Stem Obstacles In The Collegiate Setting

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Abstract

STEM has one of the largest job fields, providing competitive salaries and opportunities for advancement. Despite this potential, enrollment in STEM majors is low and attrition at the collegiate level is high. This affects economic development and diversity within the scientific community. This warrants an analysis of the major selection process and identification of factors that affect STEM students in the academic setting. In this study, STEM and non-STEM majors at a liberal arts institution were surveyed about their education experience and the process of major selection. Significant results were found for STEM majors in terms of the amount of time spent on coursework as compared to their peers, the importance of peer and instructor interaction, course factors that cause stress, and thoughts on switching majors. The findings indicate that positive peer interaction and instructor support is critical for retaining STEM students as it fosters a scientific community. For non-STEM majors, a majority reported moderate confidence in science and mathematics, reported not participating is STEM activities outside of the classroom setting, had few thoughts of changing majors, and reported not knowing anyone in the STEM field. These findings highlight the importance of exposing students to STEM careers, and retaining student interest in STEM in the high school setting.

Introduction

STEM is an area that encompasses the fields of science, technology, engineering, and math. The goal of these fields is to produce individuals who are competent in gathering information, critical thinking, and the application of material (Bybee, 2010; Chen, 2013). The STEM area is a driving force of innovation and economic growth in the US and globally as STEM individuals produce new products and innovative solutions (Chen, 2013; Donovan et al., 2014). According to a 2017 study done by the U.S. Bureau of Statistics, there are roughly 8.6 million STEM jobs in life science, mathematics, computer science, physical science, and engineering. The national average wage for these STEM occupations is double the national average wage for non-STEM occupations ($87,570 versus $45,700) (Fayer, 2017). Additionally, it is projected that STEM employment will increase by 8.8% between 2018 and 2028 in the US, with the largest growth being in computer science (Fayer, 2017; "Employment in STEM occupations", 2020).

While potential STEM careers are on the rise, the number of students enrolled in STEM majors and matriculating at the collegiate level is decreasing. Studies suggest that only 16% of high school graduates choose STEM majors when entering college and 56% of students who declared STEM majors eventually change majors, with women and minorities leaving in larger numbers (Chen, 2013; National Science Board, 2016; Xie et al., 2015). A majority of students who leave STEM switch to business (~48.7%), social sciences (~21.2%) and education (~11.1%) majors (National Academy of Engineering and National Research Council, 2012). The loss of these students has significant effects on economic development and diversity within the scientific community as a whole.

This decline has led to studies aimed at understanding why STEM students leave the field (Chen, 2013; National Academy of Engineering and National Research Council, 2012). Secondary school preparation, the culture of STEM fields, and instructional practices all contribute to a lack of student retention at larger institutions and at the community college level (National Academy of Engineering and National Research Council, 2012; Henry et al., 2019). Improvements in educational approaches in the STEM field such as active engagement instruction, more undirected experiences in the STEM setting, mentoring, and faculty professional development programs have been initiated to enhance student STEM experiences (Johnson, 2019; Freeman et al., 2014; Smith et al., 2014, Wilson, 2012). Additionally, studies directed at specific student stressors in the academic setting have focused on select groups of students (nursing, dental hygiene, or medical students) or on the rates of depression, alcohol use, or coping mechanisms (Harris et al., 2018; Venkatarao et al., 2015; Labrague et al., 2017; Beiter et al., 2015). None of these studies have been directed at natural science majors or at identifying stress factors and describing the role that social interaction plays on retention.

Similarly, a limited number of studies have focused on why few (16%) high school graduates choose a STEM major upon entering college. The limiting factor in most studies appears to be linked to mathematical abilities (Wang, 2013), however few have analyzed the major selection process behind such beliefs. A more thorough analysis can shed light on major selection and better elucidate why students are initially driven away from STEM majors.

Study Purpose

The purpose of this study is to further address issues for both STEM majors and non-STEM majors at a small institution (<4,999 students) which represent a significant portion of institutions (~74%) within the U.S. (U.S. Department of Education, 2019). This study focused predominantly on the natural science majors and to a lesser degree clinical laboratory science STEM majors. Survey response rates were collected (N=133), of which 30 were classified as STEM majors and 103 were non-STEM majors. Factors that cause stress to these STEM students were identified and the role of social (peer and instructor) interaction in collegiate STEM education evaluated. This will lead to the development of strategies aimed at decreasing attrition rates within these STEM fields. Additionally, the major selection process was evaluated for non-STEM students in order to identify factors that draw students away from STEM majors. By understanding the major selection process, deficits can be addressed at the high school setting or at larger academic institutions. The information gathered in this study will aid in increasing STEM matriculation to meet the needs of the STEM field.

Methods

Data Collection

A survey consisting of closed ended questions was compiled using the online source SurveyMonkey and distributed via email to all undergraduate students (N= 589; of which 354 were female and 235 were males) at Thomas University. The student demographic of Thomas University is unique as a majority of undergraduate students enrolled at the institution are from other cities within the state or from various states in the U.S. Additionally, many undergraduate students participate in student athletics such as baseball, softball, soccer, and swimming. This creates

additional obligations outside the classroom setting. Participants ranged from 18 to 30 years of age and were classified as either a STEM or non-STEM major. This study was approved by the Thomas University Institutional Review Board (IRB number: LW10032020).

STEM majors (N=114) consisted of students enrolled in natural science (Biology, and Natural Resource and Conservation Management) and clinical laboratory science (Medical Laboratory Science and Biomedical Laboratory Science) as these STEM degrees are currently offered by the study institution. These students completed a ~16 question survey consisting of questions that were organized into two sections. The first section focused on the science experience in order to identify items that cause stress to STEM students in the academic setting such as course pacing, time spent on each topic, amount of recall versus critical thinking in courses, and peer verse instructor interaction. The second section focused on student obligations beyond the classroom such as athletics, employment, or family obligations, that may contribute to stress and impact the ability of a student to remain in the STEM major.

Non-STEM majors (N=475) completed a ~18 question survey consisting of questions that were also organized into two sections. The first section focused on student background to STEM related fields. Questions were targeted at understanding exposure of students to STEM in the high school or community setting, confidence in scientific and mathematical situations, and perceived STEM impact on society. These questions aimed to determine how previous education experience affects major selection. A second set of questions concentrated on how/why a particular major was selected with questions centered on understanding the time it takes to obtain a degree, amount of time devoted to courses, concerns about salary within the field, and personal obligations. These questions addressed whether students selected a non-STEM major due to lack of interest or other deciding factors.

Data Analysis

Survey responses were collected over a one-month period and analyzed within their respective groups (STEM or non-STEM). A total of 26% of STEM majors (N=30) completed the STEM specific survey. Of the non-STEM majors, 22% (N=103) completed the survey. The results of each survey, STEM and non-STEM, were analyzed separately per question, answer, and gender. Responses per question were examined for frequency. All values are reported as means. In the case of multiple-select questions, students could select several answers and trends were analyzed for all answer options. Additionally, many questions had an option for open responses. For these questions, emergent thematic content analysis was utilized to identify themes present in the data (Braun & Clarke, 2006). The results of each survey are presented separately.

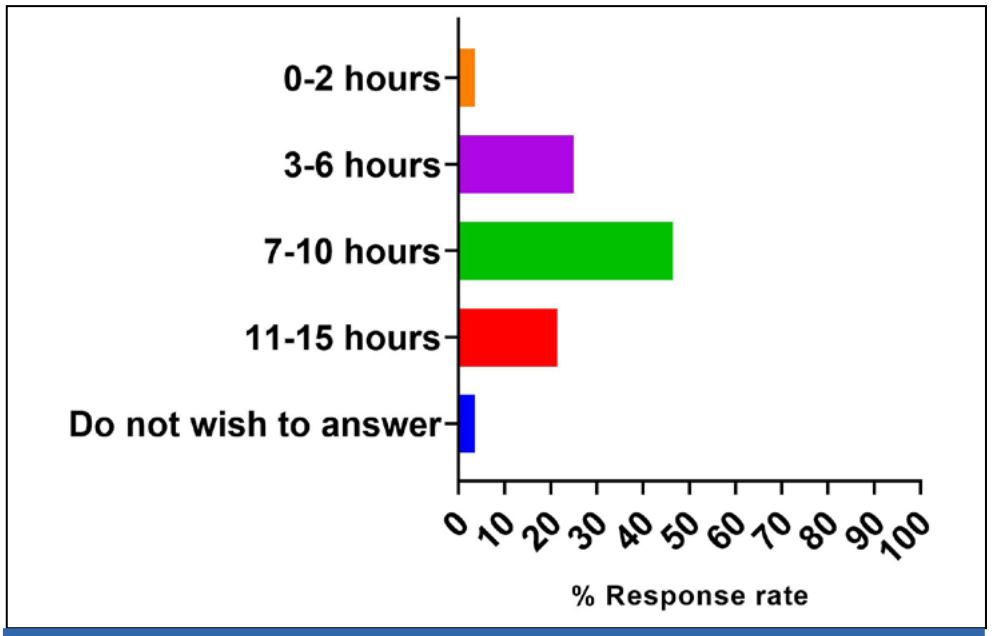

Figure 1. Hours per week STEM students spent on coursework as compared to non-STEM students.

Results

STEM survey

Of the STEM students surveyed, 26% completed the online survey about their STEM education experience, of which 20% were males and 80% were females. An important topic associated with STEM majors is the length and complexity of courses which often require laboratory sessions, out of class assignments, projects, and cumulative exams. This demands greater effort and time commitment to be successful within the major. In order to evaluate the complexity of STEM courses at this institution, students were asked to compare the amount to time spent on STEM courses as compared to their non-STEM peers. Analysis revealed that 46% of surveyed STEM students reported spending 7-10 hours a week more on course work (Figure 1). This indicates the high level of demand and rigor of science-based courses, which could deter some students from STEM majors or attribute to changing majors.

As each student has a preferred learning style for retention and comprehension of information, questions were aimed at evaluating the learning styles at this institution. A majority of STEM students, 61%, reported a combination of visual, auditory, and kinesthetic best represented their respective learning style. Such a finding indicates that multiple modalities of instruction and practical applications provide incentives for STEM students to learn. Similarly, when asked how the STEM education experience could be improved, 61% reported less recall and more application-based course design followed by 57% for practical applications (Table 1). This highlights the need for more Course-Based Undergraduate Research Experiences (CURE) for students. This could include adding CURE to existing labs or creating specific CURE courses to enhance student learning.

It is not uncommon for college students to experience stress both inside and outside of the classroom. To address factors that directly contribute to academic stress, STEM students were tasked with identifying academic items that impacted their overall wellbeing. There was no clear-cut education related stressor for STEM students as pace of the course, amount of material covered, recall of material, and formatting of exams were selected by multiple students and represented 50% of all responses (Table 1). This indicates that a variety of factors affect the classroom experience and thus learning. It also suggests that academic course stress is highly specific to individual students. When asked about how STEM students handle difficult topics, 96% reported using online resources to better understand a course topic, 69% reached out to the instructor for help or keep reading the text, and 58% reached out to peers (Table 1). This finding further indicates the need for reliable, accurate, and credible online sources of STEM information as it is the first place many students go to for help with a difficult concept.

When asked about peer interactions, 69% of STEM students reported positive relationships with other STEM students and little competition with other STEM students (Table 1). These relationships are essential for building a scientific community and fostering student retention. Such relationships become more important as students' progress through the STEM major as 53% of upper-level students (Juniors and Seniors) reported more stress than compared to when they were a lower-level student (Table 1).

It is not uncommon for undergraduate students to switch majors or to transfer institutions. To evaluate the rate of STEM students who consider switching majors at this institution, students were asked if they had considered changing majors and if so, how often. Analysis revealed that 89% of STEM majors have never considered changing

Question: What would improve your science learning experience? Select all that apply.	Response Rate
Undirected projects where students design, collect, and analyze data	29%
Practical applications of concerts	57%
Increased instructor interaction	29%
Increased student interaction	32%
Less recall and more application-based course design	61%
Question: What do you find most difficult/stressful in science courses? Select all that apply.	**Response Rate**
Pace of course	50%
Amount of work assigned	46%
Amount of material covered in the course	50%
Interaction with classmates	21%
Recall verse application of concepts	50%
Formatting of exam questions/exam structure	50%
Other	4%
Question: How do you deal with difficult situations, like if you are struggling with a difficult concept? Select all that apply.	**Response Rate**
If you don't get it the first time, you give up	4%
You reach out to the instructor for help	69%
You reach out to peer for help then the instructor if you are still having problems	58%
Find a tutor to help you	19%
You find online sources to help you	96%
You keep reading the text over and over	69%
Other	0%
Question: Have you built positive relationships with other students who are also science majors?	**Response Rate**
Yes	69%
No	27%
Do not wish to answer	4%
Question: Do you feel competition with other science majors to achieve the best grade/ critiques?	**Response Rate**
Yes	42%
No	58%
Do not wish to answer	0%
Question: Do you feel that your classmates enhance your learning or detract from it?	**Response Rate**
Enhance	31%
Detract	0%
Neutral	69%
Do not wish to answer	0%
Question: If you are an upper-level student (Junior or senior) are you more stressed now or when you were a lower-level student (Freshman or Sophomore)?	**Response Rate**
More stressed	38%
Less stressed	12%
The same	21%
Do not wish to answer	0%
Not an upper-level student	29%

Table 1. STEM Student Survey Responses (N=30)

majors (Figure 2A). This demonstrates that students who select a STEM major in a small, liberal arts institution stay within the major which could be attributed to better support, increased instructor interaction, and resources available for retention. Of the STEM students who considered switching majors, 66% indicated that instructor difficulty, time needed for courses, and outside obligations as the leading cause for this switch (Figure 2B). Additionally, when surveyed about instructor diversity, 88% of students supported instructor diversity within their courses. This diversity will exposure students to a greater variety of teaching styles, and course design to enhance learning. It will also avoid situations where students have repeated negative interactions with faculty which would promote the student to consider changing major. As instructors are critical in the education experience, this demonstrates the need for efficient, empathic, and invested instructors to retain students and provide a positive education experience.

Non-STEM Survey

A majority of college students select majors outside the STEM field. In order to understand the major selection process, non-STEM students were surveyed. When asked why students selected a particular major, 67% reported interest in the topic followed by the number of career opportunities and salary as the causes for a particular major selected (Table 2). A majority of non-STEM students, 73%, were concerned about the cost associated with earning a degree and 22% were extremely concerned about immediate job placement after graduation (Table 2). As STEM careers often require extensive education, this could deter some students from the major. When asked to evaluate perceptions of science and math, a majority of students found STEM challenging, 48%, and interesting, 35% (Table 2). This demonstrates that most students could be attracted to the STEM field if their interests are expanded upon in the classroom or extracurricular setting.

To further expand upon non-STEM student's skill levels in STEM, questions were focused on confidence levels in these areas. Responses demonstrate that 57% of students reported moderate confidence in science and 51% in mathematics (Table 2). Such a finding indicates that poor skills in these areas is not the leading factor for STEM major avoidance in this study population.

In order to assess previous exposure to STEM, students were asked about science and mathematics experiences in the high school setting. Of the surveyed students, 36% reported taking basic science courses and liking them, 27% took the basic science courses and thought the courses were just ok, and 20% took advanced science courses and liked them (Table 2). This finding indicates that a lack of interest in STEM is not a contributing factor for students selecting non-STEM majors. Additionally, a majority of students rated their high school science and mathematics experiences as average or above average, indicating that students felt they received a proficient foundation in STEM (Table 2).

To gauge student interaction with STEM professionals, students were asked if they knew individuals employed within the STEM field. Of the non-STEM students surveyed, 53% reported not knowing anyone employed in a STEM career (Table 2). This finding could account for the lack of STEM major selection as students are unaware

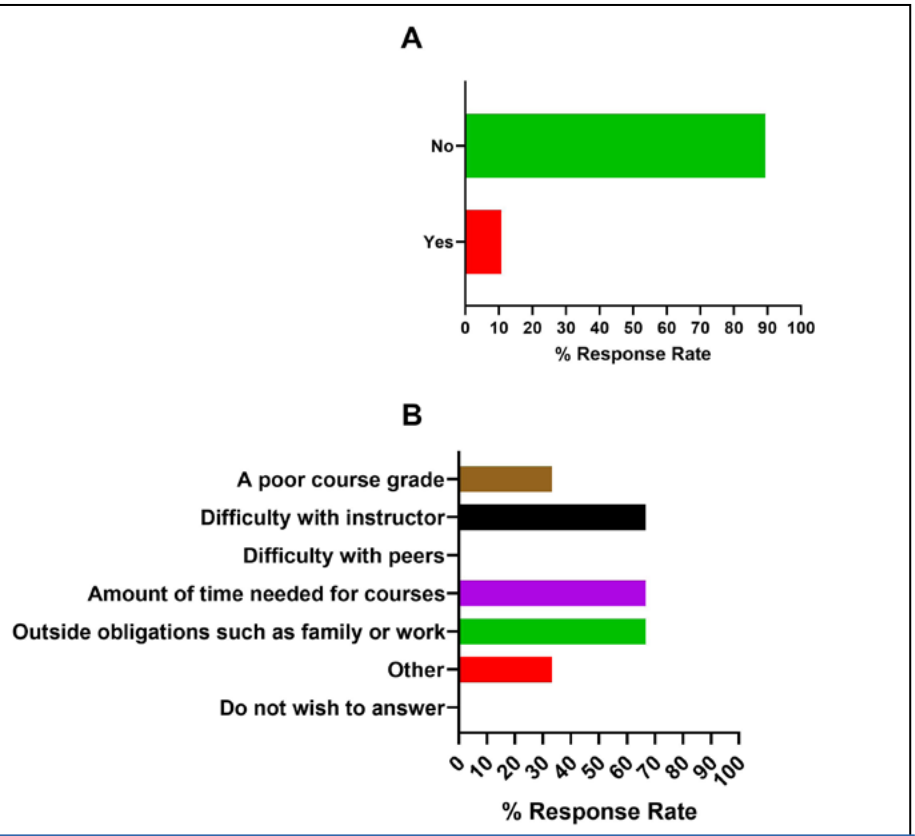

Figure 2. Analysis of factors associated with STEM students changing majors. A) Consideration of STEM students to changing majors. B) Aspects that directly contributed to consideration of changing majors.

and underexposed to the variety of STEM careers available.

When asked about exposure to science and mathematics, 82% reported not participating in science clubs or electives outside of the traditional classroom setting (Table 2). It is unclear whether these activities were unavailable or students simply choose not to participate. However, such a finding does indicate that more exposure to science beyond the structured setting could increase STEM enrollment as many students reported positive thoughts towards math and science, and 78% reported that STEM was extremely important to society. Perhaps exposure to various facets of STEM would increase interests and thus STEM major selection. This speculation is supported by the finding that while a majority, 69%, of non-STEM students have never considered switching majors, of those that did consider switching majors, 20% selected other for their response (Figure 3A). Emergent thematic content analysis of student responses for the other selection determined the cause as interests in multiple areas (Figure 3B).

Discussion

STEM is a diverse field with numerous career opportunities. As such, there is a growing demand for STEM professionals. This study addressed the STEM student experience and the major selection process in order to elucidate how education could be improved to increase STEM enrollment in the collegiate setting. The findings of this study demonstrate a variety of factors affect the classroom experience, learning, and stress level of STEM students (Table 1). This suggests that positive peer interaction and instructor support is critical for retaining students in STEM majors, as it builds a scientific community and fosters student retention. Results also highlight the importance of STEM in the high school setting, as positive exposure to STEM will encourage STEM major selection in college.

Of the STEM majors surveyed, 89% reported never considering changing majors, of those that did consider switching their major, 66% indicated that instructor difficulty, time needed for courses, and outside obligations were the leading cause for this switch (Figure 2). In comparison, 69% of non-STEM students have never considered switching majors, of those that did consider switching majors, 20%, reported the cause as interests in multiple areas and 9% due to outside obligations such as family, work, or partner (Figure 3). The majority of students, regardless of major, do not switch majors at a small liberal arts institution. Such an observation is supported by a recent national study which demonstrated the rate at which students changed majors was comparable for STEM and non-STEM students in their first three years of college (National Center for Education Statistics, 2017).

Humans are social creatures; thus interaction plays an important role in retention. The sense of belonging is a key factor in a student's ability to hold information and succeed. This study found that 69% of students reported positive relationships with other STEM students and little competition (Table 1). These positive relationships are essential for building a scientific community and fostering student retention. Studies have shown that positive social interaction increases motivation and academic achievement. When students feel that they are not valued, accepted, or legitimate members in their academic field they are less likely to persist (Zaniewski & Reinholz, 2016). Group cohorts are especially important as they establish a supportive learning community (Epstein, 2015) and lead to the development of friendships among peers which increase academic performance of students who faced uncertainty about belonging in a group (Walton & Cohen, 2007). As the study was conducted at a small institution, student interaction and relationships are built both inside and outside the classroom. This creates a STEM community that likely attributes to increased retention within the major observed at this institution. However, larger institutions would likely need to aid in the facilitation of these relationships by incorporating peer interaction in course framework. Additionally, positive role models help alleviate negative stereotypes, because students are able to see others "like them" can be successful in their field. This highlights the importance of peer mentorship programs which have been found to be valuable in STEM students' retention. A study involving required peer-cooperative learning programs concluded that these types of programs improve retention of STEM majors (Salomone & Kling, 2017). The implementation of comprehensive educational reform using peer-led cooperative learning may have the proximate effect of mitigating differences in academic preparation (as measured by SAT scores) for students in introductory STEM courses (Salomone & Kling, 2017). Another key factor for retention within STEM is fostering resilience within students, especially those from underrepresented minorities (Epstein, 2015). Resilience allows students to overcome stressful events and to persevere within STEM by defining success on a personal level. Students who define success in terms of individual learning gains and scientific growth, not academic performance, are more likely to be retained in STEM (Epstein, 2015). Instructors play a key role in the process of defining success within science and should guide students in evaluating their journey through science.

Of the non-STEM students surveyed, many showed an interest in STEM and realized its importance in society. Additionally, many felt confident in their mathematics and science skills (Table 2). However, they did not choose a STEM major upon entering college. This could be explained by the finding that 53% of the surveyed students reported not knowing anyone employed in a STEM career (Table 2). Such a finding is surprising as a variety of STEM careers are available. This indicates that a general lack of knowledge on options within the STEM field could account for low STEM major selection. The undergraduate student demographic utilized in this study is diverse. A majority of the students enrolled at the institution are

Question: Why did you choose your major?	Response Rate
Interest in Topic	67%
Number of Career Opportunities in the field	50%
Salary of Career	34%
Location of Career Opportunities in the Field	16%
Time to Obtain Degree	14%
Number of Courses Needed for Degree	8%
Instructors	3%
Rigor of Courses	2%
Other	11%
Question: Are you concerned about financial costs associated with obtaining a college degree?	**Response Rate**
Yes	73%
No	19%
Unsure	6%
Do not wish to answer	2%
Question: Did immediate job placement effect your degree selection? I.e., being able to find a job right after graduation without obtaining a post-secondary degree.	**Response Rate**
Extremely	22%
Moderately	21%
Slightly	18%
Not at All	36%
Do not wish to answer	3%
Question: Did a career with flexibility and schedule control effect your degree selection?	**Response Rate**
Extremely	15%
Moderately	28%
Slightly	13%
Not at all	44%
Question: What statement best describes your feelings toward science and math courses?	**Response Rate**
Science and math courses are uninteresting	11%
Science and math courses are challenging	48%
Science and math courses are interesting	35%
Science and math courses are unchallenging	2%
Do not wish to answer	4%
Question: Rate your perceived strength in science. I.e., how confident do you feel with your science abilities.	**Response Rate**
Strong	20%
Moderate	57%
Weak	19%
Unsure	3%
Do not wish to answer	1%
Question: Rate your perceived strength in math. I.e., how confident do you feel with your math abilities.	**Response Rate**
Strong	16%
Moderate	51%
Weak	33%
Unsure	0%
Do not wish to answer	1%
Question: Did you participate in any science and/or mathematics clubs or electives in high school?	**Response Rate**
Yes	17%
No	82%
Do not wish to answer	1%
Question: In your past science classes (high school or college), did you feel that you received adequate support from instructors when you did not understand a topic in science or math?	**Response Rate**
Yes	71%
No	26%
Do not wish to answer	3%
Question: Do you know anyone employed in a STEM field?	**Response Rate**
Yes	33%
No	53%
Unsure	14%
Question: What is the highest level of education you ever expect to complete?	**Response Rate**
Associates' Degree	4%
Bachelor's Degree	22%
Post-BA or post-master certificate	5%
Master's degree	52%
Doctoral degree	17%

Table 2. Non-STEM Student Survey Responses (N=103)

from other cities within the state, from other states within the US, or are international. This indicates that the lack of STEM career awareness is not inherent to the local area, but is instead part of a larger education issue. It highlights the importance of exposing students to a variety of STEM careers in the high school setting. As teachers influence student awareness of STEM careers and ultimately major selection, teachers must be knowledgeable on career options (Knowles, 2018). The incorporation of STEM career activities such as career explorer activities or guest speakers, can be incorporated into science lessons. This approach requires teacher awareness of STEM careers and adoption of an integrated STEM education model that focuses on community of practice (Knowles, 2018). Professional development programs such as Teacher and Researcher Advancing Integrated Lessons in STEM (TRAILS) have been developed to aid teachers in this process (Knowles, 2018). Initiatives such as TRAILS are necessary to inform students on the diversity of career options and ultimately increase STEM enrollment in the collegiate setting. This suggestion is supported by studies that demonstrate students who have parents with higher education levels were more likely to be enrolled in STEM. One study found that parents can play a critical role in influencing their children to pursue STEM (Plasman, 2021). Similarly, another study found that 15% of students with high school-educated parents enrolled in STEM fields whereas 22% of students whose parents had a bachelor's or higher degree enrolled in STEM fields (National Science Board, 2016). This may be attributed to the fact that many entry-level STEM careers require a bachelor's degree and students with less-educated parents are less likely to be aware or exposed to STEM careers ("STEM 101", 2014).

Conclusions and Future Work

This study found that most STEM students reported positive relationships with other STEM students, which supports that social interaction plays a key role in retention. These positive relationships aid in the increased motivation and academic success of students. While such relationships can easily be established at small institutions, larger institutions need to foster community with the STEM major as class sizes are larger and student-instructor interaction is limited. Implementing social events for STEM majors, STEM specific clubs/talks, internship opportunities, research experiences, or mentoring opportunities with faculty would increase student interaction and connections. Ultimately this could lead to increased retention within the major. However, this study focused predominantly on natural science STEM majors, such as those in Biology, Natural Resources and Conservation Management, and to a lesser degree the health science major of Medical Laboratory Science. Students in STEM areas such as engineering, mathematics, and computer science were not included in the study population. As such, the results

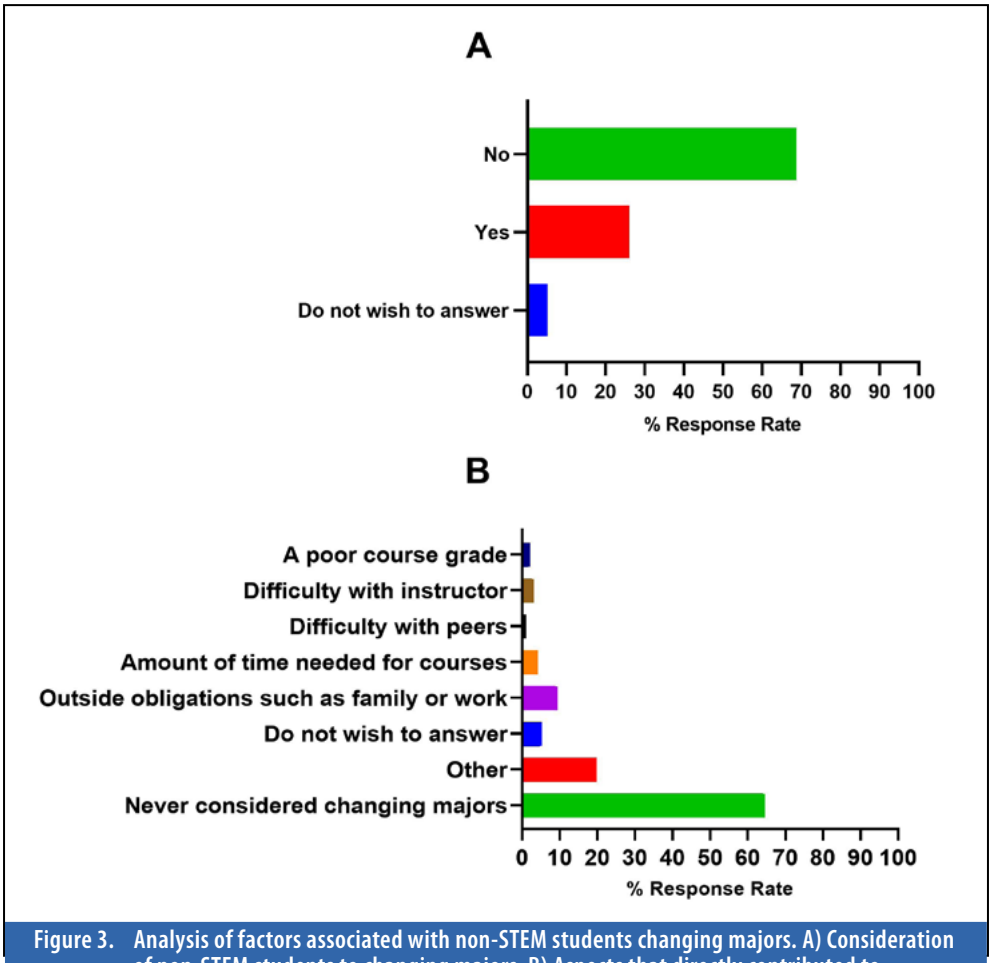

Figure 3. Analysis of factors associated with non-STEM students changing majors. A) Consideration of non-STEM students to changing majors. B) Aspects that directly contributed to consideration of changing majors.

of this study are skewed towards students enrolled in the natural sciences. Future work should specifically analyze trends for students in these areas of STEM.

An interesting finding is that the majority of the non-STEM students surveyed reported not knowing anyone employed in a STEM career. This finding is not due to the education system in the localized area of the institution, as a majority of undergraduate students enrolled are from various parts of the US. This suggests that a lack of STEM career knowledge is endemic and could account for low STEM major selection throughout the US. This highlights the importance of exposure to STEM careers in the high school setting, as this is the time that most students select a college major. Future work should focus on the incorporation of STEM careers into lesson plans, and inclusion of guest speakers or career fairs in the high school setting. As most students begin the major selection process in high school, this is a critical time to expose students to STEM careers. These activities may ultimately increase STEM majors to address the future needs of the growing STEM field.

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