in higher education and careers. The factors included environmental issues such as the "chilly classroom climate", stereotypes, and lack of role models. They also included the affective factors of tinkering and technical self-efficacy and the societal relevance of engineering. They also learned that well designed curricula can improve interest and achievement by implementing instruction that incorporates important aspects of Bandura's five sources of self-efficacy which include mastery experiences, vicarious experiences, verbal persuasion, physiological and affective states. Conversely, negative experience with these factors can lead to an individual's negative outlook on science and engineering and turn away from possible STEM educational and career pathways.

The teachers discussed their own experiences with regard to the factors. Surprisingly, at least to me, many female teachers related their own personal experience about "chilly climate", stereotypes of exclusive male STEM professionals, and correspondingly negative outlook on becoming female and minority STEM professionals. This was all exacerbated by a lack of role models. The prior experience and aggressive nature of boys excluded girls from hands-on experiences outside of school at the home as well as inside school in laboratories and other hands-on projects.

Teachers generated a variety of suggestions to ameliorate the issues that had been raised and illustrated with examples. They frequently discussed the importance of role models of females and minorities in the STEM professions as well as examples as inventors and engineers both present and past. A variety of approaches were also suggested to foster tinkering activities and associated building of tinkering self-efficacy. These included starting at the home with toys and everyday fix it activities. Such hand-on activities needed to be extended to school projects and laboratories starting at as young an age as possible, probably in elementary school. They also suggested more structured activities for labs and projects so females had opportunities with technical and tinkering activities instead of only management and recording roles. Teachers also felt it was important to force a shift away from a perception of engineering as a "cold" technical profession to a perception that it facilitates invention, innovation, and helping society and the environment.

If teachers were able to act on the suggestions discussed, the effect would certainly create a positive impact on Bandura's five sources of self-efficacy, which include mastery experiences, vicarious experiences, verbal persuasion, physiological and affective states. However, a single workshop is only a useful starting point and not a complete solution to addressing the many issues discussed. Teachers need further opportunities to discuss these issues, develop activities to address them in their own classrooms, meet together as a community of learners, and finally assess their efforts. Such an assessment might examine attitudes toward advanced STEM courses or continuing enrollment in STEM courses, as well as intention and enrollment in college STEM courses and majors.

The workshop itself was moderately successful in answering the research question of how math and science teachers', in drawing from their own experience and as augmented by an informed knowledge literature findings, what approaches, strategies, and activities they would they select to address the issues and why. The qualitative analysis of teachers' responses demonstrate that teachers took advantage of their own experience to understand gender and minority issues in STEM education and careers and could develop effective strategies and activities to address these issues. Additional effort to improve the workshop would be to include a pre and post workshop assessment tool on teachers' knowledge and awareness of gender / equity issues. The most telling impact of the workshop would be an activity in their own classrooms to determine the impact on students of a strategy-based classroom action on a gender / equity issue of their choice. Further development and reinforcement of the outcomes of the workshop would provide some hope that continuing efforts may begin to address the gender and minority gap that exists in engineering and STEM education and the workplace.

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