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Who Can Excel in Mathematics?

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WHO

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Students may erroneously believe that mathematics ability is largely innate and fixed (Kimball and Smith 2013). The evidence *seems* to support these mistaken beliefs. Women and minorities score lower on the mathematics section of the SAT (College Board 2017). When assessing students' mathematics college readiness, a larger percentage of women, African Americans, and Hispanics fell below the benchmark (ACT 2017); and, in general, in science, engineering, math, and technology (STEM) fields, the gender and racial gaps in interest, performance, and degrees awarded have not closed (Neuhauser 2015). Persistent performance gaps can serve to reinforce students' mistaken belief that women and underrepresented minorities simply have less aptitude for mathematics, which, in turn, can discourage even the strongest students from persisting. Known gender and racial stereotypes could conceivably dissuade those who have the ability and interest from studying or working in a STEM field. Additionally, because mathematics problems are often solved in a logical, abstract manner, students with learning disabilities or those who process information in a different manner could be thought to have less mathematical ability, as research has shown that students with a learning disability are perceived to be less intelligent (May and Stone 2010).

NCTM has called on teachers to create supportive and equitable classroom environments, to steadfastly advocate that all students can learn mathematics, to hold high expectations for all students and to adopt practices that offer students the opportunity to excel (NCTM 2014). The overarching aim of this article is to connect the research literature with pedagogical practices that help increase opportunities for all students to learn and

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CAN EXCEL IN MATHEMATICS?

Change the misconception that many students have that mathematical aptitude is innate.

achieve. This article illustrates classroom practices in four key areas—negative stereotypes, mindsets, participation, and problem-solving strategies—that can be used to strengthen the alignment of mathematics educators' pedagogical practices with NCTM's commitment to social justice. By providing research-based pedagogical strategies that educators can easily implement, I hope to help teachers ignite students' enthusiasm for mathematics, increase students' self-confidence, and empower all students to achieve to the best of their abilities.

TEST PERFORMANCE AND STEREOTYPE THREAT

Gender and racial performance gaps often emerge on high-stakes mathematics tests (ACT 2017; College Board 2017). However, these gaps may, in part, be caused by negative stereotypes, which have been shown to suppress the scores of women and minorities on mathematics tests (Alter et al. 2010; Good, Aronson, and Harder 2008). A phenomenon called *stereotype threat* emerges when one is in a situation that has a risk of being judged negatively on the basis of stereotypes others may believe about one's gender or race. This makes the test taker anxious about confirming the stereotype, which can negatively impact how the test taker performs (Plante et al. 2013). For example, when taking a high-stakes mathematics test, women—aware of the negative stereotype—may realize that a poor performance on the test could confirm the stereotype, which, in turn, can hinder their performance on the test. Stereotype threat has been shown to cause women (Pincho, Rodriguez, and Finnie 2013) and minorities (Alter et al. 2010) to underperform on tests. Additionally, stereotype threat has been suggested as one reason women and minorities leave STEM fields (Beasley and Fischer 2012).

Although this may seem like an insurmountable problem, research has shown that stereotype threat can be reduced (Alter et al. 2010; Good, Aronson, and Harder 2008). In one study, when gender stereotypes were nullified before taking a mathematics test by telling students that the test was unbiased and had not previously shown gender differences, stereotype threat was reduced and women's exam scores improved (Good, Aronson, and Harder 2008). In another study, when the test was reframed as a challenge rather than a diagnostic measure, by telling students the test would teach them something new, stereotype threat was eliminated and African American students' test scores rose (Alter et al. 2010). Teachers can easily employ these strategies.

Research on stereotype threat examined the impact of interventions to nullify negative stereotypes immediately before taking a test. Given how successful these strategies are, teachers may want to consider highlighting the accomplishments of diverse mathematicians throughout the year. Also, by sharing that gender and racial gaps can emerge due to differences in one's home or school environment, socioeconomic status, or beliefs rather than innate differences in ability, stereotype threat may be reduced further.

A GROWTH MINDSET

Research has shown that debunking negative stereotypes in combination with fostering a "growth mindset" can help close the gender and racial achievement gap (Dweck 2008). A growth mindset is the belief that by applying oneself to any task, one's intelligence and abilities can be strengthened (Dweck 2015). By contrast, a fixed mindset is the

belief that one's intelligence is static/permanent and cannot be altered (Dweck 2015). The type of mindset a student has connects with the motivation a student puts forth and ultimately how well he or she performs (Dweck 2006). Understandably, students who believe that intelligence can be developed will work more diligently on challenging problems and not necessarily interpret obstacles and setbacks as clues that a task is simply too difficult to accomplish.

To help students shift to a growth mindset and become more persistent, successful problem solvers, I introduced research on mindsets in an introductory college statistics class at the start of the school year. The class consisted of students of varying abilities who were directed to the mindsetworks.com website and instructed to read about mindsets and write a one- to two-page paper reflecting on their mindset and describing steps they could take to develop a growth mindset to help them master statistics. One student wrote the following:

> I noticed that if I'm doing something that I enjoy, I have a growth mindset; I don't worry about the challenges, I just want to get better at the task I'm trying to achieve. This is a technique or skill I can use to help me improve my grades and performance in statistics. . . . Every year, when I come into a math class, I tell myself, "I'm ready to fail this class." This is the fixed mindset I put myself in. . . . When I think of math, I just think negative thoughts and how bad I am at the subject. . . . I decided to come into this environment with a growth mindset to help me improve on the way I take opportunities offered to me in school. . . pretend statistics is a brand new subject I'm about to learn for the first time. . . .

This assignment helped students become aware of and change their mindsets.

Over time, students became more persistent problem solvers. Although the new perspective was helpful, it is important not to praise effort alone, as working tenaciously on a mathematics problem without making progress would mean that students' conceptual understanding may not have increased (Dweck 2015). Therefore, Dweck suggests instead acknowledging the effort put forth and then encouraging students to shift their focus to alternative unexplored strategies that could be tried. I have found it beneficial to remind students of previous challenging problems that they solved by considering alternate paths rather than prematurely concluding that all available options have been exhausted.

Real progress in mathematics requires perseverance and practice. However, some of my students' study habits were not well aligned with their new growth mindsets. Therefore, a few months into the semester, I asked students to use a Microsoft Excel® spreadsheet to record how they spent their time during a week and to use the data to create graphs and write a reflection paper. One student wrote,

> It appears like I manage my time, but when you consider the hours I'm not in school or work, I spend it hanging out far more than I could afford. . . I'm not making wise decisions. . . .

In class, students analyzed the part of the data set showing how many hours of television they watched per week. Some data points were outliers, and some students seemed shocked by the results. Armed with this information and believing that intelligence could be developed, students gradually changed their study habits.

CLASSROOM PARTICIPATION: DIVERSE VOICES

Creating a classroom environment that values all students' unique contributions and is responsive to their backgrounds is important for teachers to do. Gender and racial stereotypes may be internalized inadvertently. By grade 5, children are aware of racial stereotypes that associate Asians with math ability (Cvencek et al. 2015). Stereotypes can impact the class environment. First-year algebra teachers believe that learning-disabled students may feel stigmatized in the classroom (Lusk, Thompson, and Daane 2008). Instructors pay more attention to boys than to girls; boys dominate classroom conversations (Riegle-Crumb and Humphries 2012; Sadker, Sadker, and Zittleman 2009); and teachers rate girls who perform similarly to boys in mathematics as less proficient (Cimpian et al. 2016).

To guard against unintended stereotypical views influencing the learning environment, teachers may find it beneficial to monitor students' participation closely. I implemented a strategy that encouraged all students to contribute to class discussions. Every three weeks, I taped a large sheet of paper to the wall and asked students to add their names to the paper after they went to the board to share their work. As class participation factored into students' grades, I told the class that by the third week, all students' names had to be on the paper. Initially, some students went to the board with their peers. Students who were more reserved and nonnative speakers started to volunteer. Particularly strong students mentioned that they were concerned that they were raising their hands and not always being selected to answer questions. I replied that even by raising their hand and my seeing their work, they were letting me know that they had mastered the material, which

made me proud. Sometimes mathematically strong students were directed to assist their peers, which lessened their concerns and kept them engaged. Over time, the number of students who participated steadily increased, and their confidence rose. This strategy can help guard against any tendencies educators might have to call repeatedly on students who were perhaps socialized to be more vocal or those whom teachers may erroneously perceive to be mathematically stronger.

PROBLEM-SOLVING STRATEGIES

Alternative solution strategies could be encouraged to further increase participation. Some students are visual learners, some can think abstractly, and others prefer to work with concrete situations. Still others may have difficulty processing information quickly. Open-ended questions can be a valuable tool for use in classes with students having a wide range of abilities (Sole 2016; Kabiri and Smith 2003). Open-ended questions offer students the opportunity to employ the strategy that they understand best (Sole 2018). The choice of strategy gives students who understand problems differently a chance to recognize their mathematical strengths. Teachers may inadvertently convey that only students who can approach a problem abstractly, or work with a particular strategy, or process questions in a timely manner and identical fashion as demonstrated in class have mastered the material. Because open-ended questions afford students the opportunity to produce novel responses, these types of exercises can be used to highlight all students' strengths.

The transition to a more open-ended approach can be accomplished by removing the directions that accompany questions. For example, allow students to find the zeros of a polynomial using a method of their own choosing. Because constructing open-ended questions can be challenging, for alternative suggestions on how to locate, modify, or create open-ended mathematics questions, refer to Sole (2018).

In response to open-ended questions, some students may elect to use strategies that are tedious or appear overly simple, lacking the rigor of methods that teachers may have demonstrated. Teachers who want all students to believe that they can learn mathematics will recognize the benefits of sharing different methods and illustrating that mathematics is a creative field.

CONCLUSION

I have found that the biggest mathematical misconception that students have is the belief that only certain individuals have an aptitude for mathematics. Some students may have internalized known stereotypes that portray women, underrepresented minorities, and learning-disabled students as having less innate mathematical ability. Some students may incorrectly believe that mathematics ability is fixed. Others may associate mathematical aptitude with logical thinking. Students who process information differently might thus consider themselves as less likely to be successful in mathematics. Although these mistaken beliefs might negatively impact students' ability to master every topic in every mathematics class and may even dissuade some students from enrolling in advanced mathematics electives, these misconceptions are rarely addressed in class.

This article links the research literature with concrete suggestions for classroom practices that embrace and support NCTM's position on equity. By debunking negative stereotypes, fostering a growth mindset, and encouraging all students to participate and use or invent different problem-solving strategies, we may narrow or even close the persistent gender and racial performance gaps. By making modest changes, teachers can help create a more equitable environment that clearly expresses their belief that all students can excel in mathematics. These research-based practices were designed to encourage active participation and increase the persistence of diverse groups of students. Linking research and practice, these strategies can help all students reach their potential, creating a great learning environment that benefits students, teachers, and ultimately, by encouraging and retaining talent, the field of mathematics.

BELIEVING THAT INTELLIGENCE COULD BE DEVELOPED, STUDENTS GRADUALLY CHANGED THEIR STUDY HABITS.

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