The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #43156

The influence of self-efficacy on pre-college students' interest in STEM fields

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The Influence of Self-Efficacy on Pre-College Students' Interest in STEM Fields (Evaluation)

Introduction

Science, Technology, Engineering, and Math (STEM) careers are vital to the success of an advanced economy [1]. People in STEM jobs represent roughly 1 in 18 workers in the United States [2]. In addition, workers in STEM earn on average 26% more than those who are not employed in STEM fields [2]. Despite the large benefits of a STEM career, growth of STEM employment has plateaued, and many individuals leave those fields after joining [3]. In addition, there is a significant gap between men and women working in STEM-related fields, with men outpacing women. One potential factor in this gap can be attributed to self-efficacy.

A student's self-efficacy refers to a "Judgement about one's ability to organize and execute the courses of action necessary to attain a specific goal" [4, p. 1]. In comparison to male students, female students have lower self-efficacy in subjects such as science and math [5]. One drawback of the concept of self-efficacy in terms of interest in STEM is the subjective interpretation as to what people deem to be a "good" grade. More so, a source mentions how one person might view a "B" as a "bad" grade while another might view a "C" as a "good" grade [4]. Evidence shows that individuals with a high self-efficacy are much more likely to retain interest and perform better in STEM related fields relative to others who demonstrate lower self-efficacy [4].

Ultimately, lower self-efficacy for women in STEM has created gaps in the labor market [6]. This paper will analyze students' self-efficacy and its correlation to their interest in pursuing a STEM-related discipline in their future. Data was collected from multiple STEM summer camps during 2017-2023 (except for 2020 & 2021). The summer camps were intended to expose students to STEM. The data collected is used in a qualitative and quantitative analysis to determine if self-efficacy is related to and has any impact on students' interest in STEM.

Program Description

Students and teachers coming from multiple school districts in (state in the mountain west region) were invited to attend a week-long summer engineering camp. The camps took place in the summers of 2017, 2018 and 2019. Another similar camp was scheduled for summer 2020 but was cancelled due to the Covid pandemic.

The camps were designed to increase student interest in STEM. The camps are part of a 7-year grant funded by the Department of Education as part of the GEAR UP program. The grant's overall goal was to help over 3,000 middle and high school students improve their academic achievement, creating a pipeline of academically prepared students enrolling and excelling in college in STEM-related endeavors. During the summer camps, teachers and students participated in a variety of engineering activities. During those camps, they developed research hypotheses, proposed methods to test those hypotheses, and overall thought like engineers.

Teachers who participated applied the research and engineering camp activities to develop future classroom lessons for their classrooms to meet the Next Generation Science Standards (NGSS) framework which had engineering as a main component. The number of participating students in the 2017 camp was 33 and the number of teachers was 10. For the 2018 and 2019 camps, the number of participating students was 44 and the number of teachers was also 10. A few of the students were returning and had attended previous camps, but for most, it was their first camp of the sort. This paper builds on previous work by the same researchers [7].

Regarding recruitment, the GEAR UP schools suggest that their students apply for the camps. It was a simple system of first come, first serve. There were no restrictions on students that wanted to attend the camp as each of the schools in the program meets the minimum criteria of the GEAR UP program goals for the student population.

Participant demographics for student participants are shown in Table 1 below.

Table 1. Demographics of student participants

Category	Number (Percentage)
Age in years	N (%)
14	43 (29.1%)
15	50 (33.8 %)
16	28 (18.9%)
17	27 (18.2%)
Sex	N (%)
Male	85(57.4%)
Female	62 (41.9%)
Non-Binary	1 (0.7%)

For the five camps, students ranged from 14-17 years old, with eighth graders going into ninth grade attending the 2017 camp, ninth graders going into tenth grade for the 2018 camp, and tenth graders going into eleventh grade for the 2019 camp. Finally, juniors attended the 2022 and 2023 camps. The distribution of sexes was 57.4% male, 41.9% female, and one non-binary student.

The program was designed to promote hands-on learning and minimize passive classroom learning. The main theme of the three engineering camps was water and environmental engineering. The 2018 camp specifically included advanced water engineering with drones used in agriculture and air quality engineering. Before the camp activities started, students completed a pre-camp survey to determine what their perceptions of and interest in STEM were, as well as the factors influencing that interest. The same survey was given to students at the end of the camp to determine how the experience influenced their perceptions and interest in STEM and examine which factors influenced that interest. This research focused on the differences between males and females in terms of the factors influencing their interest in STEM fields.

Below is a description of activities that the students and teachers were involved in during the 2017, 2018, 2019, 2022 and 2023 camps. After the description of each activity, sample quotes from students are included. These quotes were taken from the journals students wrote at the end of each day.

Engineering Camp 2017:

During the **first** day of the engineering camp, activities were included to pique the students' interest in using STEM activities to better manage water resources. To begin the day, they started with an activity showing students the water cycle. Following the water cycle activity was a fish tagging activity. It showed how scientists and engineers use the process to determine the health of streams and movement of fish in the stream.

During the **second** day of the engineering camp, students visited three sites along a mountain river in a local water shed. Their first stop was upstream in the mountains. The next stop was downstream where camping, fishing, kayaking and other recreational uses of the water at a point just before the river enters the city. The last stop was after the river had passed through the city, farms, and ranches in the area. For each stop, students took various physical and chemical measurements of the water.

The **third** day of the engineering camp focused on the impacts of storm water and water treatment. This included a simulated storm water activity comparing run-off volume and intensity as rainfall was simulated on an area covered in vegetation and another area covered with asphalt/concrete. Students also had the opportunity to see what happened as a non-reactive fluorescent tracer (simulated pollution) was dumped into the local river and observed how fast and how far pollution can spread. Finally, teams of students competed at building a water filter from sand and gravel.

On the **fourth** day of the engineering camp, the focus was on wastewater treatment plants. After learning about bacteria related to treatment plants, students visited a local treatment lagoon and wetland system and a mechanical treatment plant. Students then sampled and analyzed water quality parameters from both plants.

For the **final** day, Day 5 of the engineering camp, students presented what they had learned with a poster session followed by a presentation session. Table 2 shows a summary of the activities students and teachers engaged in during the week-long engineering camp in 2017.

Table 2. Activities for participants at the 2017 Engineering camp.

Day	Activity 1	Activity 2	Activity 3	Activity 4
Monday	Water cycle	Fish tagging		
Tuesday	Measuring water properties at multiple locations along a local river, starting upstream and then going all the way downstream			
Wednesday	Water run off experiment	Storm water impacts/multiple locations	River dye activity	Building and testing a water filter
Thursday	Looking at bacteria under a microscope	Site visit to local lagoon treatment facility, water sampling and analysis of water quality parameters	Site visit to local mechanical wastewater treatment facility, water sampling and analysis of water quality parameters	
Friday	Poster session	Presentation Session		

Engineering Camp 2018 and 2019

Camps in 2018 and 2019 were structured differently than the 2017 camp. Instead of all the students and teachers working together all week, the students were split into four groups, and aside from the first and last day, each group was doing different activities each day. The groups rotated through four activities during the week. All the students experienced all the activities.

For the **first** day of the camp, students attended a short presentation by each of the facilitators of the activities. After that, the groups of students participated in assembling simple submarines/submersible ROVs (Remotely Operated Vehicles).

The **second** and **third** days of the camp involved students participating in all four activities described below. The activities were:

- **Sea Perch Submarines:** The students took the ROVs they had assembled the day before to a dam reservoir on the local river to collect water samples and underwater videos.

- **GIS Stream Data:** The students went to a stream to collect data on the water depth and water flow at multiple locations. The students looked at water characteristics as well.

- **Air Quality/Drones:** The students learned about air quality and then measured the air quality using two different methods.

- **Flying Aggies:** Students learned that farmers could use drones that take pictures to improve their fields.

The **fourth** day: The students picked one of the four activities they had done during the previous two days to do more involved research, spending a full day on the topic.

During the **final** day (Day 5) of the engineering camp, the students participated in a research poster session followed by a research presentation session. At the end of the camp, the students completed a post survey to see how their perceptions of STEM had changed or not changed.

Table 3 below shows a summary of the activities students and teachers engaged in during the week-long engineering camps in 2018 and 2019. All the groups had different schedules but participated in the same activities. Below is the schedule of one of the groups.

Table 3. Activities for participants at the 2018 and 2019 Engineering camp.

Day	**Activity 1**	**Activity 2**
Monday	Presentations summarizing the activities for the week	Building submersible ROV's
Tuesday	Sea Perch Submarines	GIS Stream Data
Wednesday	Air Quality/Drones	Flying Aggies
Thursday	Activity Choice	Working on Poster and Presentation
Friday	Poster and Presentation Sessions	

Engineering Camp 2022 and 2023

Following the Covid 19 pandemic, the camps were restructured, and the 2022 and 2023 camps became two days long, unlike the five-day long previous camps. The 2022 and 2023 camps focused on rocket design and launching activities.

In both camps, the first day, the students designed and launched water rockets. They learned how the ratio of air and water in a bottle affects the effectiveness of the rocket. Each group did multiple tests to understand the effect of said ratio to performance.

During the second day, students used educational model rockets and designed their own using the available materials, they were provided with different sizes and the tools to make their own fins. The students each experimented with different designs, then launched them and measured how high they reach and how accurate they were in landing.

Data Collection

Students' Pre and Post Surveys

During the students' first day at the engineering camp, they took a pre-camp survey. This survey included the STEM-CIS (Career Interest Survey) based on the work of Kier, Blanchard, Osborne, & Albert [8], as well as demographic information. The STEM-CIS consists of 44 questions that were based on a 5-point Likert scale ranging from 'Strongly Agree' to 'Strongly Disagree'. Four sets of 11 questions were made from 44 questions based on the four areas of STEM. An example question was *"I believe engineering is important"*.

An additional four questions were in the pre-camp survey based on the work of Talton and Simpson [7]. These questions were in the form of a 5-point Likert scale that examined peer perceptions of science. An example question was, "*My best friend likes science".* A final component of the pre-camp survey was questions related to students' informal prior experience with STEM based on the work of Franz-Odendaal, Blotnicky, French, & Joy [9]. An example of a question was, "*Which of the activities listed below have you participated in in the past year? (You can choose more than one)"* The responses to the questions looked at the following degrees of engagement: *No STEM engagement, low level of STEM engagement, moderate level of STEM engagement, and high level of STEM engagement.*

Following the camp, a post-camp survey was given that was the same as the pre-camp survey. The post-camp survey included additional questions asking the students to rate the activities they participated in during the camp. Qualitative data was collected through the pre- and post-camp surveys and the daily journals students kept. Example questions to collect qualitative data were, *"Are you interested in STEM (Science, Technology, Engineering, and Mathematics) career? Why or why not?", "What is your perception of STEM careers and their importance?",* and *"What made you choose to come to this camp?"*

Data Analysis

To draw relevant conclusions, a mixed research design method was used that enabled an accurate qualitative and quantitative data analysis. Prior to the analysis, the data was read by two undergraduate students and their faculty advisor. Once read, the students agreed on various common themes in the responses and proceeded to code the data according to those themes using the MAXQDA software. The faculty advisor served to guide the students throughout the coding process. The coding was informed by *The Coding Manual for Qualitative Researchers* by Saldana [10] and *The Qualitative Inquiry and Research Design* book by Creswell [11].

The two undergraduate students looked through the data first to decide what main coding themes to use. The main themes were: *Educational Experiences, Interests, Future,* and *Relationships/People*. The two students went through the first coding cycle by themselves and then met to arbitrate and come to an agreement about codes where there was a disagreement. Once agreements were made, the students decided on sub-themes, and came to agreements during the second cycle of coding. The target was an interrater reliability Cronbach's Alpha of 0.8 [12]. In both the first and second cycle of coding, the interrater reliability exceeded 0.8.

Afterward, the qualitative and quantitative data were analyzed together based on the recommendations from the literature about mixed methods research, such as Creswell's book, Designing and Conducting Mixed Methods Research [13].

Microsoft Excel was used for most of the quantitative data analysis except for the calculation of the *p*-values of the Mann Whitney U test, which was done in R. The qualitative analysis was performed by splitting the data into years of the camp and gender.

Results

Qualitative Data

The qualitative data was gathered from student responses to open-ended questions. Some examples of the open-ended questions were, *"Name in order the three biggest influences on your choice of career in the future."*, *"Are you interested in a STEM career? Why or why not?"*, and *"What is your perception of STEM careers and their importance?"* Based on the data, the researchers were able to produce two main themes and four sub-themes that highlight student's self-efficacy.

After the coding was finished, the frequency of each main theme and sub-theme was recorded. The data is shown below in Table 4.

Table 4 shows the two main themes which were composed of positive and negative self-efficacy. The theme *Positive Self-Efficacy* is a student talking about their academic abilities and understanding positively. Whereas the theme *Negative Self-Efficacy* is a student mentioning themselves doing poorly in academics. The sub-themes were the same for each main theme. Once the main themes were coded, those responses were then categorized into a relevant sub-theme. The first sub-theme is *Mentions Grades*. This means a student when mentioning their academic abilities, they mention their grades or grade point average. Another sub-theme is *Not*

Interested in STEM. This sub-theme refers to when a student mentions either positive or negative self-efficacy, they also stated they were not interested in STEM. Similarly for the sub-theme *Interested in STEM,* this was coded when students who reported either positive or negative self-efficacy also stated that they were interested in STEM.

Table 4. Qualitative Data - Frequencies of main themes and subthemes.

	Frequency in Females			Frequency in Males			Both
	Pre	Post	Both	Pre	Post	Both	Total
Main Themes							
Positive Self-Efficacy	19	8	27	17	7	24	51
Negative Self-Efficacy	3	3	6	2	3	5	11
Sub-Themes for Positive Self-Efficacy							
Mentions Grades	0	2	2	0	1	1	3
Not Interested in STEM	2	1	3	3	0	3	6
Interested in STEM	15	6	21	12	7	19	40
Sub-Themes for Negative Self-Efficacy							
Mentions Grades	0	0	0	0	0	0	0
Not Interested in STEM	1	1	2	2	1	3	5
Interested in STEM	1	0	1	0	2	2	3

Between the main themes, *positive self-efficacy* had a significantly higher frequency than *negative self-efficacy*. It consisted of a total of 51 responses, 27 of which were female and 24 male responses. An example response from a male student was, "*STEM fields have always been my strong suit. They come natural to me and make lots of sense unlike other fields."* This was in response to being asked if the student is interested in STEM. One female student speaking on her experience with STEM stated, *"I am in all honors classes, meaning I excel in science and math."*

Within the theme, the sub-themes were *Mentions Grades, Not Interested in STEM,* and *Interested in STEM.* The most frequent sub-theme was *Interested in STEM.* One example from a female student stating their interest in STEM was, *"I consider myself good at them [STEM Subjects] so I'm interested."* A male student under this sub-theme stated, *"Yes, I want to be an engineer because I am talented in academics and math."* An example from a female student of *Mentions Grades* was, *"In all my classes I maintain a 4.0."* Another female student responded with, "*No, I love science, but math isn't my best subject sadly".* This student had *Positive Self-Efficacy* but fell under the sub-theme of *Not Interested in STEM.*

Negative self-efficacy was the less dominant theme of the two main themes. Eleven students had responses to the open-ended questions suggesting they had negative self-efficacy. Six of the 11 were female responses while the other 5 were male responses. An example response from a female student when asked if they were interested in STEM mentioned, *"No, I'm bad at math."*

Within the theme of *negative self-efficacy*, the sub-themes were *Mentions Grades, Not Interested in STEM,* and *Interested in STEM.* Students placed a slightly more favorable emphasis on expressing the sub-theme, *not interested in STEM*. A male student mentioned in response to a question about their interest in STEM, *"At this point in life I don't think much of the career because of the school work."* A female student also mentioned under the same sub-theme, *"I am unsure whether I would be able to do many of them [STEM Careers] because I am bad at math."*

Quantitative Data

Each student who attended a summer engineering camp completed a pre-survey and a post-survey. From the perspective of determining the amount of statistical evidence that supports the main hypothesis, namely that self-efficacy increasing interest, the camp itself is unrelated. Thus, for this portion of the data analysis it was necessary only to analyze the responses to the pre-surveys, as the camp itself could be interpreted as an extraneous intervention that was irrelevant to the investigative thesis.

To determine whether there was a correlation between students' self-efficacy and interest in a STEM field, we analyzed student responses to the following questions/statements (strongly disagree/disagree/neither agree or disagree/agree/strongly agree):

1. I am able to get a good grade in my science class.
2. I am able to do well in activities that involve technology.
3. I am able to do well in activities that involve engineering.
4. I am able to get a good grade in my mathematics class.

These four questions served as an indicator of self-efficacy among the student participants. Each question measures the self-reported self-efficacy in each of the four major fields in the acronym STEM (each question respectively). We then tabulated the responses to another set of statements:

1. I like my science class.
2. I like to use technology for class work.
3. I like activities that involve engineering.
4. I like my mathematics class.

These four questions served as an indicator of interest in a STEM field (each question respectively). Finally, we decided it would be worthwhile to gauge the interest of participants in careers:

1. I am interested in careers that use science.
2. I am interested in careers that use technology.
3. I am interested in careers that involve engineering.
4. I am interested in careers that use mathematics.

These were the final four questions that we considered. These give insight into the student participants' interest in careers in STEM (each question respectively). The responses to the 'self-efficacy' statements were compared with the responses to each of the 'interest' statements, which can be loosely referred to as 'interest in STEM' and 'interest in a STEM career'.

The correlation between self-efficacy and interest in STEM

First, Pearson correlation coefficients were calculated between the responses to the 'self-efficacy' questions (#1-#4) and the 'interest in STEM questions' (#5-#8) (each respectively by STEM field). We found there to be statistically significant ($p < 0.001$ in every case) correlations between self-efficacy and interest in STEM no matter the specific STEM field and across males and females, as well as in total.

Table 5. Correlation coefficients between participants self-reported self-efficacy (as measured by questions #1-#4) and participants self-reported interest in STEM fields (as measured by questions #5-#8). All twelve of the correlation coefficients were significant with $p < 0.001$.

Pearson correlation coefficients of self-efficacy vs. interest in STEM					
	Science	Technology	Engineering	Math	Sample size
Males	0.43	0.44	0.55	0.42	86
Females	0.44	0.45	0.48	0.49	65
Non-binary	N/A	N/A	N/A	N/A	1
Total	0.43	0.47	0.52	0.45	152

We note here that the discrepancy between the N value reported here and at the beginning of the document is due to 4 students doing the pre, but not the post survey, so the 148 number signifies students who finished the camps, while 152 signifies the number of students who only started the camp.

All of the correlations are relatively close to each other except for a few observable (but not significant) differences: (1) a higher ($p = 0.570$) correlation in the 'Engineering' category for males, and (2) a higher ($p = 0.599$) correlation in the 'Math' category for females. The correlation coefficients for males and females were compared for each category within STEM and the p values are (respectively) 0.941, 0.941, 0.570, and 0.599.

The correlation between self-efficacy and interest in STEM careers.

The correlation coefficients between 'self-efficacy' (questions #1-#4) and 'interest in a STEM career' (#9-#12) are given in Table 6a. Each correlation coefficient was statistically significant, and the associated p values are given in Table 6b.

Table 6a. Correlation coefficients between participants self-reported self-efficacy (as measured by questions #1-#4) and participants self-reported interest in careers within STEM fields (as measured by questions #9-#12)

Pearson correlation coefficients of self-efficacy vs. interest in a STEM career					
	Science	Technology	Engineering	Math	Sample size
Males	0.21	0.54	0.44	0.27	86
Females	0.25	0.43	0.37	0.43	65
Non-binary	N/A	N/A	N/A	N/A	1
Total	0.22	0.51	0.41	0.32	152

Table 6b. Correlation coefficient *p* values associated with Table 6.

	Science	Technology	Engineering	Math	Sample size
Males	0.003	< 0.001	< 0.001	< 0.001	86
Females	0.023	< 0.001	0.001	< 0.001	65
Non-binary	N/A	N/A	N/A	N/A	1
Total	0.003	< 0.001	< 0.001	< 0.001	152

The correlations for the 'Science' category were the weakest, albeit still significant. The correlation coefficients presented in Table 6a between males and females were compared and no significant differences were found in the categories of STEM; the *p* values (respectively) are 0.801, 0.390, 0.618, and 0.276. The correlations in Table 5 and Table 6a were compared to determine if there were any significant differences in correlation between 'self-efficacy' and (1) 'interest in STEM', and (2) 'interest in a STEM career'. No significant differences were found.

Self-efficacy of males compared with the self-efficacy of females

The researchers put forth the hypothesis that males would have higher self-efficacy due to the well-known societal barriers that females face in STEM, as well as the associated additional encouragement that males receive in STEM.

This hypothesis was not supported by the data. In fact, there was no significant difference in self-efficacy except for in the 'Math' field. The average response was higher for males in the categories of 'Technology' and 'Engineering' whereas females had a higher average response in 'Science' and 'Math'. Under the scrutiny of the t-test and Mann Whitney U test (MWW) these differences were not significant, except in the case of 'Math'.

Table 7. Average response to questions #1-#4 (Self-efficacy), split by male and female participants.

Self-efficacy average					
	Science	Technology	Engineering	Math	Sample size
Male	4.465	4.372	4.279	4.035	86
Female	4.569	4.215	4.138	4.477	65

In hindsight, the greater female self-efficacy in "Math" was significant according to a t-test (p = 0.001) as well as the Mann Whitney U test (p = 0.001). The researchers hypothesize that due to the well-documented barriers that exist for women in STEM, that one can assume that the women *who do enter STEM* may need a significantly higher self-efficacy in math, giving them the confidence to succeed in a landscape that includes barriers that lie outside of academic skill.

Self-efficacy before and after the engineering camp

The researchers wanted to investigate the hypothesis that the self-efficacy of males would not be affected by attending the camp, but the self-efficacy of females may decrease after the camp. The reason for this hypothesis is the well-known societal barriers to women in STEM. This was not the case. The before and after self-efficacy averages are given in the table below.

Table 8. Average self-reported self-efficacy of males and females before and after an engineering camp.

Self-efficacy scores (average) per STEM field				
	Science	Technology	Engineering	Math
Male pre-camp	4.47	4.37	4.28	4.03
Male post-camp	4.50	4.38	4.40	4.16
Female pre-camp	4.57	4.22	4.14	4.48
Female post-camp	4.63	4.17	4.31	4.48

It is apparent that the camp did not affect the self-efficacy of the participants except a slight (non-significant) increase in the 'Engineering' category. It is worth noting that the camp was engineering focused.

Conclusions

When examining the qualitative data, "Positive Self-Efficacy" was the most frequent theme between male and female students. Both male and female students mentioned "Positive Self-Efficacy" at a higher rate *before* the camp than after. This could indicate that students thought more critically about their ability in STEM after participating in STEM related activities for the week.

Based on our initial research, we were anticipating students with positive self-efficacy to also be interested in STEM [4]. After analyzing the qualitative data, this was shown to be true. Among the sub-themes, 40 of the 51 students that mentioned "Positive Self-Efficacy" also mentioned they were "Interested in STEM". Suggesting that students who view themselves as good at a subject are also interested in that subject. Additionally, in our initial research it was found that male students tend to have higher self-efficacy than female students. We found that female students mentioned "Positive Self-Efficacy" at a higher rate than male students which is in contradiction to our initial research [5].

The quantitative analysis showed a significant correlation between self-efficacy and interest in STEM and between self-efficacy and interest in a STEM career. A comparison of self-efficacy among males and females revealed a significantly higher self-efficacy within mathematics among females. This could indicate that females are only attending engineering camps if they possess a significantly higher self-efficacy in mathematics thereby giving them the confidence of being able to succeed despite historic, well-known barriers that females face in engineering. Found in similar research about a STEM camp, instructors of the camp mentioned, "They stressed capitalizing on the girls' interest in STEM before they lost interest or society's gendered messages influenced them away from pursuing STEM." [14, p. 118]. This supports our earlier finding that only female students with a higher self-efficacy attend engineering camps. However, due to societal barriers and stereotypes, they could be negatively drawn away from pursuing a STEM-related future.

To improve upon our findings, future research would be well-suited to focus on actual student scores rather than self-reported self-efficacy. Additionally, it is well-documented that females face greater systemic barriers when entering STEM fields, be it college or career. Because females displayed much more self-efficacy within mathematics, future research could investigate whether females and males with the same level of self-efficacy within mathematics have similar or disparate interest in pursuing a career in STEM. A better understanding of the relationship between self-efficacy and interest can help in increasing female participation in STEM. Future research could include open-ended questions in the pre, and post surveys of an engineering camp directly related to self-efficacy to better study this with a mixed method approach.

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