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Supporting Self-Efficacy Toward Science, Technology, Engineering, and Mathematics Skills in Secondary Students

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Abstract

The purpose of this action research project was to investigate the effects of intentional teaching strategies of problem-solving skills on student's self-efficacy toward Science, Technology, Engineering, and Mathematics (STEM) subject areas. The research was set in two secondary classrooms while in a virtual environment due to the COVID-19 pandemic. The participants included 36 students who spanned between 6th and 11th grade. Over four weeks, students participated in virtual synchronous activities in different areas of STEM. Throughout the research, pre and post-questionnaires, exit surveys, field notes, and open-ended reflection questions were collected, as well as virtual attendance data. Though consistent survey participation was a challenge, students did report an increase in positive feelings about STEM throughout the study. Further research is needed on how problem-solving skills are successfully taught in a virtual setting.

Keywords: self-efficacy, virtual learning, problem-solving, secondary students, STEM

In the wake of protests across the country around racial equity, there is a growing awareness around a need for change. As white educators, we recognize our privilege and our role in it. We are working to disrupt these norms and push diversity in these non-diverse career paths. Teaching STEM courses over the past seven years has shown us the importance of students developing problem-solving skills. In search of a way to increase diversity in these classrooms, we started with self-efficacy in the basic skills needed to succeed in these areas. Representation allows for self-efficacy, and when partnered with effective problem-solving strategies, can open up opportunities not previously available. This research investigates how educators can support women and people of color (POC) in high school STEM and Career Technical Education (CTE).

We want to be disruptors in this cycle to provide more equitable career opportunities for all students. Through diversifying the labor force, this positively influences the entire field because people tend to view problems differently, allowing for more meaningful solutions (Milgram, 2011). When focused on in a secondary setting, these skills can increase interest and motivation in STEM, even if introduced outside of a traditional STEM classroom (Karl, Britsch, & Anderson, 2016).

We choose to conduct this research with our advisory classes. The purpose of the advisory model is to establish a small community within a student's daily life. Students have the same class and teacher for all their high school years, building relationships and growing in their education. Through the advisory model, we focused on improving problem-solving skills and self-efficacy with secondary students. The purpose of this research project is to determine to what extent intentional teaching strategies will help enhance the self-efficacy of women and

POC at a secondary school during distance learning in a midwestern metropolitan area in the 2020-2021 school year.

Theoretical Framework

We will be implementing problem-solving strategies to improve self-efficacy for women of color in STEM classes through classroom action research. Self-efficacy refers to one's beliefs in their ability to accomplish their goals (Escalera-Chávez, 2018). Students with high self-efficacy enjoy challenging projects, excel in expectations when working towards their goals, and see failure as learning opportunities to grow. The International Commission on Education for the 21st Century concludes that problem-solving is an essential competency within the context of STEM learning (Jamaludin & Hung, 2016). Escalera-Chávez refers to Bandura's (1977, 1986) theory of self-efficacy, stating "self-efficacy is influenced by thinking schemes, affective predisposition, and behavior" (2018). Through this research, the students participated in problem-solving activities to explore Teodorescu's problem-solving steps, *Assessing the problem, Create a drawing, Conceptualize the strategy, Execute the solution, Scrutinize the results, Sum up learning*, which is abbreviated ACCESS (Teodorescu et al., 2014). The students followed a rubric learning and applying the problem-solving process to four hands-on STEM projects in this study.

STEM careers are growing every day and needed in our evolving society. These influential fields must have representation from all demographics. While many children learn at a young age the stereotypes of what they can or cannot be when they grow up, we hope to increase confidence in our students by focusing on the skills needed to be successful in these fields. Through problem-solving skills and relatable role models, students can improve their self-efficacy and have the confidence to explore new careers that may have been previously unavailable given societal constraints.

Review of Literature

The United States workforce has devalued women and POC for centuries (Gholson, 2016). Due to the history of racism and sexism within our country and workforce, young people have preconceived notions about who or what they can grow up to be (Gottlieb, 2018). Today, these preconceptions are happening, specifically in STEM fields. In 2019, though 55% of students who identify as female took the Advanced Placement (AP) tests. Only 24.5% of students who took the AP Computer Science A exam identified as female, and 33% of students who took the AP Computer Science Principles exam identified as female (College Board, 2019). These male-dominated fields have little representation from women or POC; however, they continue to grow every day and shape the way we all live. According to the United States Department of Commerce, seven out of ten STEM positions in the United States are held by white Americans. Workers who are POC are half as likely to hold STEM positions than the overall workforce (TriCollege Libraries, 2020).

When women and POC are missing from such a worldly, progressive field, their influence, opinions, values, and views are overlooked. The term POC is used to build solidarity, but we welcome a critique of the language used in this literature review. Without the participation of people representing many backgrounds and cultures in STEM and CTE fields, we limit the valuable outcomes that we could be getting from more diverse inputs on new inventions, apps, and technology (Milgram, 2011; Casad et al., 2018). This research will investigate how educators can support women of color in high school STEM education.

Today, students have many opportunities to explore courses in high school around STEM. While most districts do not require extensive engineering or technology classes for high school graduation, they can provide students opportunities for STEM jobs without needing a traditional four-year degree (Yoon, 2017). This education provides students with a more substantial degree of usable skills upon completion of high school. There is also a strong relationship between taking rigorous courses in high school and how well students perform in college (Yoon, 2017). According to Kreisman (2017), students who take additional years of advanced vocational coursework, or CTE credits, in high school are associated with almost a 2% increase in wages upon entering the workforce. In search of ways to help women of color succeed in STEM careers, the following research focuses on skills necessary for future STEM work and how to foster those skills for women of color.

Confidence and Self-Efficacy

When students feel confident in a subject, activity, or hobby, they tend to pursue more information and become passionate about subjects where they succeed. In their study of STEM career aspirations in Black, Hispanic, and White ninth-grade students, Gottlieb (2018) stated that students with high self-confidence, especially eighth-grade students in mathematics, show a solid connection to going into STEM careers. Gushue (2006) studied Career Decision Self-Efficacy, looking into women of color's confidence in their ability to complete career decision-making goals. They found gender roles and ethnic identity influence career goals for women of color.

Casad et al. (2018) also recognized that the underrepresentation of women of color in STEM contributed to lower confidence and self-efficacy. They researched psychological interventions to increase women of color's interest in STEM fields. Referencing Carol Dweck's theory of growth mindsets, the goal was to help students believe they could be successful and belonged in a specific field (Casad et al., 2018). Having a growth mindset means one does not look at failures as a representation of their intelligence (e.g., I will never be good at math) and instead looks at them as skills to learn (e.g., I am not good at math yet, but if I study or work at it, I can do better) (Dweck, 2006). Casad et al. implemented various interventions to teach a growth mindset. One was to teach the brain's fundamentals and how it works like a muscle, similar to working out. This analogy allows students to see how their efforts towards learning new things affect their brain development and contribute to their success (Casad et al., 2018). Another study by Lin-Siegler et al. (2016) had a different method for a growth mindset intervention. Specifically, students read a biographical novel on a well-known scientist learning about their successes and failures for a science class. Students learned that even famous scientists were met with failure and still succeeded and therefore had a greater connection and willingness to learn science (Lin-Siegler et al., 2016). It is unclear how long growth mindset interventions need to continue in order to have a lasting impact. Casad et al. recommend that both long-term (e.g., 8 weeks) or brief interventions can yield success in a classroom.

Problem Solving Skills

As the 21st-century workforce grows and advances, many find that young people are not equipped with the necessary skills to be successful. Employers across all industries believe that soft skills, such as interpersonal qualities, are essential and often more important than hard skills, such as knowledge and technical skills to succeed in the workforce (Robles, 2018). In order to have successful STEM education, a greater emphasis needs to be placed on inquiry, project, and problem-based learning, moving away from some of the traditional education strategies (Erdogan & Stuessy, 2015). These instructional strategies are examples of soft skills. Significant research exists promoting these models, not limited to STEM education. Erdogan and Stuessy also encourage a variety of soft skills, such as problem-solving and critical thinking.

The International Commission on Education for the 21st Century points to problem-solving as an essential competency within the context of STEM learning (Jamaludin & Hung, 2016). There are explicit teaching strategies that can teach problem-solving skills and critical thinking strategies, which provide students with options to think through problems (Teodorescu, 2014). Though practical problem solving is not easy to quantify (Astuti, 2020), educators still need to promote them to reduce the inequity in STEM fields. In secondary schools, STEM integration courses shift from traditional lecture-based classrooms to curriculum that involves more inquiry and problem-based learning approaches (Erdogan & Stuessy, 2015; Ring, 2017).

Kyllonen (2018) stated that teaching students problem-solving skills could effectively reduce inequality in STEM jobs. Having students solve complex problems in real-world settings can prepare them for the workforce. Problem-solving skills are currently extremely valuable to the workforce, which will continue in the future (Kyllonen, 2018). More than ever, content knowledge will not be enough to be successful in the job market. Students will need various skills, particularly skills that require them to think (Astuti et al., 2020). Fostering these skills among students will help increase their confidence and self-efficacy around STEM subjects and open career opportunities in previously inaccessible areas.

There are several theories on problem-solving methods and how to teach them in the classroom. Many studies suggest doing client-based projects where students apply the skills of their subject matter to real-world situations (McCale, 2008) or implement “20% time” or genius hour projects (Crevier, 2018). Genius Hour, started by Google, is where employees can work on independent projects. Crevier (2018) describes how when students have the freedom to decide what and how they learn, they are more engaged and understand the learning better. Through all of these projects to increase students' problem-solving skills, teachers need to facilitate and guide them through the process. Teodorescu (2014) refers to Polya's four-step approach, Beichner's GOAL protocol (Gather information, Organize, Analyze, and Learn), Reif's research approach, Schoenfeld teaching strategies, Wright and Williams' WISE procedure (What is happening, Isolate the unknown, Substitute, and Evaluate), and Heller's five-step framework before building his protocol which he abbreviated ACCESS. Teodorescu takes a systematic approach to problem-solving and includes classroom experiences (Teodorescu, 2014). Though Teodorescu designed this strategy explicitly for collegiate level physics problems, the steps naturally transfer to other problem-solving types, giving students a framework to follow when attempting to solve a problem.

Women Role Models / Culturally Relevant Representations

To ensure students can identify career opportunities in STEM, educators need to represent all races and gender identities into the curriculum. When students can see themselves in people in the field, they are more likely to persist in that field of study (Lane, 2016; Karl et al., 2016). Students can develop a sense of identity in STEM by learning about people who are similar to them in these careers, in addition to seeing people who fall outside of the typical narrative of what a scientist or engineer looks like (Casad et al., 2018). Carlone and Johnson (2007) describe various components that contributed to strong STEM role models. The first component, performance, is the ability to conduct STEM practices and demonstrate professional work publication. Recognition or being acknowledged as a successful STEM person is another component contributing to STEM identity. The final piece, competence, describes role models with full comprehensive knowledge of their content (Carlone & Johnson, 2007).

Using these components, educators can identify successful women of color in STEM to share with their school community. Milgram (2011) suggests developing outreach materials that feature female role models similar to the Rosie the Riveter campaign in World War II. Providing students with these visual representations of themselves allows them to reform what potential identities may look like. Also, creating clubs or groups promotes a cohort culture, promoting affinity and a sense of belonging (Carver et al., 2017). A student's understanding of belonging contributes to their overall success (Lane, 2016). Role models can instill a sense of belonging and identity compatibility in underrepresented STEM groups (Casad et al., 2018).

Conclusion

Educators are at the forefront of influencing students into future careers and inspiring their interest in various fields of study (Gushue, 2006). By increasing self-efficacy, encouraging problem-solving skills, providing role models, being culturally relevant, and creating safe places (Karl et al., 2016), allows for a shift in identity during critical development years (Zachmann, 2017). Some research exists on strategies that promote self-efficacy in women or self-efficacy in POC. However, research is lacking when looking into where these areas overlap and how we increase women of color's involvement in career areas that are traditionally underrepresented. This aligns well with many of the same strategies colleges use to retain students by providing role models, intentionally teaching skills, and providing real-world experiences (Carver et al., 2017). Unfortunately, there is a lack of research for women of color in secondary STEM classes.

Based on our findings in this literature review, we explored whether integrating STEM curriculum strategies such as problem-solving skills, hands-on projects, and investigating professional women of color in the field can increase self-efficacy in STEM courses for secondary students. We promoted the value of a growth mindset throughout each hands-on project. Students had the opportunity to fail, learn from their failures, and find hard work to help them succeed in these courses. We taught students specific problem-solving strategies that they can use throughout all of their classes. In addition, all students investigated professional women of color in computer science and mathematics careers, learning their background, strengths, weaknesses, and accomplishments in STEM. Through these interventions, we examined how students' self-efficacy in STEM changes throughout the course.

Methodology

We completed classroom action research to improve classroom practices (Hendricks, 2017). This study investigated the extent to which intentional teaching strategies of problem-solving skills affect students' self-efficacy toward STEM subject areas. Quantitative data was collected using pre and post-questionnaires addressing student interest in STEM and exit surveys after each activity. Qualitative data such as field notes were used to monitor student engagement during problem-solving activities. We also collected open-ended reflection questions students filled out as a group during some of the problem-solving activities to describe how they collaborated.

Our research took place in two virtual secondary (6th - 11th grade) classes in the midwestern United States in the winter of the 2020 - 2021 school year. The sample size consisted of 36 students, consisting of two 6th graders, three 7th graders, two 8th graders, 25 9th graders, two 10th graders, and two 11th graders. Twenty-five students identified as white, and eight identified as POC. Twenty students identified as male, and 16 identified as female. None of the students identified as non-binary or non-gendered. The researchers identified as white females, each teaching for seven years at their respective schools. Both researchers hold bachelor's degrees in education. One researcher is a mathematics and computer science teacher, and the other is a business and dance teacher.

We used our literature review to identify our interventions, such as the ACCESS problem-solving process and use of role models, to our current advisory courses over two months, including two weeks of winter break. We created four problem-solving activities to correspond with STEM subject areas. We had two activities that were full class discussions and two that were small breakout group projects. We decided to alternate between doing full class discussions and small breakout group projects in planning our schedule. These activities had to be further adapted to a virtual class, using google tools and learning management systems. We created a pre-questionnaire (Appendix A) using questions adapted from the Friday Institute for Educational Innovation (2012) that could be given to the students at the beginning of the study and at the end in order to measure the difference in their self-efficacy and STEM interest. This questionnaire told us about how students perceived their success in STEM. Students completed the pre-questionnaire and began the STEM-based problem-solving activities one week after. Each week we planned an activity based on an area of STEM and featured a woman of color who is a professional in that field. We prepared to take field notes (Appendix B) during the activities, watching for participation and general student reactions. Over the course of a month, we prepared to meet with our students virtually once a week for 30 minutes to complete the problem-solving activities and shared videos on professional women of color in that field. Throughout these activities, as instructors, we moved between breakout rooms and recorded observation field notes. The field notes provided us with daily logs focusing on student engagement and participation and served as a natural built-in reflection tool.

Student participation started when they filled out the Pre-STEM Interest Questionnaire, indicating their current interest and success in science, technology, engineering, and mathematics. The questions asked were both open-ended and using the 5-Point Likert scale (e.g., 5 being most favorable and 1 being less favorable). The first four questions asked general demographic information such as age, race, and what STEM classes students had taken already. This helped us identify which students already have background knowledge or experience in these subjects. The following 17 questions used the 5-Point Likert scale, gauging students' current self-efficacy in response to science, mathematics, technology, and science-related questions. The last four open-ended questions had students describe their current perception of their problem-solving skills, career goals, hobbies, and a chance for them to share other information that might give us more insight on how or why they answered some of the questions.

The first week, we met with students for 30 minutes in a video call. We started by introducing them to the ACCESS problem-solving process, specifically looking at *Accessing the Problem, Brainstorming Strategies,* and *Summing up Your Learning*. After, students completed the Moon Landing Activity (Appendix C), which focused on science. Students received a list of items that they had to rank from most important to least important if they were stranded on the moon. Students first ranked these items individually before collaborating with a random group of classmates in virtual breakout rooms. As a group, students had 10 minutes to reach a consensus on the order of the items. Students completed a four-question exit survey at the end of class (Appendix D), which focused on student understanding and perceived usefulness of the activity. Two open-ended questions included students describing what activity they completed that day and how the activities could be improved. Two questions used the 5-Point Likert scale where students could rate their understanding and how applicable these skills are to their future.

The second week we continued with the same structure and explored the world of technology through artificial intelligence (Appendix E). Students brainstormed different types of artificial intelligence using a collaborative Jamboard. We displayed the ACCESS model for the students before they independently completed an activity, AI for Oceans from code.org (AI for Oceans, 2021), training robots to recognize the difference between fish and trash to help clean the ocean. We gave each student the link to complete the same exit survey after completing the AI for Oceans activity.

In the third week, the focus was on mathematics. This task featured all of the problem-solving skills from the ACCESS model. Students divided into virtual breakout rooms to complete the 16 Grid Activity (Appendix F). For this task, they used the integers 1, 2, 3, and 4, with a combination of mathematical operations, to find the numbers 1 - 16. Students completed the activity using a shared google doc to record their findings as a team. The goal for each group was to complete these activities as quickly as possible. Groups were asked a series of reflection questions after completing the task to be answered together. After completing this activity, we provided the exit survey to the students.

During the fourth week, the activity focused on engineering and how technology tools are built to solve problems. Students looked around wherever they were and documented picture evidence of different types of engineering. Using Padlet as a collaborative online platform, students identified various technologies that solve problems. Students thought about what skills would be needed to be engineers and how they relate to problem-solving. We showed a video showing positive role models in STEM and gave a final exit survey.

After completing the four weeks of problem-solving activities, students completed a post-questionnaire. This final questionnaire had the same questions as the pre-questionnaire given to the students at the beginning of the study. Having the same questions on both questionnaires allows us to measure the difference in their self-efficacy and STEM interest. By gathering this data and looking at the differences, we could determine the effectiveness of our interventions.

We noticed which students consistently showed up and participated in each activity and which students did not join the virtual classes. We re-invited students who did not attend various activities and reminded students to fill out exit surveys through email communication, as well as in video meetings. During the activities, some students did not verbally contribute to the group. By switching to using a shared google doc, students could contribute to the overall group without turning on their microphones in our virtual classroom setting.

Analysis of Data

The purpose of this study was to investigate to what extent intentional teaching strategies of problem-solving skills affect student's self-efficacy toward STEM subject areas. The subjects of this study were 36 6th - 11th-grade students from two different public secondary schools. Sixteen students in the study identified as female, and 20 identified as male. No students identified as any other gender. Due to the COVID-19 pandemic, the schools were entirely in virtual, distance learning when we collected the data during the 2020-2021 school year. The quantitative data was collected by using questionnaires, surveys, and attendance data. In addition, qualitative data was collected through open-ended response questions during the activities and field notes.

Participation Demographics and Participation Rates

Student response rates played a role in the conclusions we could draw from the data. We planned on disaggregating the data based on gender as well as specific races. Due to a limited number of participants identified as students of color, we are not disaggregating our racial statistics any further than students of color and white students. Seventy-five percent of students identified as white. We compared the number of male and female students who filled out the different surveys and questionnaires. Figure 1 shows the number of students who completed each of the surveys based on their gender. Female students were about 30% more likely to fill out the surveys and questionnaires throughout the activities than their male counterparts. 100% of female students filled out both the pre and post-questionnaire, compared with only 85% and 60% of male students.

Figure 1. Student Participation Throughout the Study Based on Gender Identification in School Records.

We compared the number of students who participated in each specific survey to the total number participating in the study. We gave four exit surveys throughout our research to gauge understanding and feedback from students completing the activities. We understand that this graph does not help answer our guiding question on the effects of problem-solving skills changing students' self-efficacy towards STEM. Still, we think it provides essential context around the data we collected. For example, some students did not fill out the pre-survey but did participate in some activities and completed exit tickets. In looking at the graph, we see a dip for the second exit ticket. We can attribute this some to the style of the activity. Students were responsible for completing an asynchronous activity on code.org before completing the exit survey. Because students had to complete an independent activity, we believe this led to a lower response rate. According to our field notes, both classes had less discussion and participation during the second activity than any other activity. Students also shared about difficulties with videos loading and playing over the Google Meet, and general wireless issues, noted in our field notes, as well as the exit surveys. Upon reflection, we gave students the Google Form link before leaving the virtual meeting for further activities. As can be seen in activities three and four, many students completed the exit survey. We never had 100% of students in attendance for the virtual meeting complete the exit survey after the activities. We saw a range from 35% to 94% of the students in attendance completing the exit survey after the activity.

Effectiveness of the Activities

Over the course of a month, we ran four different activities based on each area of STEM. After completing the activities, we asked students to rate their understanding and perceived usefulness of the activities. Figure 2 shows the overall student perception of understanding over the four activities. Students reported 90 different times that they understood the tasks, where no students reported having questions, and one student reported being lost at the end of the activity.

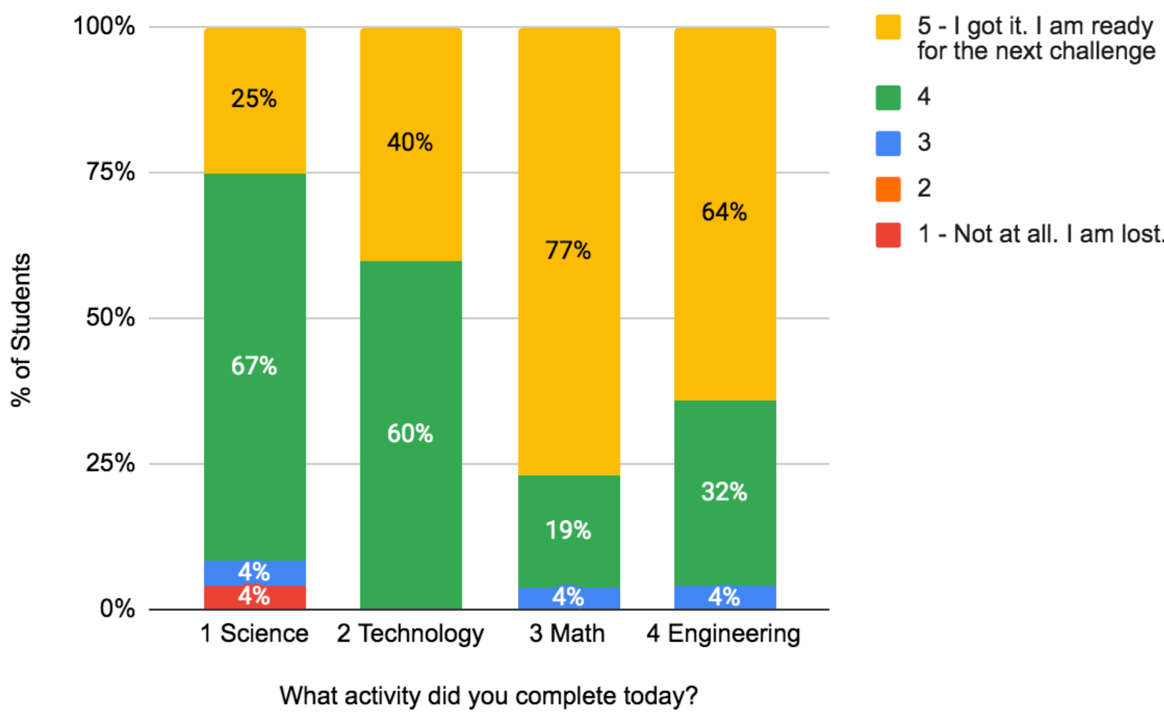

Figure 2. Student Exit Survey Responses of Level of Understanding. This figure shows the responses broken down by activity.

Overall, students reported that they understood the activities, with 76% saying they completely understood the mathematics challenge. The technology activity's overall positive rating may be attributed to the extra steps needed to complete the technology exit survey (mentioned above). This may be a false positive - students who struggled to understand what to do may have opted not to complete the survey. Only 15 students completed the survey, roughly half of the number who completed each of the other ones.

We also asked students to self-report the usefulness of each activity to their daily life. At the start of our data collection, we found that about 2/3rds of students thought the activity was useful. By the fourth activity, this number had increased to 88% of students found it useful. As each activity progressed, more and more students reported that the things they learned would help them in the future. Our first activity focused on science, where 34% of students claimed they did not believe the activity would help them in real life. This activity had students prioritize materials to use on the moon. Students actively discussed the usefulness of each item and were engaged in the small groups. Our field notes show students turning their mics on to discuss and ask questions. One student was very savvy about the moon's atmosphere and was able to answer the questions and help the other students. Another student asked, "How do you know all of this?" inquiring on each other's prior knowledge.

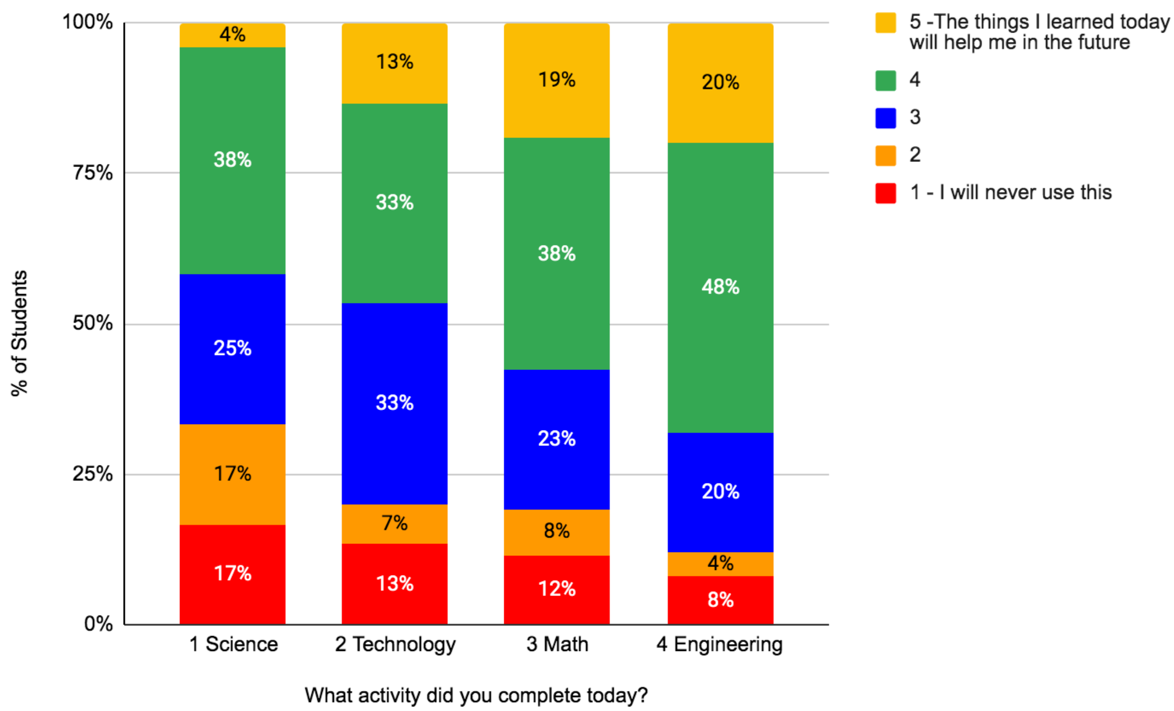

Figure 3. Percentage of Exit Ticket Responses Ranking the Usefulness of the Activity. This figure illustrates student exit ticket responses.

In comparing the pre-questionnaire data with the post-questionnaire data, we found little change between the two surveys. Of the 36 participants, 28 completed both the pre and post-questionnaire. The questionnaires contained 17 statements that students reported on a 5-point

Likert scale the degree to which they agreed or disagreed. When we compared the pre-questionnaire to the post-questionnaire, we looked at the number of individual students who changed their answers, whether positive, negative or stayed the same. These differences were then added together to determine a weighted average change for each of the questions. Of the 17 statements, eight changed favorably (more students rated their abilities higher on the post-questionnaire than the pre-questionnaire), the change was the same for three statements, and the change was negative for six statements. When looking at the change between questions, the most significant difference was the statement "math is hard for me." Nine of the 28 students decreased the amount they agreed with this statement between our two surveys, four students by multiple points on the Likert Scale. Four students increased the amount they agreed with this statement, all by one point. Fifteen students had no change from the pre-questionnaire to the post-questionnaire. In contrast, however, the question that had the greatest negative change was the responses to "I am good at math," where five students reported a lower response on their post-questionnaire than pre-questionnaire, with only one student reporting a positive change on this statement. Twenty-two students had no change between the two questionnaires for this question.

Figure 4 shows the results for each of the six statements that showed negative change. This was measured using a weighted average. A change of two points in either direction was weighted twice as much as a change of one.

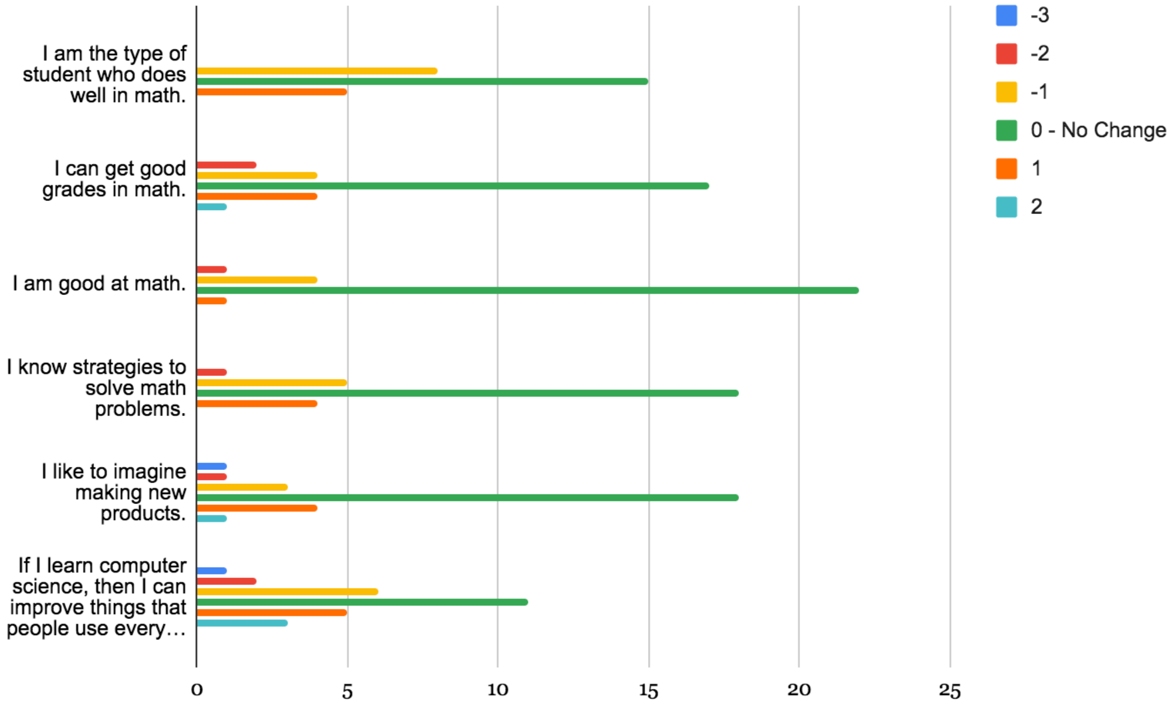

Figure 4: Negative Pre to Post-Questionnaire Changes. This figure shows the changes of student responses on the six statements with overall negative change. The x-axis count represents the number of students who changed their response for that statement, and to what degree their response changed.

Eight statements had a positive change from the pre to post-questionnaire. For these eight questions, two of them were negatively worded (i.e., Math is hard for me, I can understand most subjects easily, and math is difficult for me), so the response values that are -3, -2 or -1 would be “good” responses. In Figure 5, the most beneficial responses are at the bottom to maintain consistency across graphs.

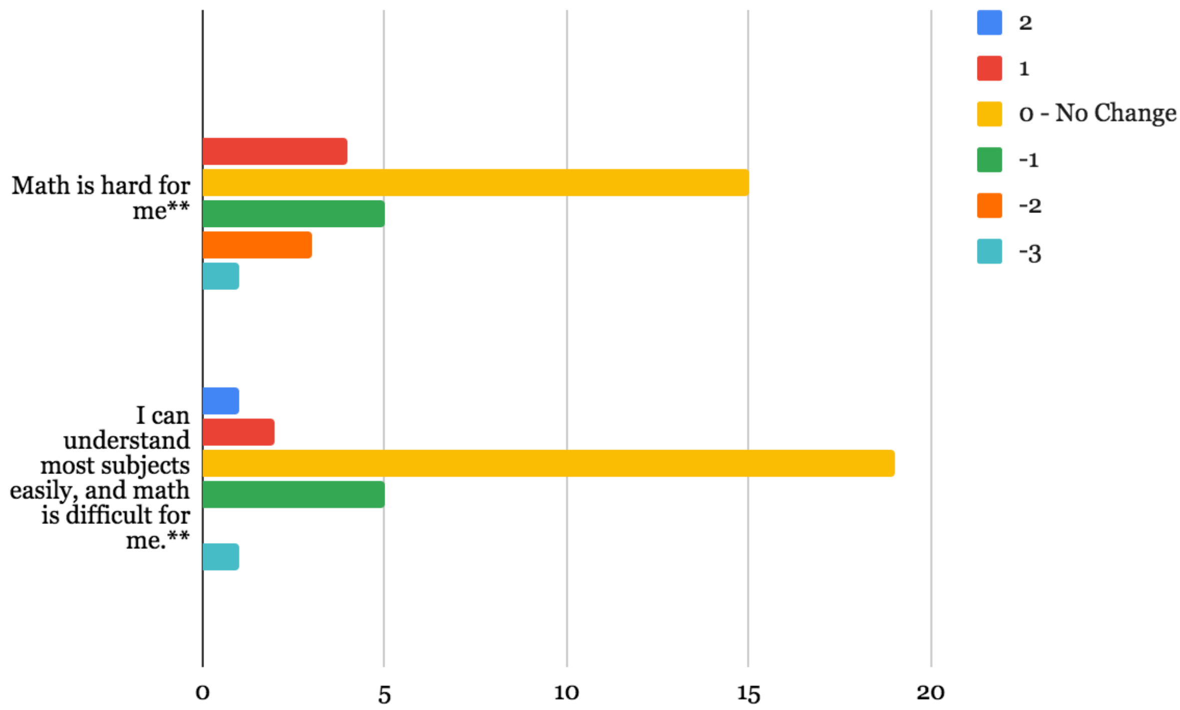

Figure 5: A Comparison of the Negatively Worded Questions from Pre to Post Questionnaire. Responses that show a negative response are an overall good response, and the x-axis is the number of students whose responses changed.

In looking at the other six statements that had overall positive change, two focused on curiosity or creativity, and four focused on invention or product design. Overall, most students' responses changed little for all of these questions. The only exception is "Knowing how to use math and science together will help me to invent useful things," where 10 students increased by one point, and one increased by two demonstrated in Figure 6.

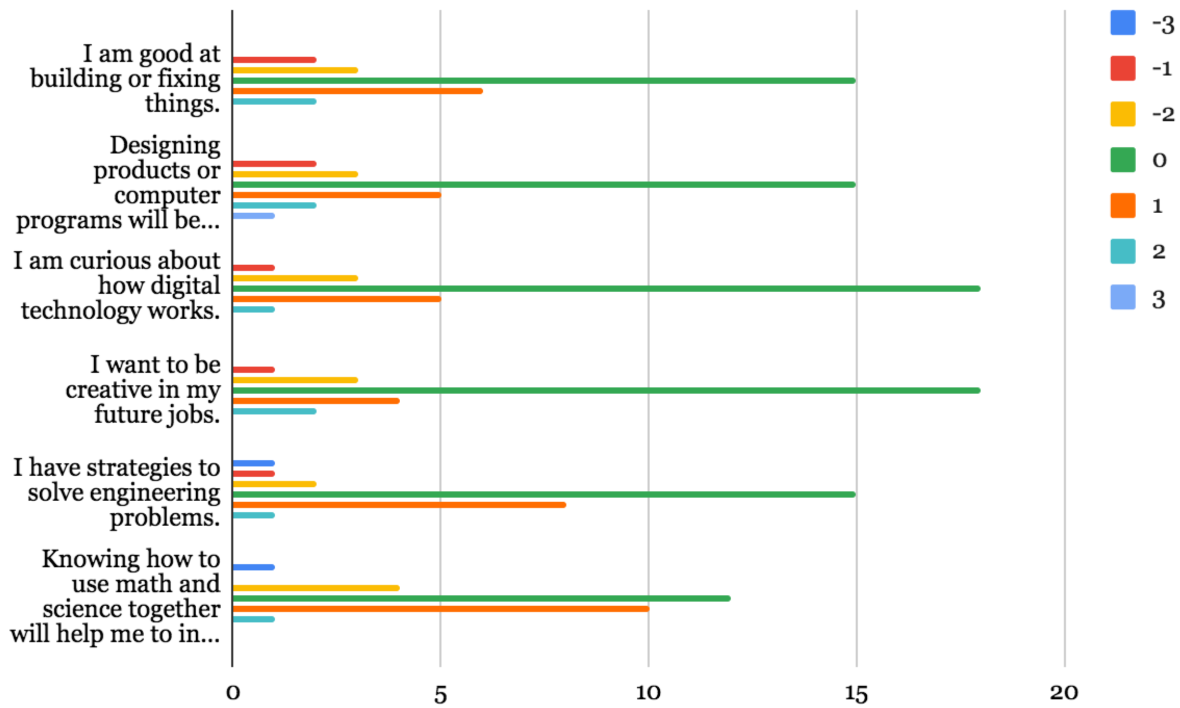

Figure 6: Positive Pre to Post-Questionnaire Data. The x-axis shows the change in student responses between the surveys.

On all but three of the 17 statements, most students' pre and post-questionnaire responses were the same. The three statements that did not follow this trend were a.) If I learn computer science, then I can improve things that people use every day. b.) I am interested in what makes machines work, and c.) Knowing how to use mathematics and science together will help me to invent useful things. Both statement a and c showed an overall positive change, where statement b showed no overall change. Three statements had zero change from the pre to post-questionnaire, shown in Figure 7.

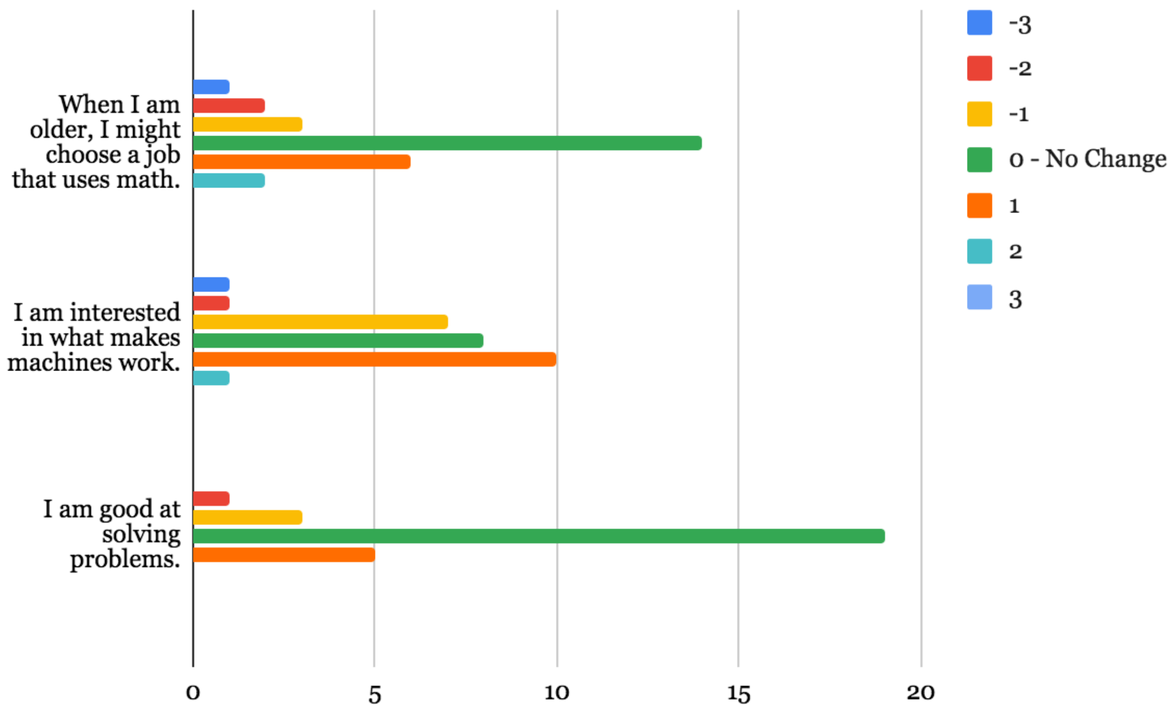

Figure 7: No Change Pre to Post-Questionnaire. The x-axis shows the number of students who changed their responses.

For the statement "I am interested in what makes machines work," this is the only statement where any of the changes in responses were greater than the number of students who stayed the same, with ten students shifting one point positively. Though none of the activities explicitly looked into precisely what makes machines work, this was the question that saw the greatest number of students change their response both positively and negatively. Figure 8 shows more detail in how students responded.

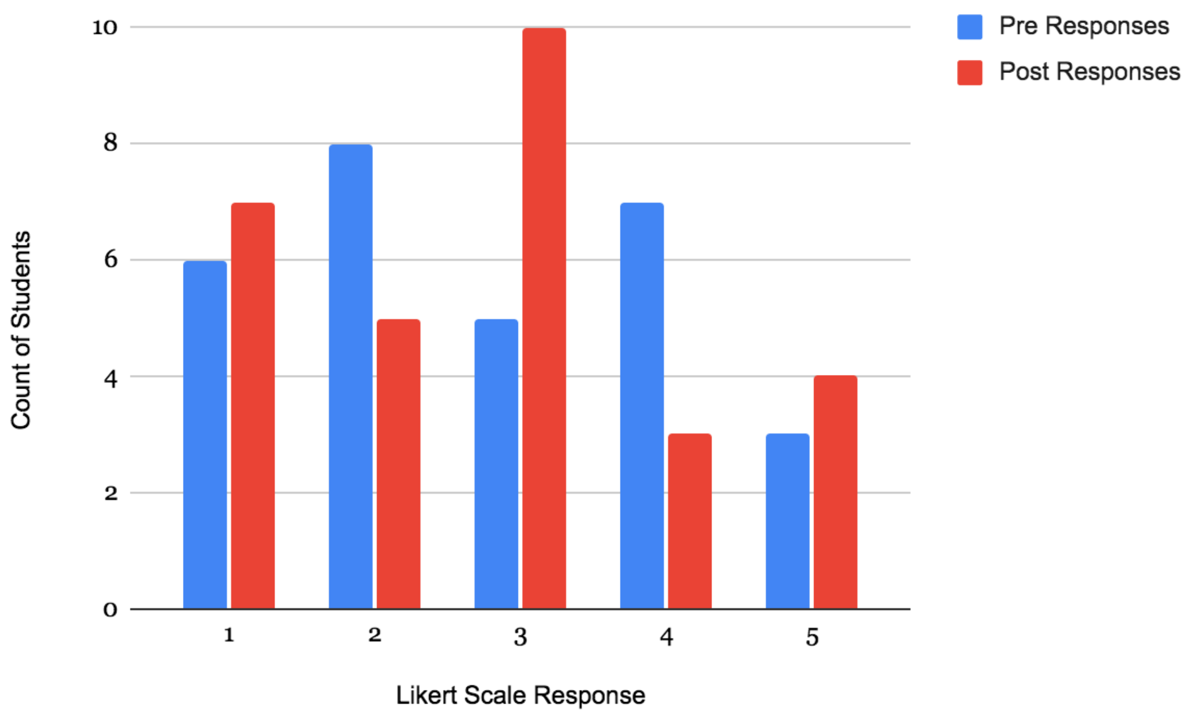

Figure 8: Student responses to the statement "I am interested in what makes machines work."

Overall, students shifted toward the center on this question, where previously, they favored responses of 2 and 4. This shows that students may have a more neutral response to learning about machines after the STEM activities. Students tended to rank themselves favorably on the 5-point Likert Scale, but across the board, rankings of 3, 4, and 5 were more common on the post-questionnaire than the pre-questionnaire.

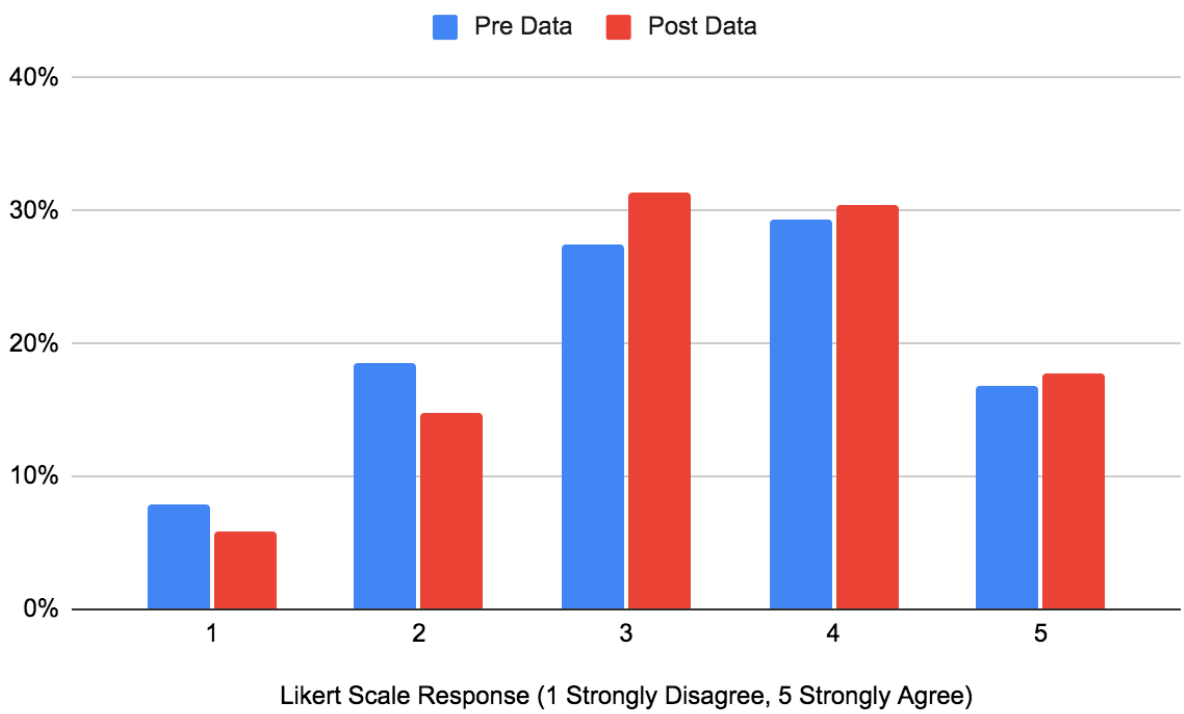

Figure 9. Comparison of Pre and Post-Questionnaire Responses about Efficacy toward STEM. This figure shows the average percentage of all responses for each question in pre and post-questionnaire.

The research data focused on pre and post-questionnaires, four exit surveys, and field notes taken by each instructor. In general, students had very little change in their self-efficacy toward STEM. This may be because 47% were already confident (level 4 and 5 on the Likert scale) in their STEM skills, giving them little room to grow throughout our study.

Action Plan

The purpose of this study was to investigate to what extent intentional teaching strategies of problem-solving skills affect student's self-efficacy toward STEM subject areas. Overall, we found that the female students in our study already had a high self-efficacy in STEM. Throughout the study, we found an increased engagement of our female students who participated in each activity and completed all tasks. When designing our project, we were expecting to have a larger number of students of color participating in our study. Still, we ended up with a minimal amount of meaningful data due to the COVID-19 pandemic, making it challenging to make generalizations.

While the purpose of the STEM activities was problem-solving, learning how to prioritize, and working collaboratively, we wonder if, as educators, we did not fully explain the purpose of the activity, specifically the use of the problem-solving rubric. It is possible students reported they would not use these activities in their future because they interpreted it literally, as they have no plans to go to the moon or create artificial intelligence.

Throughout our findings, we conclude that students were more engaged during the STEM problem-solving activities than any other activities done this school year. The advisory classes often do various departments' activities, especially the counseling team, with activities focused on social-emotional learning. These canned curriculums often lacked genuine participation from the students. Based on our field notes and student attendance, we found that the STEM activities we used had higher participation levels than the other curriculum.

Virtual learning played a significant role in the quantity and consistency of the data collection process. Students and teachers were in their homes attending classes online using a video call tool, Google Meets. Students joined the virtual meeting once a week and participated in the group activities. Students completed activities using collaborative virtual tools such as Google Docs, Jamboard, and Padlet. Family dynamics, caring for younger siblings, poor internet connection, and low self-motivation contributed to the challenges students faced during distance learning, causing them to miss class meetings and forget to complete virtual assignments and tasks. As documented in field notes, students verbally reported when the internet was running slowly and when inconsistent editing activities made it difficult to participate in the activities. While in a classroom setting, researchers can collect data on surveys because of a greater degree of control over student participation and can help troubleshoot technology. In the distance learning setting, technology issues and lower attendance rates contributed to a drop in overall participation.

As teachers, we found that it was challenging to collect reliable data in a distance learning setting. In general, students had very little change in self-efficacy after completing the problem-solving activities in each STEM area. When looking at how they would use these skills in their everyday life, most students found mathematics and engineering most valuable. We believe our data would be different if we could spend more time with these students, especially in person, because we were limited to between 30 and 45 minutes a week. We could have used this time to focus more explicitly on problem-solving activities, exploring careers, and inspirational role models. Simultaneously, conducting this research in a virtual setting while our students were under various traumas from the pandemic devalued our data and made it difficult to confidently answer our research question.

This study looked at all areas of STEM individually. If all four activities were blended, it might help students see their growth and self-efficacy. This could increase the perceived usefulness because it would reach a broader scope of interests instead of focusing on one specific area. This also aligns with what some science standards are moving to, which promotes cross-curricular discovery.

It is challenging to conduct activities and collect meaningful data while in a pandemic. When direct student participation is limited, it is hard to gain a formative understanding of where students are physically and mentally. When in a classroom, it is easy to coerce students into participation, and students are more willing to talk with one another face to face than they are over a virtual google meet. Teachers are limited with ways to encourage student participation digitally, as students can simply ignore or log off of the virtual meeting.

We hope to embed more STEM activities within soft skill lessons for our advisory classes based on our results. We hope to share this information with our counselors to improve the current lessons and make them more engaging. With more student engagement, specifically in mathematics, we will incorporate this subject's activities with other skills such as writing, time management, concentration, and basic numeracy. By teaching other soft skills like problem-solving through STEM subjects, more students would be workplace-ready when graduating from high school.

Student engagement has a significant impact on student learning. Women were consistently more reliably filling out google surveys and were active participants in the meet. Looking at our students of color who had the ability to participate in the study, mostly our female students of color showed up to the virtual classes and fully participated. Many of our male students of color did not attend any classes. We see this as an equity issue when it comes to distance learning and is an area that could be researched further, in addition to engagement strategies that work well with virtual instruction to bring some of these students back into the mix.

Collaborating with another teacher during this research was highly beneficial, specifically during distance learning, when collaborating with other professionals was very limited. We were able to work together to co-plan lessons, which was exceptionally rare due to the distance teaching-learning model. Teachers all stayed at home and spent significant periods of time in relative isolation. During distance learning, due to the multiple responsibilities teachers took on, it was helpful to hold each other accountable and work through setbacks together. This collaboration allowed us to share distance learning teaching strategies and make adjustments to our study to fit our different learning models, with a more extensive student base than simply the students in our classes and giving us someone to bounce off ideas with.

As we embark on future action research, it would be beneficial to investigate the effects of intentional teaching strategies on student learning and traumas during the pandemic. Students have had their lives dramatically disrupted over the past year, leading to many uncharted areas of study. Further research could also look at the problem-solving skills of students after the pandemic. In virtual learning, students had to do a lot of problem-solving to find meetings, understand the technological structure, comprehend assignments, and advocate for their education using different strategies. It will be interesting to see how many women and students of color pursue careers in STEM after this pandemic experience where science and technology kept our world functioning to some degree of normality. While this study encountered unforeseeable, worldly challenges, the results support student learning in STEM classrooms.

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Appendix A
Sample of Pre and Post-Questionnaire

DIRECTIONS: There are lists of statements on the following pages. Please read each statement and think about your life and how you feel. Do you agree or disagree with the statement? How strongly do you agree or disagree? For each statement, select a single button for each statement that is the best answer. There are no "right" or "wrong" answers!

Age:
Grade:
How would you describe yourself? (American Indian, Asian, Black or African American, Native Hawaiian or Pacific Island, Hispanic, White)
Please list any Science, Technology, Engineering, or Math classes you have taken in middle or high school.

Rank from Strongly Disagree to Strongly Agree the following statements:

- When I am older, I might choose a job that uses math.
- Math is hard for me.*
- I am the type of student who does well in math. x
- I can understand most subjects easily, but math is difficult for me.*
- I can get good grades in math.
- I am good at math.
- I know strategies to solve math problems.
- I like to imagine making new products.
- If I learn computer science, then I can improve things that people use every day.
- I am good at building or fixing things.
- I am interested in what makes machines works.
- Designing products or computer programs will be important in my future jobs.
- I am curious about how digital technology works.
- I want to be creative in my future jobs.
- I am good at solving problems.
- I have strategies to solve engineering problems.
- Knowing how to use math and science together will help me to invent useful things.

*Responses were inverted for these questions to match with Positive & Negative values.

How do you solve problems in your life? List specific steps you take.
What are your long-term career goals?
What are your hobbies or things you like to do in your free time?
What else would you like us to know about you if anything?

ADAPTED OCTOBER 2015 KATIE CODERS STUDENT ATTITUDES TOWARD STEM SURVEY DEVELOPED FROM THE UPPER ELEMENTARY SCHOOLS (4-5TH) S-STEM SURVEY FRIDAY INSTITUTE FOR EDUCATIONAL INNOVATION (2012)

Appendix B

Field Notes/Narrative Template

Field Notes/Narrative	
Date/Time:	Setting:
Student Alias:	Instructor:
Descriptive Field Notes:	Reflective Field Notes:
Student Dialogue (Description of interaction)	Instructor reflection on dialogue
Perceived Student's Self-efficacy towards the current lesson	Predictions/Future follow up

Appendix C

Moon Landing Activity

You are a member of a space crew scheduled to rendezvous with a mother ship on the lighted surface of the moon. However, due to mechanical difficulties, your own ship was forced to land at a spot 200 miles from the rendezvous point.

During re-entry and landing, much of the equipment aboard was damaged and, since survival depends on reaching the mother ship, the most critical items available must be chosen for the 200-mile trip.

Fifteen items are listed as being intact and undamaged after landing. Your task is to rank them in terms of their importance for your crew to allow them to reach the rendezvous point. Place the number 1 by the most important item, the number 2 by the second most important, and so on through to number 15 for the least important.

My ranking	Salvaged items	Team ranking
	Box of matches	
	Food concentrate	
	50 feet of nylon rope	
	Parachute silk	
	Two .45 caliber pistols	
	One case of dehydrated milk	
	Two 100-pound tanks of oxygen	
	Stellar map	
	Self-inflating life raft	
	Magnetic compass	
	Five gallons of water	
	Signal flares	
	First aid kit containing injection needles	
	Solar powered FM receiver	
	Portable heating unit	
Score		Score

Appendix D
Exit Survey

What activity did you complete today?

How would you rate your understanding of today’s activity?

- On a scale of 1 to 5, with 1 being “Not at all, I am lost” and 5 being “I Got it!! I am ready for the next challenge!”

How useful was today’s activity in your daily life?

- On a scale of 1 to 5, with 1 being “I will never use this” and 5 being “The things I learned today will help me in the future”

What would make today’s activity more effective or better?

Appendix E
Computer Science Activity

1: What is Artificial Intelligence? With your breakout group, come up with a definition and/or visual that represents artificial intelligence (AI). Use a collaborative whiteboard (Jamboard) to brainstorm using words and images.

2: Watch video on "What is Machine Learning" from code.org
https://www.youtube.com/watch?v=KHbwOetbmbs&t=1s

3: Reflect. How did your JamBoard representation compare to what you learned from the video?

4: Discussion: What are the benefits and drawbacks of AI?

5: Watch video on "Ethics & AI: Equal Access and Algorithmic Bias" from code.org
https://www.youtube.com/watch?v=tJQSyzBUAew

6: Complete the "AI for Oceans" activity training robots to understand the difference between garbage and fish. https://studio.code.org/s/oceans/stage/1/puzzle/2

Appendix F
Mathematics Activity

16 Grid

Use the numbers 1, 2, 3 and 4 to get the numbers 1 - 16.

Rules:
1.) You must use all numbers once (1, 2, 3, 4), and only one time.
2.) You may use addition, subtraction, multiplication, division, and exponents.
3.) Fastest group wins.
4.) You may record more than one solution for each individual number. A possible solution for 10 is provided below.

1:	2:	3:	4:
5:	6:	7:	8:
9:	10: 1 + 2 + 3 + 4	11:	12:
13:	14:	15:	16:

16 Grid

Reflection Questions:
1.) What was your group strategy for solving this problem?

2.) What strategies would work better now that you've done it once?

3.) How would it be different if you were trying to come up with the numbers 1 - 25?

4.) What made this activity challenging?

5.) What were the most challenging numbers for your group to come up with answers for, or which numbers did you find last?