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Original Article

At-Risk Freshmen Student Retention After STEM Intervention

Edna Orozco, EdD[1]; George Padilla, Ph.D[2*]

[1] University of Texas Rio Grande Valley, 1201 W. University Drive, Edinburg, Texas 78539

***Corresponding Author**
George Padilla

ABSTRACT

Background: Science, Technology, Engineering, and Mathematics (STEM) areas are one of the fastest-growing majors in the nation. Engineering is projected to add the second largest number of new jobs from 2016 to 2026 with 140,000 new jobs (Torpey, 2018).According to the National Center for Education Statistics despite all the research done throughout decades to improve the issue of retention in STEM areas about half of the students who pursue a degree in STEM will either leave or change majors.
Purpose: This study aimed to sample at-risk college freshmen students from the College of Engineering & Computer Science, to describe and explain the association between retention after the first year of at-risk college freshmen students in a STEM program and completion of a STEM intervention, to identify the reasons STEM students decided to stay in the program after completing a STEM intervention, and to identify how to improve the STEM intervention.
Method: A Chi-square test of independence was used to find if there was an association between the completion of a STEM intervention and the retention rate of at-risk freshmen students and focus group interviews.
Results & Conclusions: The quantitative analysis, a test of independence X^2 (chi-square)found no statistically significant association between STEM intervention completion and retention. The qualitative analysis provided five themes describing the students' STEM intervention experience was also provided: learning activities and processes, mentorship, sense of belonging, and transitioning from high school to college.

Key Words: *STEM, College, Intervention, Student Progress*

INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) areas are some of the fastest-growing majors in the nation. The STEM labor force represents 23% of the total U.S. labor force, with higher proportions of men (Chen, 2012, 2015; Lukas & Spina, 2022; National Science Board, 2020).STEM careers are among thehighest-paying occupations andmost influential in driving economic growth and innovation in the U.S.(U.S. Bureau of Labor Statistics, 2022; Knox, 2023; Thomasian, 2011). STEM occupations include computer, mathematical, architecture and engineering, life, and physical science occupations as well as managerial and postsecondary teaching occupations related to these functional areas, and sales occupations requiring scientific or technical knowledge at the postsecondary level (U.S. Bureau of Labor Statistics, 2022).

The U.S. science and engineering workforce is critical to the United States to remain competitive as a global economy and sustain the capability to continue technological and innovative advancements (Varma & Freehill, 2010). STEM occupations are considered high contributors to global competitiveness, and communities, and the U.S. may be positively impacted by having an increase in professionals in this area (Hira, 2010).Employment in STEM occupations is projected to increase by 12.5% from 2014 to 2024 (Fayer et al., 2017). Engineering is projected to add the second largest number of new jobs from 2016 to 2026 with 140,000 new jobs (Torpey, 2018).

Despite the rapid growth of student enrollment at university programs, student graduation rates, and ample opportunities in the workforce for college graduates, there is still a need to increase the number of students entering, graduating, and working in STEM fields, especially minority groups such as Hispanics (Archer et al., 2012; National Science Board, 2020; Ruarte, 2018). Even though students enroll in STEM programs at universities, there is a high probability that minority groups, during the first semester or first year of school, will decide to drop out or change majors for varied reasons (Chen & DesJardins, 2010; Chen 2015; Kenaet al., 2013, Lucas & Spina, 2022). A significant number of university students drop out in their freshmen year (Jeno et al., 2018). Decades of studies completed on university retention have concluded that many factors affect attrition rates, graduation rates, and student enrollment (Chen & DesJardins, 2010; Chen, 2015; Chen et al., 2020; Cooper, 2011).

According to the National Center for Education Statistics (NCES) (2017) despite all the research done throughout decades to improve the issue of retention in STEM areas about half of the students who pursue a degree in Science, Technology, Engineering, or Mathematics (STEM) will either leave or change majors. There are still high attrition rates and underrepresentation of Hispanics, minorities, women, and vulnerable populations in STEM education and the workforce. Reports on dropouts in higher education suggest that 25% of students never complete their bachelor in STEM education degree. Only 43% of the students complete their degree within the stipulated time (Jeno et al., 2018).

Low retention rates especially impact minority groups, including Hispanics who are underrepresented in STEM college programs and in the STEM workforce (Davis & Finelli, 2007; Chen & DesJardins, 2010; Chen 2015; Kena et al., 2013, Lucas & Spina, 2022).The lack of diversity and underrepresentation of minorities, especially Hispanics in education and the STEM workforce, is concerning, not only for the STEM careers but also for the growth in global leadership and the global economy for our nation (Bowman & St. John, 2011). Producing enough numbers of graduates who are prepared for STEM occupations has become a national priority in the United States (Chen, 2015; The White House, 2016; The White House, 2022). This priority will not be met with high attrition rates in STEM university programs (U.S. Bureau of Labor Statistics, 2022).

Despite decades of research towards the retention of students in STEM programs, there is little research related to interventions at the university level, especially interventions that aim to help minority groups (Davis & Finelli, 2007; Hite & Spott, 2022; Reena, 2018; Tomasko et al., 2016).STEM intervention programs are used by universities to improve student program completion. STEM intervention programs are quite unique and vary depending on the location the intervention program is established within the university, participant characteristics, funding resources available, and services offered (Rincon & George-Jackson, 2016).

According to Rincon and George-Jackson (2016),a STEM intervention program, as defined by the United States Government Accountability Office, includes one or more of the following objectives:

1. Attract or prepare students to pursue classes or coursework in STEM degrees
2. Provide undergraduate or graduate training in STEM
3. Attract graduates to pursue STEM careers
4. Increase the ability of K-12 or postsecondary institutions to promote education in the STEM fields.

STEM intervention programs aim to create an environment of preparedness and a sense of belonging by:

1) Helping students with feedback on their performance,
2) Creating opportunities to interact and engage with other students, mentors, and faculty,
3) Promote the use and awareness of academic support at the institution. (Hoffman et al, 2016).

Thus, STEM interventions can help to create a sense of clarity for academic expectations, learning communities for students, and exposure to challenges and stressors among other factors that promote a sense of belonging and ultimately student success. Research has shown STEM interventions have a positive impact on student retention (Hoffman et al, 2016; Tomasko et al., 2016; Strayhorn, 2012). Critically, identifying potential improvements to STEM intervention will support universities in effectively allocating their resources and increasing the quality of the future lives of their students, families, and communities.

Methodology

A mixed-methods research study was completed on at-risk college freshmen students in aHispanic Serving Institution(HSI) university at the College of Engineering & Computer Science (CECS). The quantitative part of the research study focusedon identifying if an association existed between at-risk STEM freshmen students completing a STEM intervention and STEM program retention. The qualitative part of the research study consisted of acquiring the perceptions of at-risk college STEM freshmen students who completed the STEM intervention students in focus groups. These students were asked to provide information about how STEM intervention supported their retention and how to improve the STEM intervention. The study received university Institutional Review Board for Human Subjects Research approval.

The following research questions guided the research study.

RQ1: Is there an association between the retention rate of at-risk college freshmen UTRGV CECS students who complete a STEM intervention and similar students who do not complete a STEM intervention?

RQ1 Research Hypothesis, H_1:There is an association between the retention rate of at-risk college freshmen UTRGV CECS students who complete a STEM intervention and similar students who do not complete a STEM intervention.

RQ1 Null Hypothesis, H_o:There is no association between the retention rate of at-risk college freshmen UTRGV CECS students who complete a STEM intervention and similar students who do not complete a STEM intervention.

RQ2a: As perceived by at-risk college freshmen UTRGV CECS students who completed the intervention, how does a STEM intervention impact program retention?

RQ2b: As perceived by at-risk college freshmen UTRGV CECS students who completed the intervention, how can a STEM intervention be improved to support program retention?

The study's population included college freshmen students in a HSI university (95% Hispanic/Latinx) in south Texas. CECS had a 1620 student enrollment during the 2021-2022 academic years including 484 students identified at-risk by the university. The retention rate for allfull-time freshmen students in the study's university's CECS in Fall 2020-Spring 2021 was 76.6%.

CECS offered a voluntary one-week STEM intervention that included five days of activities as shown in Table 1:

Table 1: STEM Intervention Activities

Activity	Learning Objectives	Skills	Assessment
Monday: Demolition Derby	Resourcefulness Time Management Finding Alternative Plans Open Mind Listening to Others	Creativity: the ability to generate ideas that are novel, varied, abundant, and functional.	Ideation Metrics: developed by Vargas Hernandez et al. the metrics are quantity, quality, novelty, and variety.
Tuesday: Blade Design	Strategizing Considering Multiple Factors Taking Informed Decisions Explaining Decisions Communicating Alternatives	Decision Making: Ability to organize info, define options, evaluate choices, and tradeoffs, and communicate decisions.	Self-efficacy student surveys: students will evaluate their perceptions.
Wednesday Reverse Engineering	Problem Framing Effective Communication of technical ideas to non-engineers; Writing Skills Conflict Management	Problem Framing: the ability to understand, define and prioritize complex problems.	Peer Reviews: students will evaluate their work, individually and as a team.
Thursday: Blast Off	Safety Considerations Prioritization of Information Project Management Delegating Deadlines and Responsibility	Project Management: the ability to break a problem into tasks and schedule them to meet a required deadline.	External Reviews: faculty and senior students will be invited to provide real-time direct feedback to students on their project plans.
Friday: Drone Task	Design Creativity Literature Review Time Management Conciseness Presentation Skills	Oral Communication: the ability to deliver an effective and engaging presentation.	Evaluation Rubrics: Faculty and TAs will use these rubrics to evaluate student presentation skills.

(Marquez et al., 2022)

An email was sent to the 484 at-risk students asking if they wished to participate in the STEM intervention. One-hundred-twenty-two (122) students chose to participate, although not all participated and/or completed the intervention.Thus, the 484 CECS at-risk student data yielded three student subgroups (Figure 1) :

(1) Students who agreed to participate and COMPLETED STEM intervention (COMP),
(2) Students who agreed to PARTICIPATE and did NOT COMPLETE the STEM intervention (PNCOMP),
(3) Students who did NOT PARTICIPATE and did NOT COMPLETE the STEMintervention (NCOMP).

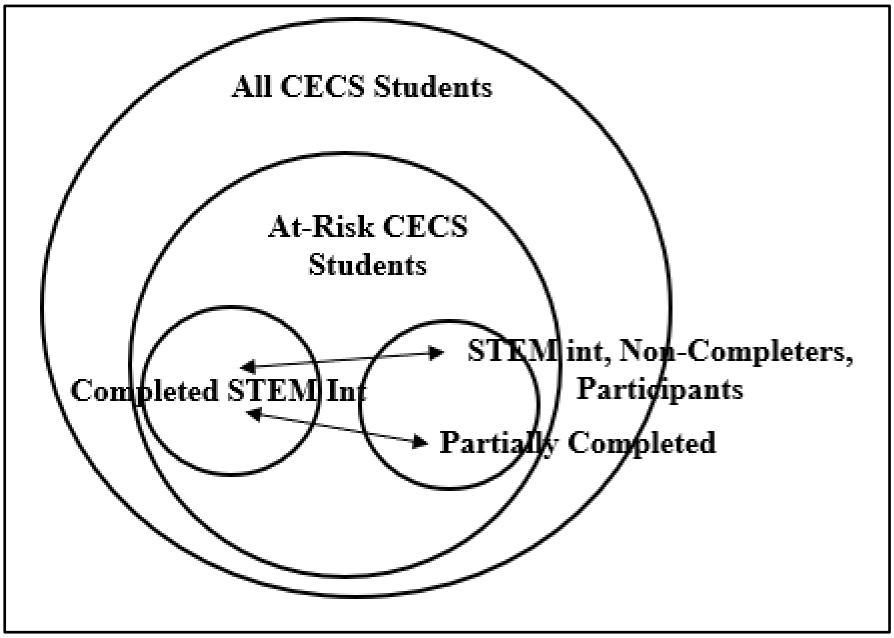

Figure1: Student Population in the Research Study

These subgroups provide an opportunity to assess if completion of the STEM intervention supported a greater increase in student retention.

FINDINGS AND DISCUSSION

Table 2 includes the number of students in each subgroup and their retention rates.

Table 2:Count and Percent Retained by Group

		Not Retained	Retained	Total
COMP	Count	12	38	50
	Percent	24.0	76.0	100.0
NCOMP	Count	121	278	399
	Percent	30.3	69.7	100.0
PNCOMP	Count	13	22	35
	Percent	37.1	62.9	100.0
All	Count	146	338	484
	Percent	30.2	69.8	100.0

Table2shows STEM intervention completers (COMP) had the highest retention rate (76.0%), followed by students who did not participate and did not complete the STEM intervention (NCOMP, 69.7%), and finally, the students who participated and did not complete the STEM intervention (PNCOMP, 62.9%). The data clearly shows that STEM intervention completers had a much higher retention rate than the other two subgroups.COMP had a similar retention rate (76.0%) compared to the previously cited overall retention rate of all CECS full-time freshmen students (76.6%)during the 2021-2022 academic years including students not identified as at-risk.

A Chi-square test of independence (X^2)was used to compare retention rates of the three student subgroups. The null hypothesis was assessedat the 0.05 level of significance. The results show therewere no significant relationships between any of the subgroups:

- COMP and NCOMP, X^2 (1, N=449) = 0.853, p = .0.356);
- COMP and PNCOMP, X^2 (1, N=85) = 1.713, p = 0.191);
- PNCOMP and NCOMP, X^2 (1, N=434) = 0.701, p = 0.403).

In summary, the Chi-square test of independence (X^2) results showed no statistical significance between any of the subgroups studied, although STEM intervention completers did experience a higher retention rate than the other two groups. Thus, no association between STEM intervention completion and retention of at-risk college STEM freshmen students was supported by this study's data and results, and the study's null hypothesis was not rejected. However, it is important to note the Chi-square test includes limitations. One limitation is that it is very sensitive to sample size (McHugh, 2013). Since the population size of the NCOMP was almost eight times larger than COMP, this large difference in group sample size may have limited identifying association. Another Chi-square test limitation is that an individual cannot fit in more than one category (McHugh, 2013).This latter limitationwas accommodated by separating the PNCOMP students into their own subgroup for analysis.

To complete the qualitative part of this study,the 50STEM completers were emailed a questionnaire asking if they wished to participate in the interview part of the study. One semi-structured focus groupand two individual interviews were completed: 15 total COMP students were interviewed. The interview questions focused on their feelings about their STEM intervention participation, whether the STEM intervention provided them with a sense of belonging, why they stayed with the STEM program, and how could the STEM intervention be improved. After the interview data was collected and transcribed, open coding (Ravitch & Carl, 2021). Analysis of qualitative data was done to establish categories and themes with supporting evidence from the focus groups results are shown in Table 3. This process was done with NVivo software, followed by triangulation with two STEM instructors.

Table 3: NVivo Codebook

Code	Description
University Anxiety	Student transitions from high school lo university with a sense of anxiety due to the changes of school
Sense of belonging at the university	The student believes they belong to a university
Parent Support	The student has support from parents, financially, psychology, when entering university
Program Uncertainty	The student is not very familiar with the program or bachelor
STEM background	Student presents some knowledge in the area of STEM
University Environment	Student does not understand the dynamic of the university
University Comfort	Student feels comfortable navigating through the university
First Day of School Feelings	Student feelings on their first day of school
Loneliness	Students experience a feeling of not knowing other students
STEM Degree familiarity	Student understands the coursework needed for a STEM Degree
Academic Rivalry	Student feels a sense of competing academically with other students
Lack of Faculty Trust	No relationship between Faculty and Incoming STEM students
Lack of knowledge of the university	Student does not know the different services available at the university for students
Sense of belonging in a new group of people	Student experiences a sense of belonging when part of the STEMintervention
Mentorship	Student receives structure and help from a mentor in the STEM intervention
Self-confidence addressing faculty	Student feels self-confident to approach faculty after STEM intervention
Lack of Student Connections	Students do not interact with college students due to taking core courses instead of engineering courses
Core curriculum advantage	The student earned about two years of the core curriculum while in high school
Gender Disparity in STEM programs	Lack of women representation in STEM program
Student Organization advantage	Students develop a sense of comradeship while being part of a student organization
English Language Learner disadvantage	Students first language is other than English

Five main themes were identified.

1. Projects & freedom: Students appreciated the fact that they were allowed to ―think outside the box" while working on projects in groups. They believed that hands-on projects were challenging butsparked their interest in engineering. The difference between the STEM intervention and regular coursework was that regular coursework made students feel a disconnect. Regular coursework does not allow that much freedom. The students did recommend they be given time to debrief, relax, and allow their minds to rest after a project, ―Sometimes the STEM intervention was overwhelming." They also recommended extending STEM intervention from one to two weeks. Students identified the following supports in STEM intervention:
    a) Knowledge and skills, academic preparation;
    b) Performance capability;
    c) Motivation, values, and self-concept;
    d) Rewards, recognition, and incentives;
    e) Tools, environment, and processes; and
    f) Expectations and feedback.

These six categories are specifically supported by past researchers (Araque et al., 2009; Hardy & Aruguete 2014; Reena, 2018)

2. Mentorship: Students in the STEM intervention made connections with faculty, student organizations, graduate students, and themselves, incoming freshmen. The strongest bond happened between STEM intervention participants and graduate student mentors. Students stated how it felt easier to approach these mentors than faculty, and how the relationship student-mentor felt more natural, compared to having to ask faculty for advice in higher education.However, they shared disappointment that the mentorship did not last more than a semester in most of the cases.
3. Sense of Belonging: Students believed that during the STEM intervention, they had a group of people to support them, who made them feel welcomed. One student shared: ―Your activities got us into talking. So, we can break the ice, you know. Sometimes we are so quiet because nobody says anything. But when somebody starts talking and starts directing an activity then we do talk. We break the ice."However, when the regular school year started, they felt alienated from their core curriculum courses and CECS. Also, these students who participated in the STEM intervention felt they did not have a sense of belongingin the Engineering program because they had no experience or knowledge in the field compared to the upper-level students who had already been in the program. As Baumeister and Leary (1995) stated, human beings need to form and maintain at least a minimum quantity of lasting, positive, and significant interpersonal relationships, otherwise, lack of this need ends up in detrimental well-being. STEM intervention allowed students to create relationships.
4. Family and Higher Education: Students in this program showed a level of importance to family and education. Even though some students received acceptance into other programs and universities, their final decision came down to being close to family and to the resources available locally. Family playsa significant role in these students' lives. Students who decided to attend CECSshared how they were seeking that feeling of being close to or almost at home: ―So, I live on campus, and I go home like every weekend. So, it's really nice to be on your own, but also be here next to your family."
5. Transitioning from High School to Higher Education: Students interviewed understood that the engineering discipline is not easy. Transitioning from high school to higher education was not easy either. Students mentioned how, in their first year, they either thought about changing their majors or quitting higher education. However, family, friends, faculty, mentors,and personal resilience made a difference. Students mentioned how their future was uncertain, but small changes could make a difference to the present, and maybe then it would have an impact on the future: ―So, in my second semester here I was thinking about dropping out or changing majors. but I have that mentality of just kind of go with it. See how it goes, and the more I continued, the more I said, yeah, I am gonna stick to engineering. And since I like to work with my hands, I felt staying with mechanical engineering was my best bet."

In response to finding recommendations for the STEM intervention, several items were discussed:

1) Mentors: Students agreed that mentors were crucial to gather advice and information on higher education. They recommended employingmentors who are students who are not about to graduate. Some participants provided their information so they could be mentors for the upcoming STEM intervention in the summer of 2023.
2) Grouping of Students: Participants were well divided with several students preferring to be grouped with students in their same major, while other participants preferred grouping with students with different majors. The reasons some participants preferred to be grouped with the same major included starting to know those people who in the future will be in the same engineering courses, have similar likes, and even a similar major. Participants who preferred to be grouped with other majors wanted to get to know other people in engineering and begin increasing their networking in engineering.
3) Time management of the projects: Students felt somehow overwhelmed by the structure of the STEM intervention projects, to the point that there was no resting time, except for lunch. They felt that it was a constant stress going over and over different projects. Their advice was to pick fewer projects and to make them a two-day project instead of an hour project. According to the students, this was going to bring a sense of challenge, but with less stress. Some of the feedback the participants shared included having sports integrated so they would be able to relax their minds from so much fast-paced engineering.
4) STEM intervention duration: The majority of the participants wished the STEM intervention would last more than one week. They recommended two weeks. Some participants recommended STEM intervention follow-ups in the middle of the semester. Students who participated in the STEM intervention were boosted with energy to start their semester; however, they felt lonely, and not belonging to engineering or higher education towards the middle or end of the semester. They recommended STEM intervention reach out to them and check on them, maybe not for a whole STEM intervention week, but for some time to talk about their semester, their struggles, and their thinking. They strongly suggested this follow-up could be done by engineering students, rather than by faculty.

CONCLUSION

This mixed study investigated whether a statistically significant association between STEM intervention completion and the retention rate of at-risk college engineering freshmen students existed, the reasons at-risk STEM students decided to stay in the program after completing a STEM intervention, and ways to improve the STEM intervention to support engineering program retention of at-risk college freshmen engineering students. In the quantitative analysis, a test of independence X^2 (chi-square)found no statistically significant association between STEM interventioncompletion and retention. Testing limitations may have affected the statistical results. Nonetheless, STEM intervention provides an avenue to distinctly increase student retention, albeit not to a statistically significant level. Qualitative analysis provided the opportunity to understand reasons why students decided to enter the Engineering program at this college rather than at another college—close to family. Five themes describing the students' STEM intervention experience were also provided: learning activities and processes, mentorship, a sense of belonging, and transitioning from high school to college. Participants also provided information about why they decided to remain in the STEM program past their first year and how the STEM intervention impacted their journey in their first year in higher education. They also suggested four STEM intervention improvements.

There are multiple opportunities to continue studying this topic since there are few studies specifically focused on STEM interventions in higher education (Hite & Spott, 2022; Reena, 2018; Tomasko et al., 2016). Research and publication on this topic are relevant and in need. Producing enough numbers of graduates who are prepared for STEM occupations has become a national priority in the United States (Chen, 2015; The White House, 2016; The White House, 2022). Hence, future research on how to retain these students in STEM programs has great potential to support this national priority.

While any university STEM program can improve its STEM intervention based on the findings in this study, future research could work toward finding a larger number of students completing the STEM intervention comparable to the number of students who did not complete the STEM intervention to minimize possible population statistical testing size effect. Future research can also focus on an association between longer than one-week STEM intervention completion and retention of at-risk students. Moreover, future research canfurther focuson other student populations, such as first-year students, first-generation students, low socioeconomic status students, females, other minority students, and other student groups that need greater support in college STEM program retention. Finally, future research studies could focus on why students decided to drop out and how to help them returnto the STEM program. Student retention in STEM programs provides a great opportunity for future studies because of its potential impact on the future of students, communities, the U.S. national economy, and the U.S. international economic standing.

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