CULTIVATING K-12 STUDENT INTEREST IN STEM

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Abstract

In recent years, there has been a tremendous push for teachers to emphasize science, technology, engineering, and mathematics (STEM) education, in all K-12 classes. Teachers play a critical role in student interest and mindset towards STEM fields. This paper examines some of the research related to STEM education in the United States, math anxiety, growth mindset, and the teacher's role in student interest in STEM. The subsequent study focuses on the teacher role and teaching practices that may encourage or deter students from STEM. It surveys college students between the ages of 17 and 22 about their current STEM interest as well as K-12 experiences with various STEM activities. The study will be conducted through an online survey, and it aims to provide a description of teacher influence on interest in STEM within their students.

Cultivating K-12 Student Interest in STEM

In today's society, there is a greater push than ever towards career choices involving science, technology, engineering, and math, otherwise referred to as STEM. According to an article published by economicmodeling.com, STEM fields have seen exponential growth since the Great Recession. From the 2009-2010 academic year to the 2015-2016 academic year, the number of students enrolled in undergraduate STEM programs grew by a staggering 43% (Wright, 2017).

Parallel to this growth in undergraduate students seeking STEM degrees, there has also been a push to incorporate STEM education into the typical K-12 curriculum. This is primarily fueled by the fact that the United States typically scores below any other first-world country on tests that measure STEM achievement. Within the overall movement to promote STEM education, there are multiple smaller movements to promote STEM education and careers, as well as researchers who focus on factors that affect STEM interest and performance. These same researchers also focus on what can be done to lessen negative factors and increase student interest and performance.

Many students, parents, and teachers have experienced some sort of anxiety about mathematics. Perhaps they enjoyed and understood mathematics until they encountered something more abstract like algebra, or perhaps they have always had an innate aversion to it. As it turns out, mathematics anxiety experienced at any point in a student's academic career can impact their mindset towards mathematics past just that one year. Cultivating a growth mindset can be helpful for students seeking to overcome and prevent math anxiety.

Literature Review

STEM Education in the United States

As the world becomes increasingly high-technology, many are worried that the United States is losing its competitive economic edge due to lack of interest in STEM fields (Harrington, 2015). Because of this, there has been a recent push towards better STEM education in the K-12 classroom. This movement truly began in 2009 when the Obama administration launched a campaign to support a stronger STEM curriculum in K-12 schools in hopes that more students would pursue a STEM field in college ("STEM might win," 2018). According to the United States Department of Education website, a STEM education equips students with the "Knowledge and skills to solve problems, make sense of information, and know how to gather and evaluate evidence to make decisions."

According to a 2016 journal article by researchers Yu Xie, Michael Fang, and Kimberlee Shauman, definitions of STEM education can vary by grade level. For example, in grades K-6, STEM education is typically considered to be the required math and science curriculum. As students move into high school however, the definition of STEM suddenly expands to include things like computer science, social sciences, and basic engineering technology classes. They attribute this expansion to the fact that students simply now have more options within their science and mathematics curricula (Xie, Fang, & Shauman, 2015). The expanded definition of STEM could also lead to increased interest once a student begins high school, as the new definition might now contain one of their interests.

The website weareteachers.com proposes a slightly different definition ("STEM might win," 2018). It proposes that the key to STEM education is integration. It goes on to say that an effective STEM education at all levels includes the involvement of hands-on, real world experiences whenever possible. According to an article from the National Science Teaching Association (NTSA), both weareteachers.com and Xie's sociological study are correct when it comes to STEM education. The key to STEM education does exist within integration, but there is room for flexibility and interpretation as to what that integration could--and should--look like (Gerlach, 2012).

Math Anxiety and Growth Mindset

Test anxiety is a common phenomenon among students that many teachers are familiar with. Math anxiety is also surprisingly common among students, but teachers are not as aware of this. Researchers Susan Fiske, Sian Beilock, and Erin Maloney explain that many people have a fear of math. This fear can be so intense that people limit their career options by avoiding mathematics at all possible costs. This fear and anxiety towards math is called math anxiety. They further define math anxiety as experiencing "Fear and apprehension when faced with the prospect of doing math" (Fiske, Beilock, & Maloney, 2015). A 2014 study reports that around 25% of college students and 80% of junior college students reported a moderate to high degree of math anxiety.

Typically, math anxiety is caused by a combination of cognitive predisposition and exposure to negative attitudes towards mathematics and related fields (Fiske, et. al., 2015). These negative attitudes can come from students' peers, parents, and teachers. Female teachers with math anxiety are far more likely to pass that anxiety on to their female students and reinforce negative gender stereotypes in STEM fields. However, this does not appear to hold true for male students (Beilock & Hertz, 2017). In order to target math anxiety in students, further study must be made on the differences between parents and teachers exhibiting high and low levels of math anxiety and their interactions with students.

In her book Mathematical Mindsets, Jo Boaler points out that everyone is born with the ability to do mathematics, including the students who feel a level of math anxiety (Boaler, 2016). She explains that a growth mindset is a key factor in students' sense of mathematical self-efficacy.

Growth mindset came as the result of the work of psychologist Carol Dweck. It is best defined as the ability to which a student thinks his or her intelligence is fixed or fluid (Bostwick, Collie, Durksen, & Martin, 2017). Students with high growth mindset assessment scores believe that intelligence is highly fluid and can continue to develop and change across the lifespan. In contrast, a student with a fixed mindset believes that their intelligence is fixed and will not grow and change across the lifespan. Typically students who experience high levels of math anxiety tend towards a more fixed mindset than those who do not. Boaler attributes this to the fact that students with a growth mindset believe that they are capable of learning and doing many things with work and perseverance.

Teacher Role in STEM Education and Appreciation

Educators play a critical role in student perception of content. According to a 2015 study, teacher quality significantly impacts student achievement. Thus, the higher the teacher quality, the greater student achievement will be within a given content area (Fiske et. a., 2015). In a 2018 study, Aarek Farmer studied the impact of content knowledge and teaching ability on student motivation. Farmer found that motivated students believe that their teachers have deep, robust content knowledge. Moreover, "For motivated middle and high school students, the perception of their teacher's content knowledge was the highest predictor of the level to which they were motivated" (Farmer, 2018). The study stated that if students believed that their teachers had strong content knowledge, they were more likely to believe in their own ability to succeed in the class. In conclusion, "For highly motivated students, content knowledge was the factor that had the most impact on the degree to which the student was motivated" (Farmer, 2018).

The ideal for every teacher is that they make mathematics accessible for all of their students. In order to do this, Farmer's (2018) research suggests that, in addition to working on a growth mindset, teachers should increase their own self-efficacy and mathematical knowledge. Part of cultivating a growth mindset in students lies in classroom rhetoric. Often teachers do not realize they are sending implicit messages that some students are better at math than others. They do this by providing greater opportunities for rigorous tasks only to the students they perceive as smart, instead of all of their students (Sun, 2018). In the same article, Sun suggests that educators need to move from the growth mindset rhetoric and into instructional practice. She notes that an easy way to do this is to "Encourage students to 'believe in yourself.'" Three other strategies for fostering a growth mindset include emphasizing understanding vs. procedure, eliminating fixed-label language, and maintaining rigor as students struggle and make mistakes (Sun, 2018).

Method

Participants

Participants in this study included 241 undergraduate students, primarily at Kansas State University. This included 178 females and 61 males between the ages of 17 and 22. Some participants chose not to disclose their gender or age. Of the participants who chose to provide their ethnicity, 211 were Caucasian, 12 were Hispanic/Latinx, 3 were Asian, and 2 were Native American. There were no Black/African or Pacific Islander participants. Everyone who participated in this study did so voluntarily.

Materials

Considering the primary research questions and available resources, a survey was the best option for this study. It was created using Qualtrics Survey Software. There was a three-question demographic section. The survey included general questions about math anxiety, fixed vs. growth mindset, and whether or not the participant took honors or Advanced Placement courses in high school. An extensive list of STEM majors was provided. Participants' majors were determined as STEM if they were explicitly science, technology, engineering, or math, or if STEM classes made up the majority of the coursework. Without directly describing them as STEM majors, each participant was asked if they were majoring in anything listed. Based on their answer, the participant was classified as a STEM major or non-STEM major. This was done to avoid participants mislabeling their major as STEM. For STEM majors, questions were asked about the timing of their initial interest, types and frequency of STEM activities they participated in, and the level of support they've received from teachers, parents, mentors, etcetera. For non-STEM majors, questions were asked about the timing of their initial disinterest in STEM, what factors contributed to that disinterest, and if caregivers or teachers had a specific role in deterring the participant from STEM. Finally, it was noted at the end of the survey that the purpose of the study was to understand how students develop interest in STEM fields and what educators can do to foster that interest. Participants were asked to share any additional information they felt may be useful given the purpose of the study.

Design and Procedure

The research design of this study was non-experimental and correlational as it studied the relationship between one's K-12 experience and their undergraduate major. The survey was primarily distributed online through various Kansas State campus listservs. It was sent through the Kansas State University College of Education, and the Kansas State University Math Department. It was also shared on Facebook by the Alpha of Clovia 4-H Cooperative Leadership House, Kappa Kappa Gamma sorority, and several users' personal accounts.

Results

Before examining specific variables, we looked for common trends among survey participants. Of all participants, 74.48% were female, and 88.28% of all participants were Caucasian. Of all participants, 54.39% experienced at least "some anxiety" from mathematics during their K-12 experience. Only 14.23% reported experiencing no anxiety due to math. 63.6% of participants took honors, Advanced Placement, or International Baccalaureate classes. Of those that took such courses, 78% reported their average honors/AP/IB grade as an A. When asked if they thought practice and determination or fixed genetic traits have a greater impact on one's ability to perform mathematical tasks, only 1.67% of participants chose fixed genetic traits alone. Most participants (48.12%) chose practice and determination alone, and 44.35% believed it's a combination of the two. The majority (36.55%) of the study's participants were grouped into the STEM major category, with the rest falling into the non-STEM major category. For the list of undergraduate majors classified as STEM, refer to Appendix A.

Of those who were categorized as STEM majors, most (41.46%) became interested in STEM during high school. The most frequently listed activities which initially sparked participants' interest in STEM were math or logic puzzles and games, a class, and building with legos or blocks. Most (36.25%) of the STEM major group participated in STEM-related activities daily during their K-12 experience, and 38.75% participated in such activities weekly. When asked if someone helped spark their initial interest in STEM, the most common answer (34.97%) was a teacher, and the second most common answer (22.7%) was a parent or guardian.

An overwhelming majority of STEM major participants (96.4%) said their decision to enter a STEM field was supported by their parent(s) or guardian(s). The majority (74.7%) also said they have a supportive peer or mentor in their field of study. STEM major participants listed the three most common ways teachers supported their interest in STEM, respectively, were verbal encouragement, additional STEM-related coursework, and STEM-related clubs.

Of those categorized as non-STEM majors, most (37.6%) became disinterested in STEM during high school, and 31.2% became disinterested in middle school. Non-STEM majors reported the most common factor (35.02%) for not majoring in STEM fields was greater interest in another topic of study. Belief that they were not smart enough to enter a STEM field (14.44%) and belief that majoring in STEM is too difficult (12.27%) were the next two most common answers. When asked if their parents supported their decision not to enter a STEM field, 86.26% of STEM majors said yes. 57.35% of non-STEM majors reported that their parent(s) or guardian(s) were not STEM majors, and 71.85% reported that their parent(s) or guardian(s)' field of study had no impact on their decision to major in a specific field.

Non-STEM majors were asked to answer two open-ended questions. The first was, "What deterred you from STEM?" Answers to this question seemed to match the results for factors that contributed to non-STEM majors' decision not to enter a STEM field of study. The most common answers involved greater interest in another subject area, and perceived difficulty of STEM. Of the 117 non-STEM majors who answered the question, here are five results:

- "Didn't necessarily have a 'natural inclination' towards it; my brain is more fitted for arts and sciences."
- "I enjoyed those subjects, but I felt I wouldn't cut it after graduating when I would be in the field."

- “Lifestyle of careers, and the fact that it is mostly men in STEM.”
- “The way teachers taught it. They didn’t make it fun to learn anymore and just made me feel dumb.”
- “I found it boring and rigid.”

The second open-ended question that non-STEM major participants were asked to answer was, “What do you wish a teacher could have done in order to make STEM more appealing?” There was a myriad of suggestions including: utilize multiple entry points or methods for solving problems, use creative applications, less homework, more hands-on activities, providing more background information, having more patience with students, lessening time constraints, making content more relevant and real-world, opportunities for individualized instruction, encouraging females, promoting growth without dwelling on failures, and showing more enthusiasm for content.

Using data gathered from the survey results, specific variables were analyzed using ANOVA. These include the number of female participants, the number of white participants, how many participants reported having at least some anxiety due to math during their K-12 education, how many participants believed that practice and determination have a greater impact on one’s ability to perform mathematical tasks than fixed genetic traits, and at what point participants became interested in STEM during their K-12 education. Each of these variables was compared to whether or not participants were majoring in a STEM field.

These results showed that there was a significant difference in the proportion of male and female participants who were STEM majors (p-value = 0). There was a significant difference in the proportion of those with and without mathematical anxiety who were STEM majors (p-value = 0.0004). There was also a significant difference in the proportion of those with and without an interest in STEM during their K-12 education who were STEM majors (p-value = 0). There was no significant difference between white and non-white participants majoring and STEM. There was also no significant difference between participants majoring in STEM who believe that practice and determination have a greater impact on one's ability to perform mathematical tasks and those who believe fixed genetic traits have a greater impact. Please refer to Appendix B for the specific regression ordinary least squares results. Appendix C shows the correlation between the five aforementioned variables and whether or not one was majoring in a STEM field.

Implications and Future Study

Based on the data and results of this study, there are several points which can be made. Every person's K-12 education and life experiences, leading up to their decision to choose a field of study are unique. While one's gender, age, ethnicity, levels of anxiety, educational background, and upbringing may contribute to this, it is impossible to pinpoint one factor as the sole cause of either attraction or repulsion to STEM. The significant difference in the proportion of male and female participants who were STEM majors, and the negative correlation between females and majoring in STEM show women in this study were less likely than men to be STEM majors. There was also a significant difference in the proportion of those with and without math anxiety who were STEM majors, and a negative correlation between those with anxiety due to math and majoring in STEM. However, gender or math anxiety do not prove causation for choosing or not choosing to study STEM. Additionally, there was a significant difference in the proportion of those with and without an interest in STEM during their K-12 education who were STEM majors. This may seem trivial, as it makes sense that those interested in STEM before college would likely major in it. It is important to note though, as it shows that a significant number of participants in this study who chose to major in STEM developed an interest in STEM during their K-12 education. Again, this does not prove that one's K-12 education is the sole factor in the decision to study or not to study STEM in college, but it does show that it may have some impact.

If this study were to be repeated in the future, there are several changes which could be made. First, allowing nontraditional undergraduate students who are not between 17-22 years of age to take the survey may have diversified results as they are more likely to have experienced more direct and traditional instruction in their K-12 education. It might also be interesting to know what experiences between their K-12 education and undergraduate education contributed to their decision to pursue or not to pursue a degree in STEM. Second, identifying participants' majors as STEM proved to be more complicated than expected. Several participants' noted at the end of the survey that they disagreed with the provided list of STEM majors and believed their field of study should be classified as STEM. These majors included agricultural education and anthropology. The list of majors included in the survey was also specific to Kansas State University. Perhaps the survey should have been administered to more distinct populations, such as those who are specifically majoring in engineering, math, or a designated field of science or technology. Instead of identifying those majors as STEM, and others as non-STEM, the survey could have referred to fields of study in a more general sense, labeling participants as STEM or non-STEM majors in a more discreet way. Knowing that participants also disagreed about the classifications of STEM fields, it may have been beneficial to ask what they believe STEM is, how to classify a specific field as STEM, and why they believe their field of study is or is not STEM.

Conclusion

Though we cannot claim that educators are the sole factor which contributes to a student's choice to enter a STEM field after their K-12 experience, the results of this study lead us to believe that classroom experiences do play at least some role in this decision. Based on some participants' individual answers to survey questions, that role may be especially critical compared to other contributing factors. Thus, educators have a responsibility to teach STEM content in an appealing, effective, and understandable way. Because it is evident that there are so many factors which play a role in one's decision to choose a specific undergraduate field of study, educators should be careful to differentiate instruction so that every student has equitable access to STEM content.

It is important to note, however, that the goal of educators is not that each student should attend a four-year university following high school graduation to pursue an undergraduate degree in something STEM-related. Rather, the goal should be to help each student develop a well-rounded conceptual understanding and respect for science, technology, engineering, and math. In today's modern world, the impact of technology continues to increase, creating more STEM-related careers, and deepening connections between STEM and non-STEM fields. Additionally, STEM teaches students to think critically and analytically, construct logical arguments, modify intricate ideas, and problem solve. These skills aren't just useful for scientists, technicians, engineers, and mathematicians, but are needed for any and every possible career path. Therefore, in order to set students up for success beyond their secondary education, educators must recognize the importance of providing students with frequent and diversified opportunities to learn STEM.

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Appendix A

For the purpose of the survey, the following majors were what we chose to classify as STEM fields.

Q7 Are you pursuing a degree in any of the following fields?

Animal Science
Bakery Science
Biology
Chemistry
Engineering (all disciplines)
Feed Science
Food Science
Horticulture
Kinesiology
Life Science
Management Information Systems
Mathematics
Medical Laboratory Science
Milling Science
Physics
Statistics

○ Yes

○ No

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Appendix B

Regression Ordinary Least Squares Results

Using data gathered from the survey results, specific variables were analyzed using ANOVA. These include the number of female participants, the number of white participants, how many participants reported having at least some anxiety due to math during their K-12 education, how many participants believed that practice and determination have a greater impact on one's ability to perform mathematical tasks than fixed genetic traits, and at what point participants became interested in STEM during their K-12 education. Each of these variables was compared to whether or not participants were majoring in a STEM field.

Table 1. Factors of stem major

	(1) m1
female	-0.070
	(0.048)
white	-0.062
	(0.068)
anxiety	-0.059**
	(0.021)
practicedeter	-0.000
	(0.037)
steminterest	0.344**
	(0.014)
Constant	0.334**
	(0.088)
Observations	220

Note. Robust standard errors.
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Appendix C

Correlation Results

The same software, variables, and data used to create the regression table in Appendix B were used to create the following correlation table.

	stemma~r	female	white	anxiety	practi~r	stemin~t
stemmajor	1.0000					
female	-0.2522	1.0000				
white	0.0483	-0.0664	1.0000			
anxiety	-0.2462	0.1024	-0.1773	1.0000		
practicede~r	-0.0727	0.1619	0.0602	0.0707	1.0000	
steminterest	0.8165	-0.2287	0.0806	-0.1701	-0.0657	1.0000