# Addressing Challenges of Community and Academics for CS Pre-Majors: CS Redshirt Program

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***Abstract*—Mirroring the trend of the growth of Computer Science (CS) programs nation and worldwide, the CS program in the College of Engineering at Tennessee Technological University has experienced similar growth in the number of students enrolling in its B.S., M.S., and Ph.D. programs. This growth of enrollment in CS has been accompanied by a growth in another student population at the university that is often overlooked: Interdisciplinary Studies - Interest in Computer Science (ICSC) majors. This population represents students who have qualified for admission at Tennessee Tech, but have not qualified for entry into the CS program. Indeed, just as the freshman class of CS has grown 44%, the ICSC program has grown 63%.**

**To address the problem of retention and migration into CS from ICSC, we have developed the *pre-CS Redshirt* program, which is aimed at providing increased advising, peer mentoring, tutoring, and connections to faculty. Launched in Fall 2020, the challenges facing these students have been compounded by COVID-19. In order to study initial effectiveness, we measured Fall-Spring retention, comparative GPAs for students in the CS and ICSC programs, and conducted a survey of students to measure students' sense of belongingness with the measured population including students of all levels currently enrolled in the CS program as well as the *pre-CS Redshirt* students.**

***Index Terms*—computer science, retention, engagement, mentorship**

## I. Introduction

Since 2016, the Department of Computer Science (CS) in the College of Engineering at Tennessee Technological University has experienced a sharp growth in the number of students enrolling in its B.S., M.S., and Ph.D. programs. Particularly, the B.S. program has grown from 364 students in Fall 2016 to 533 students in Fall 2020. Much of this growth has been driven by the growth in the freshman class, which rose from 79 students in Fall 2016 to 140+ students in Fall 2020. This growth of enrollment in CS has been accompanied by a growth in another student population at the university that is often overlooked: Interdisciplinary Studies – Interest in Computer Science, or ICSC. This population represents students who have qualified for admission at Tennessee Tech, but have not qualified for entry into the CS program due to the admission standards related to GPA and standardized test scores. Indeed, just as the freshman class of CS has grown 44% since 2016, so to has the ICSC program grown (up 63% in the same period).

To appreciate the differences between the CS population and the ICSC population, one must consider the relative retention rates of these students. The CS university one-year retention rates (i.e., students retained in the university but not necessarily in Computer Science) in the years 2016 – 2018 were 78%, 73%, and 74%, respectively. In contrast, the one-year ICSC university retention rates were 48%, 67%, and 76%, respectively in those same years. However, the retention rates into any major were only 22%, 33%, and 48%, respectively, with only 7%, 0%, and 4% migrating into CS after one year, and 15%, 13%, and 8%, respectively, eventually migrating into the CS program. This remarkable difference in student retention is alarming. However, the story does not end there. Further examination of these two populations also reveals that the ICSC population is far more diverse than the CS population, whereas the CS program is roughly made up of 20% non-white students, the ICSC population is approximately 45% non-white.

The experience of the ICSC student can best be described by the word disqualification. Besides being disqualified from the CS program, these students face many other barriers. For instance, being disqualified from the CS program and the College of Engineering also disqualifies these students from living in the freshmen dorms intended for engineering

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students. In addition, due to federal regulations on Course Program of Study (CPoS), these students are disqualified from certain forms of financial aid when they have to take remedial courses to qualify for the CS program. Finally, disqualification means ICSC students are not included in various mailing lists and other forms of departmental contact, inviting them to student club meetings, department-sponsored events, and other similar community-building activities.

Knaphous-Soren et al. [1] described ongoing work at six universities that are part of a consortium of *Redshirt in Engineering* programs after which our own program is similarly modeled. The term "*redshirt*" is drawn from college athletics and refers to the extra year of preparation or eligibility often granted to student athletes. In this paper, we describe our instantiation of the effort, which includes a focus on building connection to the CS community, preparation and development of the students, and institutional support structures (including access to stipends for students that participate in the program). In addition, we report on the impact of the program on the sense of belonging [2]–[5], and provide initial results on the success of the students. This paper is structured as follows. Section II reviews background and presents related work. The program is described in Section III and provides an overview of some of the methodologies used in the design of our support elements.

## II. Background and Related Work

### A. Context

The *pre-CS Redshirt* program is meant to support students who are admitted into the university but do not qualify for admission into the College of Engineering and Department of CS. Our goal is to successfully migrate *pre-CS Redshirt* students into CS and establish a strong foundation of sustained success. Compared to those students in the main CS program, this group of students is much more diverse and face many roadblocks on their path to success. These roadblocks include:

- Lack of Academic Preparation – students admitted to the university but not admitted to the CS program do not meet one of a few academic qualifications including inadequate skills in mathematics (as indicated by a sub 22 ACT mathematics score) or a high school GPA that was below expected standards (3.0).
- Lack of Connection to the CS Community – *pre-CS Redshirt* students face social roadblocks that limit their connection to the rest of the CS student community. For instance, students in this category do not get invited to live in the Engineering Residence Hall. In addition, since their major is not specifically CS, they do not get regular communications typically sent to majors through institutional e-mail lists.
- Limitations on Scholarships – the *Course Program of Study* (CPoS) regulations govern how state and federal aid is applied toward funding tuition. Students in the *pre-CS Redshirt* category ultimately must use elective credits on remedial courses instead of electives in the major. Typically, students in this population graduate in five years compared to the traditional four, which causes an additional financial strain on these students.

### B. Related Work

Knaphaus-Soran et al. [1] describes a six-university consortium of *Redshirt in Engineering* programs that have been in place since 2009. The participating institutions include University of Colorado-Boulder, University of Washington, Washington State University, Boise State University, University of California-San Diego, and University of Illinois at Urbana-Champaign. Many of the program elements that we present in this paper mirror exactly the elements found in the programs described in [1], including the methods used to recruit students into the program, mentoring, and course work. In their experiences they have been able to achieve success rates ranging from 82% to 99% second year retention. We are finding in our own pilot of this model that we are experiencing the same level of success demonstrated by the aforementioned consortium.

Approaches to measuring belongingness in higher education programs include work by Hoffman et al. [2], Johnson et al. [3], Malone et al. [4], and van Herpen et al. [5]. Each of these works measure belongingness in different contexts to ours, but have in common the notion that belonging happens vertically (between faculty and students) and horizontally (between students), and in both formal and informal contexts. Our approach uses a survey that is most similar to the structure used by van Herpen [5], focusing on the behavior interactions between faculty and staff, and peers, but stresses general interactions rather than those interactions that are impacted by learning or knowledge gained.

## III. Redshirt Program

In this section we describe the *pre-CS Redshirt* program at Tennessee Technological University including the program goals, the structure of our program, and methodologies employed.

### A. Program Goals

The *pre-CS Redshirt* program has three primary goals: *retention* of *pre-CS Redshirt* students, increased *diversity* of the CS program, and long-term *success* of the students.

*a) Academic Success and Retention:* Table I summarizes statistics on the retention and migration patterns of students in the ICSC program In 2016, 27 students began in ICSC program, with 8 (30%) being retained in the first year and 2 (7%) migrating into CS in that same time period. For this cohort, a total of 4 (15%) of the original 27 students migrated into CS. In the subsequent cohort of 2017, 24 started, 8 (33%) were retained in the first year, and 3 (13%) migrated to CS. In 2018, 25 started, 13 (52%) were retained in the first year, but only 2 (8%) had migrated to CS after 3 semesters. Our goal is to achieve improved migration into the CS program after the first year and beyond by providing increased academic interventions and social-support structures.

| Year | Declared ICSC | 1-year retention | 1-year migration | Total migration |
|---|---|---|---|---|
| 2016 | 27 | 8 (30%) | 2 (7%) | 4 (15%) |
| 2017 | 24 | 8 (33%) | 0 (0%) | 3 (13%) |
| 2018 | 25 | 13 (52%) | 1 (4%) | 2 (8%) |

TABLE I
RETENTION STATISTICS AT TENNESSEE TECH FROM 2016–2018

*b) Community and Diversity:* Students entering the ICSC are a far more diverse group than students entering directly in the CS program. Addressing the needs of the ICSC Redshirt students will impact the diversity of the CS program. In addition, by introducing these students into the CS community earlier (i.e., upon entry to the university instead of just upon their migration into the program), the experience of the students directly entering the CS program will be enhanced. That is, the CS program becomes more diverse by including the ICSC students in all of the events and opportunities afforded to CS majors.

*c) Student Success:* We are interested in ensuring that students that participate in this program are provided full access to the degree program by ensuring that pre-requisite remedial courses that they must enroll in do not create limitations in the future elective courses available to them. Student success is not just defined by whether students enter the program or are retained in the program or not. It is a holistic measure that also ensures that the knowledge gained is relevant to future careers, and whether the students graduate as debt-free as possible. We are interested in establishing corporate partnerships and seeking individual donors to create scholarships allowing students to complete the extra *pre-CS Redshirt* year without foregoing elective credits on remedial courses.

### B. Program Description

The *pre-CS Redshirt* program aims to meet the goals described in Section III-A by focusing on four key areas:

1) Course Work
2) Academic Advising
3) Academic Support through mentoring
4) Financial Support

These elements closely mirror the program elements described by Knaphaus-Soran et al. [1] and are presented below.

*a) Course Work:* Tennessee Tech has a first-year *Connections* course that is focused on helping students make the adjustment to life and study on campus. Historically, students admitted into the CS program were placed in a version of the course tailored for engineering majors while the *pre-CS Redshirt* students were placed in a university-level course without a tie to specific majors. This separation from the course tied to majors was a significant barrier to fostering belongingness to the program. Over the past few years we have transitioned from having CS students be embedded amongst other engineering majors towards having CS-only sections. Starting with the most recent incoming class we have also made the step to move *pre-CS Redshirt* students into a specialized section specifically for ICSC majors. Starting in Fall 2021, the *pre-CS Redshirt* population will be fully integrated into the CS-specific sections in order to fully acknowledge their membership in the departmental community.

The course itself focuses on a number of topics relevant to first-year students including *on-boarding* into university life, initial *career* preparedness, *exploration* into the major (including an overview of CS disciplinary concentrations), and engagement in *project-based* learning with a small collaborative project.

*b) Academic Advising:* Academic advising at Tennessee Tech has been moving towards a centralized model that has all students advised in a university-level student success center that will be effective in Fall 2021. Prior to this, students were generally advised by academic advisors housed in the college of the major. However, for students in the ICSC program, advising was housed first in the College of Arts and Sciences and more recently in the College of Interdisciplinary Studies. This structural difference was significant in that the channels of communication between the department and these academic advisors was minimal. With the launch of the *pre-CS Redshirt* program, explicit communication between these advisors and the department was established as part of a move of advisors into the university student success center. The advisors were then trained about specific needs and concerns that are relevant to the *pre-CS Redshirt* students in order to better support the migration of these students into the CS program proper. The academic advisors were also integrated into the program's mentoring structure, as described in Section III-C.

*c) Mentoring:* Informally, our water cooler conversations focus on the outcomes associated with failure to migrate from the ICSC pre-major program into the CS program. Specifically, the general consent seems to focus on providing more academic support that focuses on the lack of academic success associated with the *pre-CS Redshirt* students. We, instead, have chosen to emphasize our implementation of the *pre-CS Redshirt* program is upon community through the use of *peer mentors* rather than adding yet another peer tutoring program.

We recruit peer mentors from amongst our current computer science population, with our recruitment of these students being focused upon those with demonstrated levels of success both academically and in community-level activities (such as participation in extra-curricular activities). We also use a *tiered* mentoring approach whereby program coordinators, academic advisors, and faculty are involved in mentoring both in group settings and one-on-one. For group sessions, we employ the use of *Agile Retrospectives* [6] whereby teams of peer mentors review the successes, challenges, and issues raised during their mentoring sessions. For our one-on-one mentoring sessions (both between peer and *pre-CS Redshirt* students and staff/peer mentor interactions) we trained mentors on the use of a modified *Powerful Questions* approach [7]. The approach focuses on five key areas (i.e., intent, rapport, openness, listening, and empathy) and enables mentors to

conduct conversations in meaningful ways so as to build strong connections with their mentees.

*d) Comprehension-Based Tutoring:* One of the biggest academic challenges for *pre-CS Redshirt* students is also the same challenge that first-year CS majors face: success (or rather, lack of success) in mathematics courses. Currently, the Department of Mathematics and the College of Engineering Student Success Center provide access to a number of support systems aimed at supporting students including *supplemental instruction*, *mathematics support laboratories*, and standard tutoring. Supplemental instruction [8] and other tutoring approaches have long been used in higher education. In order to complement these existing approaches, we chose to train our peer mentors to provide *comprehension support* [9], [10] instead of specific disciplinary support. That is, we developed a technique for helping *pre-CS Redshirt* students systematically approach problem solving rather than mechanics and methodologies for different technical disciplines. This approach provided a mechanism for our peer mentors to provide academic tutoring without needing expertise in various technical disciplines and alleviated concerns of our mathematics colleagues over consistency and alignment of approaches being taught in courses. The technique is affectionately called "SPOCK", which is an acronym for the following steps of a process adapted from [11]: a) *Survey* the problem, b) Break the problem into *Parts*, c) Solve the problem *One* part at a time, d) *Check* your results, and e) *Know* where to find additional help. Anecdotally, our peer mentors were far more confident in their tutoring of *pre-CS Redshirt* students using this approach as some also had a history of struggling in mathematics but could certainly talk through the process in helping others verbally process what was meant by questions being solved. Interestingly, as we communicated with potential peer mentors regarding our intent to use a comprehension support methodology rather than traditional tutoring, the size of our pool of peer mentor candidates increased. As we continue to use this approach we intend to further study the effectiveness of this approach to tutoring as well as other associated impacts.

### C. Methodologies

To support the program, we employed a number of approaches in preparation, recruiting, and training of *pre-CS Redshirt* students.

*a) Personas and Pre-Orientation Contact:* In preparation for academic advising and recruiting, we used *design personas* as a way to better create pathways for students in our program [12]. A *persona* in this context is a profile of a fictional person that is used as an archtype for potential students. For our purposes, personas provided the mechanism for understanding the backgrounds and eventual course loads for *pre-CS Redshirt* students. In addition, these personas allowed us to lay the ground work for communicating expectations to students as they enter our program. This approach has the potential for being effective for all of our students but was especially useful for *pre-CS Redshirt* students as they are often surprised by the curricular pathways when they learn that the program can take longer than the typical 4-year degree program.

*b) Recruiting:* Students in the *pre-CS Redshirt* program are placed into a section of the aforementioned *Connections to Computing* course and provided instruction relevant to their pathway. In this course, students are informed of the key aspects of the *redshirt* program, and provided an opportunity to *opt-in* to the mentoring and tutoring programs. The benefits and expectations of the program are also communicated in writing in the form of an *award* letter provided to the student.

## IV. Results

In this section we describe the results of implementing the project at Tennessee Technological University, including levels of attainment in retention, sense of belonging, and support.

### A. Retention Goal

The primary goal of the program is to support students in their efforts to migrate from the ICSC program into the CS program. We measured the success of these efforts through traditional metrics of grade point average (GPA) and projected retention in the program as determined by whether students have enrolled for the Fall semester after first entry. For the pilot program, we tracked the success metrics for *pre-CS Redshirt* students, ICSC first-year majors that opted-out of the program, and regular CS major first-year students. Table II summarizes the academic success rates of the three populations. Specifically, the table shows that while the *pre-CS Redshirt* students had a lower average GPA than the regular population, it did have a higher average GPA over the students in the ICSC population that opted-out of the *pre-CS Redshirt* program. In addition, of the three populations, the *pre-CS Redshirt* students are projected to have a higher Fall-to-Fall retention rate and that the retention rate of this population is higher than the historical retention rates from Table I. In addition, the overall ICSC retention rate (i.e., combining the opt-in and opt-out students) is roughly 77%, which is far above the traditional rates.

| Population | $n$ | Avg. GPA | GPA $> 2.5$ | Projected Fall Retention |
|---|---|---|---|---|
| Redshirt (opt-in) | 17 | 2.65 | 10 (59%) | 14 (82%) |
| ICSC (opt-out) | 9 | 1.98 | 2 (22%) | 3 (33%) |
| Regular CS | 113 | 2.96 | 85 (%75) | 80 (71%) |

TABLE II
RETENTION DATA FOR *pre-CS Redshirt*, ICSC, AND REGULAR CS

In examining these results, we make note of the fact that the students achieved these levels of success during the academic year most greatly impacted by COVID-19. It is also worth noting that the non-*pre-CS Redshirt* students were required to enroll in the same *Connections* course mentioned in Section III-B, with the ICSC opt-out students being placed with *pre-CS Redshirt* students. The non-*pre-CS Redshirt* students, however, did not have access to the peer or faculty mentoring, and did not receive stipends related to the program. More to the point, the *pre-CS Redshirt* students were the beneficiaries

of targeted advising, peer and faculty mentoring, and participation stipends.

### B. Community

The second barrier mentioned in Section II was access to the CS community. While we are still unable to have the *pre-CS Redshirt* students housed in the Engineering residence hall, we were able to provide connections to peer mentors as our main instrument for affecting a sense of belongingness.

*a) Survey:* To evaluate community and belongingness in the the CS department, we conducted a belongingness survey [2] that most closely models the variant proposed by VanHerpen [5]. In particular, our survey consists of 29 questions related to interactions with faculty and staff, formal interactions with peer students, informal interactions with peers, and belonging. The questions used in the survey are shown in Figure 1 and are partitioned according to the behavioral interactions (faculty, formal peer, informal peer) and belongingness. Responses were measured using a 5-point Likert scale ranging from *strongly agree* to *strongly disagree*. The survey was released to our internal social networks and via e-mail. Students (participants and control groups) could elect to opt-out from the survey. The control groups consisted of non *pre-CS Redshirt* first-year students, sophomores, juniors, and seniors. The distribution list was approximately 500 students, from which we received approximately 90 responses, for a return of approximately 18%.

Table III shows the calculated mean and standard deviation for each of the population subgroups. Included in the table is the size of each of the measured cohorts in the overall sampling. Of particular note is the differences between the *Redshirt* and *First-Year* columns. Specifically, these populations of students are comparable with respect to time in the program and interaction opportunities, outside of having access to peer mentors. In general, the average responses for *pre-CS Redshirt* students is higher than their first-year counterparts. In addition, the trend of the *pre-CS Redshirt* student responses are mostly higher than or comparable to the average responses of the other populations.

| | Cohorts | | | | |
|---|---|---|---|---|---|
| Interaction | Redshirt n = 12 | First-Year n = 18 | Sophomore n = 16 | Junior n = 16 | Senior n = 28 |
| Faculty Staff | 3.91 (0.56) | 3.70 (0.34) | 3.85 (0.46) | 3.86 (0.48) | 4.08 (0.37) |
| Formal Peer | 3.10 (0.75) | 2.92 (0.78) | 3.16 (0.74) | 2.88 (1.01) | 3.39 (0.87) |
| Informal Peer | 3.39 (0.67) | 3.14 (0.40) | 3.21 (0.65) | 3.07 (0.49) | 3.41 (0.49) |
| Belonging | 3.78 (0.61) | 3.45 (0.57) | 3.34 (0.66) | 3.08 (0.91) | 3.76 (0.40) |

TABLE III
SUMMARY OF MEANS (STANDARD DEVIATION) OF RESPONSES BY EACH POPULATION

*b) Analysis:* To better understand the differences observed in Table III, we conducted a multivariate analysis of variance (MANOVA), with the survey responses in the categories of faculty/staff interactions, formal peer interactions, informal peer interactions, and belongingness forming our independent variables, and the *population* groups of *Redshirt, First, Sophomore, Junior*, and *Senior* years forming our dependent variable. Our null hypothesis (there is no difference between the groups of means of the populations with respect to behavioral interactions and belongingness) was tested across the independent variables in aggregate as well as in smaller permutation sets.

Across all of the different permutations, we observed a statistically significant effect amongst the formal peer interaction behaviors and belongingess. As shown in Table IV the $p$ values under each of the metrics of *Wilk's lambda*, *Pillai's trace*, *Hotelling-Lawley trace*, and *Roy's greatest root* were less than $0.05$. In addition, we performed an Anova test of *belonging* (independent variable) and *population* (dependent variable) and found a significant effect, with $p = 0.038$ (see Table V).

| Population | Value | Num DF | Den DF | F Val | Pr > F |
|---|---|---|---|---|---|
| Wilks' lambda | 0.79 | 8.00 | 160.00 | 2.47 | 0.02 |
| Pillai's trace | 0.22 | 8.00 | 162.00 | 2.50 | 0.01 |
| Hotelling-Lawley | 0.25 | 8.00 | 111.99 | 2.46 | 0.02 |
| Roy's greatest root | 0.14 | 4.00 | 81.00 | 2.84 | 0.03 |

TABLE IV
MULTIVARIATE LINEAR MODEL RESULTS

| | df | sum sq | mean sq | F | PR( > F) |
|---|---|---|---|---|---|
| Population | 4.0 | 5.74 | 1.44 | 2.67 | 0.038 |

TABLE V
ANOVA TEST - BELONGING (IDV) AND POPULATION GROUPS (DV)

The results in Tables IV and V validate that the formal peer interaction behaviors and belongingness variables provide measures suitable for differentiating between the populations. However, our fine-grained analysis seeks a different result. Specifically, is the sense of belongingness for *pre-CS Redshirt* students different than the other populations in the program? To answer this question, we performed a Pairwise Tukey analysis with the intent of showing that no differences exist between *pre-CS Redshirt* students and the other populations. Table VI shows the results of the pairwise comparison of the each of the populations. Of note in these comparisons is that there is no significant difference between the sense of belonging between the *pre-CS Redshirt* students and each of the given peer populations.

*c) Threats to validity and Discussion:* The study of belongingness was performed during the middle of the global pandemic of 2020. As such, the sense of belonging in the control populations, especially for first year students that began their college careers online, and sophomore students that had only one full semester with a face-to-face education before moving to the online modality, may have been impacted greatly. While the sample size of each group exceeds the number of dependent variables, the group sizes could stand to be larger.

**Faculty/Staff Interactions**
I have a positive relationship with at least one of my professors in the major.
I know the names of my professors.
I seek my faculty mentor's help if I have a question.
I can easily go to my faculty mentor if I have comments or questions.
I seek my academic advisor's help if I have a question.
I can easily go to my academic advisor if I have comments or questions.

**Formal Peer Interactions**
Sometimes I talk to my peer mentor about personal matters.
I talk to fellow students and discuss course material or assignments.
I mainly work alone in major courses (reverse coded)
I mainly work alone in gen-ed courses (reverse coded)
I like getting feedback from fellow students.
I invite fellow students to work together with me on assignments.
I listen to the remarks of fellow students.
I find it difficult to find (a group of) fellow students with whom I can work together.
I think contact with fellow students helps me to get better grades.
I work well together with fellow students.

**Informal Peer Interactions**
I am interested in my fellow students.
I hardly know anyone in my major.
I am engaged with my fellow students.
I invite fellow students to spend time together.
I have attended student group meetings.
I intend to attend student group meetings in the future.

**Belongingness**
I have close personal contact with fellow students.
I feel that my family values are accepted by fellow students.
My appearance (language, accent, looks) is accepted by fellow students.
I feel accepted by fellow students.
I feel that I belong in this major.
I feel that I have someone to help me understand difficult homework problems.
I have someone reliable to get me class notes/assignments if I were to get sick.

Fig. 1. Belongingness Survey Questions (based on [5])

| Pop 1 | Pop 2 | mean diff | p-adj | lower | upper | reject |
|---|---|---|---|---|---|---|
| First | Junior | -0.316 | 0.742 | -1.070 | 0.438 | False |
| First | Redshirt | 0.333 | 0.724 | -0.439 | 1.104 | False |
| Redshirt | Soph | -0.519 | 0.352 | -1.300 | 0.263 | False |
| First | Senior | 0.327 | 0.586 | -0.302 | 0.956 | False |
| First | Soph | -0.186 | 0.9 | -0.899 | 0.527 | False |
| Junior | Redshirt | 0.649 | 0.187 | -0.170 | 1.468 | False |
| Junior | Senior | 0.643 | 0.078 | -0.044 | 1.330 | False |
| Junior | Soph | 0.13 | 0.9 | -0.634 | 0.894 | False |
| Redshirt | Senior | -0.006 | 0.9 | -0.712 | 0.700 | False |
| Senior | Soph | -0.513 | 0.179 | -1.154 | 0.128 | False |

TABLE VI
PAIRWISE TUKEY ($\alpha = 0.05$)

We had expected there to be some impact of the faculty/staff interactions upon the sense of belonging for students, but believe that our lack of results have more to do with our inability to formalize the mentoring interactions between faculty and participants than anything else. This was impacted, again, by the university's response to COVID-19 as we were unable to conduct a pre-program workshop to prepare faculty for their roles as mentors.

### *C. Student Support*

Upon completion of each semester in the program, students were awarded stipends to help offset costs incurred from having to enroll in elective courses outside of their programs of study. The initial stipends awarded were provided through a Tennessee Board of Regents Student Engagement, Retention, and Success Grant. As these students initially entered the university in the ICSC program, this support is likely the only university level scholarship or stipend awarded to them. The

department established a scholarship program supported by corporate gifts and we intend on increasing our partnerships in order to arrive at long-term sustainability of the program.

## V. Conclusions and Future Investigations

The *pre-CS Redshirt* program at Tennessee Technological University was developed in order to create a more viable pathway for students accepted into the university but not into the College of Engineering. This previously underserved population is a much more diverse population than our traditional CS population. By creating a support structure that better serves this population of students, we provide broader access to computing degrees, and ultimately computing careers, to students that have been previously unreached. Our success rate in recruiting participants into our initial pilot of this program is much smaller that we had hoped to originally implement, which we believe is due to being launched in the middle of the global COVID-19 pandemic of 2020. In particular, we had a much smaller incoming class of ICSC students than one might expect, given our most recent history of enrollment growth. As we scale the program to a greater number of students, it is our intent to study how the approach can be extended to our traditional population of first-year students.

Our overall results of the program are extremely encouraging, especially in regards to the retention metric (e.g., 82% first-year retention compared to historical retention between 33% and 52%). In addition, our study of belongingness [2]–[5] has yielded a foundation for further study into how we might improve community building within our department. Finally, we have found via conducting retrospective sessions with our peer mentors opportunities for further improvements in creating strong interpersonal bonds, which are likely to lead to creation of learning communities. Our hope is to study the effect of belongingness upon culture within an academic setting using an approach similar to that of Gannod et al. [13].

Across the College of Engineering at Tennessee Technological University, other efforts focused on sister populations in other disciplines are commencing. One such effort will largely mirror the program we have describe here but in the discipline of Civil Engineering. Other efforts will be focusing on the academic outcomes, again in other disciplines. All of these efforts will provide opportunities for us to compare the efficacy of each relative approach.

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## References

[1] Emily Knaphaus-Soran, Ann Delaney, Katherine Tetrick, Sonya Cunningham, Pamela Cosman, Tanya Ennis, Beth Myers, Jana Milford, Donna Llewellyn, Eve Riskin, Janet Callahan, Kevin Pitts, and Michelle Ferrez. Work in Progress: Institutional Context and the Implementation of the Redshirt in Engineering Model at Six Universities. In *ASEE Annual Conference and Exposition*, 2018.

[2] Marybeth Hoffman, Jayne Richmond, Jennifer Morrow, and Kandice Salomone. Investigating "Sense of Belonging" in First-Year College Students. *Journal of College Student Retention: Research, Theory and Practice*, 4(3):227–256, 2002.

[3] Dawn R. Johnson, Patty Alvarez, Susan Longerbeam, Matthew Soldner, Karen Kurotsuchi Inkelas, Jeannie Brown Leonard, and Heather Rowan-Kenyon. Examining sense of belonging among first-year undergraduates from different racial/ethnic groups. *Journal of College Student Development*, 48(5):525–542, 2007.

[4] Glenn P. Malone, David R. Pillow, and Augustine Osman. The general belongingness scale (gbs): Assessing achieved belongingness. *Personality and Individual Differences*, 52(3):311–316, 2012.

[5] Sanne G.A. van Herpen, Marieke Meeuwisse, W. H.Adriaan Hofman, and Sabine E. Severiens. A head start in higher education: the effect of a transition intervention on interaction, sense of belonging, and academic performance. *Studies in Higher Education*, 45(4):862–877, 2020.

[6] Esther Derby, Diana Larsen, and Ken Schwaber. *Agile retrospectives: Making good teams great*. Pragmatic Bookshelf, 2006.

[7] Will Wise and Chad Littlefield. *Ask Powerful Questions: Create Conversations that Matter*. Createspace Independent Publishing Platform, 2017.

[8] Deanna C Martin and David R Arendale. *Supplemental Instruction: Improving first-year student success in high risk courses*. National Resource Center for The First Year Experience, 1992.

[9] Lydia Yang and Bette Grauer. Examining the effectiveness of scholars assisting scholars program among undergraduate engineering students. *ASEE Annual Conference and Exposition, Conference Proceedings*, 2018-June, 2018.

[10] Rolando García, Juan C. Morales, and Gloribel Rivera. The Use Of Peer Tutoring To Improve The Passing Rates In Mathematics Placement Exams Of Engineering Students: A Success Story. *American Journal of Engineering Education (AJEE)*, 5(2):61–72, 2014.

[11] Guide to solving math word problems. http://www.llcc.edu/student-services/cas/helpful-handouts/guide-to-solving-math-word-problems/. Retrieved November 16, 2020.

[12] John Pruitt and Jonathan Grudin. Personas: practice and theory. In *Proceedings of the 2003 conference on Designing for user experiences*, pages 1–15, 2003.

[13] Gerald C. Gannod, Willam F. Eberle, Douglas A. Talbert, Robert A. Cooke, Kathy Hagler, Kathy Opp, and Jasmin Baniya. Establishing an agile mindset and culture for workforce preparedness: A baseline study. In *2018 IEEE Frontiers in Education Conference (FIE)*, pages 1–9, 2018.