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Increasing Women's Participation in Math and Science Careers: Causes and an Intervention

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Introduction

Even though women are 50.7% of the US population (US Census Bureau, 2008), they only receive 46% of math and statistics bachelor's degrees, 47% of physical and related health sciences bachelor's degrees and 21.37% of engineering bachelor's degrees (National Science Foundation, 2003). Additionally, in these areas women have only 43.5% of the jobs in the physical and related sciences and only 19.7% of the jobs in engineering (National Science Foundation, 2003). While this under-representation of women in math and science related fields seems to be an “adult” problem, the real problem begins much earlier. Looking to fourth graders' performance on the National Assessment of Educational Progress mathematics section, males performed better than their female peers by two points on average (U.S. Department of Education, 2007). The problem of the under-representation of women in careers in math and science related fields is a prevalent problem in the United States and because of it, many women may not be exploring fields in which they could succeed and enjoy.

A review of the literature on women in math and science suggests that women do not pursue math and science related careers because of stereotype threats in society and low self-efficacy, and that implementing changes in the classroom through training for teachers might provide an effective intervention to increase the number of women in math and science. This paper will explore explanations for the under-representation of women in math and science related careers, propose an intervention for the problem, evaluate current interventions and suggest ways to measure and test the effectiveness of the proposed intervention.

Causes of the Problem

In order to explain the under-representation of women in math and science related careers, many studies have explored the predictors to women's achievement in math and science and the causes for women's lower performance in these areas. Suggested causes for women's performance in math and science include stereotype threat and stereotype internalization, and suggested predictors for women's achievement in math and science are high ability, self-efficacy and the types of subjects studied in high school.

According to Steele (1997), stereotype threat is:

> a situational threat – a threat in the air – that, in general form can affect the members of any group about whom a negative stereotype exists. Where bad stereotypes about these groups apply, members of these groups can fear being reduced to that stereotype. And for those who identify with the domain to which the stereotype is relevant, this predicament can be self-threatening (p. 614).

In the focus of this paper, women are experiencing a stereotype threat in the domain of math. Steele explains that threats can be experienced in several different ways. Stereotype threats can be experienced during performance in the domain area, for example a math test, and can cause emotional reactions that could directly interfere with performance (Steele, 1997). Steele (1997) also wrote that the threat in a chronic situation, such as a classroom or a workplace, can pressure "disidentification", which can lead to decreased motivation and not caring about the domain in relation to the self. In regards to women in math, Steele would argue that women under-perform and are underrepresented in math and science not because of their feelings about their ability, but because they experience emotional reactions to stereotypes and have disidentification. Ultimately, Steele (1997) believes that stereotype threats influence people due to the fear individuals have about confirming others' negative stereotypes about them.

The literature widely supports stereotype threat; many studies have been tested stereotype threat, and stereotype threat has been found to impair the performance of the stereotyped groups (e.g. Spencer, Steele, & Quinn, 1999; Sekaquaptewa & Thompson, 2003). Spencer et al. evaluated stereotype threat in three studies that together showed that women under-perform on difficult math tests when compared to men, and that the differences in performance were eliminated when the stereotype threat was reduced; they did this by describing the math test as one that did not produce gender differences. Sekaquaptewa and Thompson (2003) also found that reductions in stereotype threat reduced the performance differences across the genders. These findings support stereotype threat theory and suggest that interventions to increase the number of women in math and science need to focus on reducing or eliminating stereotype threat from the learning and work environment.

In addition to stereotype threat, research has shown that stereotype internalization and implicit attitudes also affect women's math performance and career choices (Kiefer & Sekaquaptewa, 2007; Bonnot & Croizet, 2007; Nosek, Banaji & Greenwald, 2002). In examining stereotype threat and implicit stereotypes, Kiefer and Sekaquaptewa (2007) found that implicit stereotypes about gender and math moderated the effects of stereotype threat on women's math performance. In the reduced threat condition, women who had lower levels of implicit stereotyping performed better on the test than women who had stronger implicit stereotypes, but in the stereotype threat situation all women, regardless of level of implicit stereotypes, had poorer performance (Kiefer & Sekaquaptewa, 2007). Similarly, Bonnot and Croizet (2007) found that stereotype endorsement significantly influenced women's self-concept of math ability and that these women still saw themselves in more “feminine” careers (Bonnot & Croizet, 2007). Bonnot and Croizet (2007) concluded that even though women have counter-stereotypic majors, women still have stereotype internalization that may impair their performance and career choices. In another study examining math and science stereotypes, Nosek, Banaji and Greenwald (2002) found that overall, both men and women showed strong identification with their own gender group and strong gender-math stereotypes, but that women had more negative attitudes toward math and less identification with math and science concepts. Nosek et al. concluded that the choices and preferences of the individual are constrained by group stereotypes. These findings all show that women have internalized gender-math stereotypes and tend to have more negative attitudes about math. The findings suggest that interventions need to focus on reducing stereotype internalization, as well as reducing stereotype threat.

Research has also shown that high ability and self-efficacy are predictors of math achievement and educational and career choices (Nauta, Epperson & Kahn, 1998; O'Brien & Fassinger, 1993). In a study examining the predictors of high level career goals among women in math, science and engineering majors, Nauta et al. found that there were significant relationships between ability, role-model influence, and self-efficacy and women's career goals. In a similar study, O'Brien and Fassinger (1993) found that career choices of young women were predicted by ability, agentic characteristics, such as self-efficacy and independence, gender role attitudes and relationship with mother. More specifically, the women who had selected nontraditional careers had high ability and strong agentic characteristics, and the women who had more liberal attitudes about gender roles had high math self-efficacy (O'Brien & Fassinger, 1993). Together these studies suggest that improving self-efficacy and math ability, and providing role-models for girls should be targeted in interventions aimed at increasing women in math and science.

In addition to high ability and self efficacy, another predictor for women's career choices in science and math is the number of elected high school science classes taken (Farmer, Wardrop, Anderson & Risinger, 1995). Farmer et al. found that the number of elective science classes taken during high school was the most important predictor for women's persistence into a science-related career. This conclusion can also help guide interventions, by encouraging high school women to elect more science classes.

Interventions: Problems to Target

The research into causes for women's under-representation in math and science and into the predictors for women pursuing math and science careers suggest that an effective intervention to increase the number of women in math and science would need to target stereotype threat in the classroom and improve women's attitudes and feelings about math and science (Steele, 1997; Nosek et al., 2002). A way to target these issues is to implement changes in the classroom, by training teachers to change and improve teaching methods, starting in elementary school and continuing on through high school, in order to reduce stereotype threats and improve self-efficacy. These issues seem to be the most important since they are found to be very strong causes and predictors for women's under-representation in math and science; other factors might be influenced through the changes in these first two. For example, changes in the classroom might produce more role-models that could inspire young women, and reducing negative attitudes and stereotype threat might improve women's math ability. Details of the proposed intervention will be discussed later in this paper.

Previous Interventions

Researchers have previously studied and suggested interventions designed to increase women in math and science and change the environment and attitudes. Steele (1997) implemented a program called “wise” schooling, Nauta et al. (1998) suggested interventions designed to increase self-efficacy in math and science, and Gavin and Reis (2003) proposed guidelines for teachers in the classroom.

Steele's (1997) “wise” schooling was implemented at the University of Michigan as changes in the learning environment that were designed to reduce the stereotype threat of African American students. Some of the changes implemented included optimistic teacher-student relationships, giving challenging work, stressing the “expandability of intelligence”, providing role models and building self-efficacy (Steele, 1997, p. 625). Steele (1997) concluded that the program was effective because these students did have higher achievement compared to similar students who were not in the program. This study, however, had limitations. One limitation is that it studied a group of African American college students who may not accurately represent all individuals facing stereotype threats; specifically, it may be hard to generalize these results to all women in math and science.

Others have proposed guidelines and suggestions for interventions, but have not empirically tested their ideas themselves. For example, in their study on predictors of high level career choices of women, Natua et al. (1998) suggested several ideas for interventions aimed at increasing the number of women in math and science. Their ideas for interventions included increasing self-efficacy, providing role models and reducing role conflict that the students experience, for example balancing work and family (Nauta et al.). Similarly, Gavin and Reis (2003) proposed guidelines for teachers in the classroom that are aimed at encouraging girls in math. Their guidelines include taking personal responsibility to encourage talented girls, creating a safe and supportive learning environment, providing single-sex learning opportunities, using language and activities that are relevant to girls, creating a challenging environment and providing role models for girls. Both of these suggested interventions have limitations because they have not been empirically evaluated. Future studies need to examine the effectiveness of these intervention ideas.

Overall, there have been many suggested interventions for increasing women in math and science, and seemingly few empirically evaluated programs. However, the conclusions made from Steele's (1997) study on stereotype threat and the “wise” schooling, suggests that a similar program designed for women in math and science may be effective. In regards to stereotype threat, simply reducing the threat during a test has been shown to increase women's math performance (Spencer et al., 1999). However, interventions for long term participation in math and science need to be developed and tested.

Proposed Intervention

Given the few empirically studied interventions on women in math and science, an effective intervention needs to be designed and tested. The proposed intervention would consist of training teachers who teach grades 2-12 to be aware of stereotype threats and aim to reduce them in the classroom. It is meant as a primary or preventative intervention when introduced in a young classroom and as a secondary and tertiary intervention when it is implemented in the more advanced grades. The goal is to reduce stereotype threat, stereotype internalization and to increase self-efficacy starting at a young age, which would then lead to more women pursuing careers in math and science.

The intervention program would include revision of teaching methods and improvements in the learning environment in the classroom by educating teachers on stereotype threat and how to reduce it in the classroom. Teachers would attend annual seminars and follow-up small group discussions after the seminars. Elements of Steele's (1997) “wise” schooling would be discussed, including having optimistic teacher-students relationships, stressing the expandability of intelligence, providing role models and building students' self-efficacy. Guidelines proposed by Gavin and Reis (2003) would also be discussed in the teacher training program, including assuming personal responsibility for encouraging girls in math, creating a safe and supportive learning environment, using language and activities that are relevant to girls, and creating challenging work. Teachers would also be educated on how to measure and improve students' self-efficacy, as suggested by Nauta et al. (1998), in order to identify students who need help increasing their self-efficacy.

Since this proposed intervention consists of ideas from Steele (1997), Gavin and Reis (2003) and Nauta et al. (1998), this new intervention is similar to these but is an improvement on them. This intervention improves Steele's (1997) intervention, since it begins to target girls at a young age, and the intervention complements the ideas suggested by Gavin and Reis (2003) and Nauta et al. (1998), since it incorporate their ideas into younger and older groups. The differences in target age would hopefully prevent stereotypes and stereotype threats from forming and give girls a better opportunity to excel in and pursue math and science fields.

Measuring Effectiveness

In order to test this intervention for effectiveness, a large longitudinal study would need to be completed. The participants in the study would consist of students in school systems grades 2-12. This population is targeted because stereotypes about math are learned and endorsed during these ages (when students are learning math). Only focusing on younger girls would miss difficulties later in development, and focusing only on older girls and women would be too late, since stereotypes and self-efficacy would already be formed and endorsed. The intervention would be tested in four school systems that have grades 1-12. Two school systems will have teachers undergo training and be monitored for changes in the classroom, and two school systems will not receive intervention. In total, there would probably be about 6,000 students receiving the intervention, if schools with approximately 3,000 students are selected for the study. The design of the study is quasi-experimental since schools can be assigned to different treatments, but genders cannot be assigned to the students.

Critical Evaluation of Intervention

The desired outcome would be increases in the females' self efficacy in math and science at the end of high school and persistence into a science or math related career. To measure this outcome, participants would be evaluated every couple of years over 15 years, and then at the end of the 15 years to determine if more women went into math and science related professions. This length of the study would enable all students pass through the program and possibly through 4 years of college. Evaluations would consist of scores of self-efficacy, math achievement, and career choices. Teachers and their classrooms would also be monitored for changes in reduction of stereotype threat, building self-efficacy and in encouraging their students by having optimistic relationships. Teachers who were not making progress would be reminded of the seminar topics and encouraged to make changes in their classroom. To test the overall effectiveness of the program, the rates of women in math and science professions in the intervention schools would be compared to the rates of those in the non-intervention schools and to see if there was a meaningful increase in the number of women in these fields.

Limitations and Applicability

Given enough resources to hold of annual seminars, this intervention would be applicable to real life. Teachers in schools would attend seminars educating them about stereotype threat and would then make changes in their classrooms to reduce stereotype threat. This intervention and study would have some limitations, however; the schools selected for the study might not represent all schools, all students or all teachers across the United States. The program is also based off of Steele's (1997) “wise schooling” and it was only tested on African American college students; as already discussed, this group of individuals, given their ethnicity and age, do not represent the participants in this intervention. However, even with these limitations, there is reason to believe that the changes made regarding the reduction of stereotype threat in the learning environment would affect women's participation in math and science because women tested in reduced stereotype threat environments perform at the same level as men (Spencer et al., 1999). Significant changes in the classroom that would lead to increased self-efficacy and more positive attitudes about math could also lead more women into math and science, since women who have nontraditional careers have high math ability, self-efficacy and independence (Spencer et al., 1999; O'Brien & Fassinger, 1993).

Conclusion

An intervention is needed to encourage women in math and science because there is an under-representation of women in these areas. Because researchers have found that causes of this problem are stereotype threat, stereotype internalization and low self-efficacy, an intervention is needed to encourage women in math and science, build their self-efficacy and reduce stereotype threats. The proposed intervention in this paper targets students in grades 2-12 by educating teachers about stereotype threats and encouraging them to make classroom changes that would help girls become more confident in their math abilities and reduce stereotypes. The intervention would need to be tested for effectiveness through a longitudinal study examining many students through their education and their career outcomes, and would hopefully lead more women to pursue math and science related careers. Studies have shown that reducing stereotype threat improves women's math performance (Spencer et al., 1999), so by decreasing the threat in the everyday learning environment, it is hoped that more women would feel comfortable and able to study and choose careers in math and science.

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