Implementing National Best Practices to Improve STEM Retention in a Liberal Arts College Setting

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Introduction

The Foundation for STEM Success (FS^2) program is a model for STEM student success that uses a student-centered approach to academic preparation and learning, and creates an integrated institutional network of supports that increases students' self-efficacy, sense of belonging to their major, and belief in the importance of their contributions to society. These are key factors that affect retention in STEM fields [1]-[7]. The FS^2 program is funded by the National Science Foundation, is focused on engineering and computer science (CS) majors and is designed to improve retention and graduation rates. The FS^2 program is currently in the fourth and final academic year and has engaged 470 first-year engineering and computer science students. The paper describes the main challenges in implementing these retention initiatives in a small college setting and outlines approaches to overcome these challenges.

Goals

The primary goals of this five year project are to: (1) increase first-year retention to 80%, (2) increase second year retention to 71%, and (3) increase the five-year graduation rate to 65%.

Approach

To accomplish the project goals, the FS^2 program is divided into four initiatives (1) a summer intensive program, (2) a revised gateway course for engineering and CS majors, (3) affinity housing, and (4) a peer and faculty mentor/tutoring program. The FS^2 project elements have been piloted at large public institutions, and this project expands their application and assesses their effectiveness within a smaller Liberal Arts college setting. The FS^2 program initiatives are aimed at first-year students and support students' adjustment to the challenges and rigors of a high quality academic program. The initiatives are led by engineering and CS faculty and involve upper-class students to serve as mentors for the first-year students. The program initiatives are designed to contribute to students' academic preparation and self-efficacy in first-year mathematics courses. In addition, these initiatives nurture a sense of belonging to a major and increase social integration within an academic community, and increase a student's belief that their chosen major contributes to society. These are key factors that have been shown to affect retention in STEM fields [8]-[11].

Initiative #1: Summer Bridge Program

The Summer Bridge Program is a two-week initiative to improve the preparation of students for college-level studies, particularly first-year mathematics (see Figure 1). This program also includes career exposure through hands-on activities, seminars, and field trips. The first week schedule for the 2015 Summer Bridge Program is shown in Figure 2. The target population for the summer bridge program is students with: low high school grades; low standardized math

scores; low math placement (i.e. algebra or precalculus). Participation in the summer bridge program is often a requirement for admission to the college. The Summer Bridge Program has three goals, (1) to improve student preparation and first-year mathematics placement through a mathematics review, (2) to excite new students about their chosen majors through activities meant to create a sense of belonging, and (3) inform students about career options.

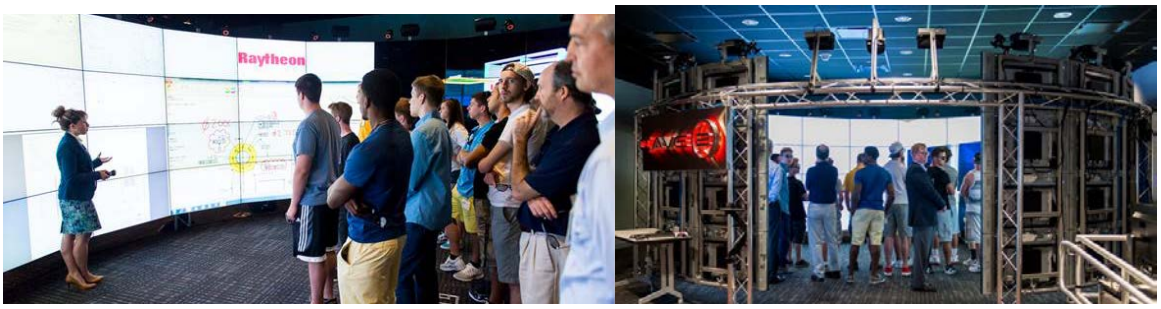


Figure 1 Sumer Bridge Students on a tour of Raytheon's "CAVE2" 3D visualization studio

	Monday (8/21)	Tuesday (8/22)	Wednesday (8/23)	Thursday (8/24)	Friday (8/25)
8:00 AM	Pick up MackCards	Breakfast	Breakfast	Breakfast	Breakfast
9:00 AM	Introduction to the Program	Math (Bordogna)	Math (Bordogna)	Math (Bordogna)	Math (Bordogna)
10:30 AM	Break	Break	Break	Break	Break
10:40 AM	CE Hands-On Activity (Veletzos)	Library Tour (CJ Wong)	Additional Math	Fanuel Hall	Gaming Club (Stuetzle)
12:00 PM	Lunch	Lunch	Lunch	Lunch	Lunch
1:00 PM	Solar Eclipse (Duston) 1:30-2:30	ME Hands-On Activity (Gallagher)	Field Trip (Amazon Robotics) Closed Toe Shoes	Field Trip (Boston Bridge Tour)	EE Hands-On Activity (Adams)
2:30 PM	Break	Break			Break
2:40 PM	CE Hands-On Activity (Veletzos)	ME Hands-On Activity (Gallagher)			EE Hands-On Activity (Adams)
4:00 PM	Adjourn	Adjourn			Adjourn
5:00 PM	Dinner*	Dinner	Dinner	Dinner	Dinner
6:00 PM	Evening activity	Evening activity	Evening activity	Evening activity	Evening activity
7:00 PM	HW time	HW time	HW time	HW time	HW time
10:00 PM	Official lights out	Official lights out	Official lights out	Official lights out	Official lights out

Figure 2 Schedule for the First Week of the 2017 Summer Bridge Program

Initiative #2: Revised Gateway Course

The Introduction to Engineering gateway course is a required course for all incoming engineering students and serves as a first-year experience for engineering students. The gateway course provides inspiration about the disciplines, builds a strong sense of belonging to a community, and develops communication skills. As part of the FS^2 project the gateway course has been expanded to include CS majors and has been revised to include a collaborative team-building design project. This interdisciplinary design project offers first-year engineering and CS students with valuable experience working in teams on a hands-on practical problem. The project incorporates multiple engineering and CS concepts and emphasizes teamwork. The

primary focus is on knowledge and comprehension of basic concepts within the context of a real-world application. The courses culminated in a design competition that includes a judged poster session and design demonstrations build by the interdisciplinary teams (see Figure 3).

Figure 3 Photos of the 2015 gateway course design competition. The teams were required to design and build a wind turbine and were judged on the power output of their design.

Initiative #3: Affinity Housing

The affinity housing initiative is a living/learning community (LLC) of students majoring in engineering or CS. The affinity house was rebranded the "iTEC LLC" for Innovations Through Engineering and Computing. The iTEC LLC activities are intended for students living in the iTEC LLC but available and advertised to all engineering/CS freshman students. Activities consist of professional development sessions, nightly mentoring/tutoring in the iTEC LLC dormitory, and community building activities. Specific activities have included a guest lecture by Henry Petroski (Professor at Duke University and author of numerous engineering and design related books including "To Engineer is Human"), tours of local construction sites and engineering/CS companies (iRobot, Raytheon, Haystack Observatory, Amazon Robotics), and internship advice form upper classmen and recent alumni.

Initiative #4: Advising, Tutoring and Mentoring Program

The Advising, Tutoring, and Mentoring (ATM) program consists of a team of well-performing, upper-division engineering and CS peer mentors. Each peer mentor is responsible for a cohort of fifteen freshmen and reaches out to meet with their cohort several times a semester. The peer

mentors help the new students build their aspirations and academic confidence by welcoming and orienting them to the campus and its culture, and sharing with them their own academic/personal experiences and coping strategies.

A tutoring schedule (group and individual tutoring) for topics critical to first-year students (i.e. mathematics, programming, physics and chemistry) is developed each semester. The peer mentors serve as tutors for the program, and they are required to complete peer tutor training in accordance with tutoring standards for the College. To ensure a sustainable supply of tutors, the FS^2 program encourages lower-division students to consider becoming peer tutors for the ATM program as they continue their studies. These future tutors will be able to use their experience as freshmen and sophomores to help the students who follow after them.

Cohort Demographics

Table 1 indicates that the cohorts have been predominantly male (on average 86% male) with a B/B+ weighted HS GPA. Roughly one quarter of each cohort is Under-represented, and 35% of each cohort is 1st generation. These demographic characteristics of the cohorts have remained fairly consistent over the four cohorts. The average GPA has remained steady over the four cohorts, however the third cohort had a slightly lower GPA. The first two cohorts have very similar math backgrounds and more than 50% of each cohort placed into Calculus. The 2016/17 and 2017/18 cohorts have lower math backgrounds with just over a third placing into Calculus.

Table 1 FS^2 Cohort Demographics

Cohort Year	Cohort Size	Male	Female	Under-represented	1st Generation	HS GPA Average	Calculus Placement
2014/15	101	88 (87%)	13 (13%)	22 (22%)	28 (28%)	3.27	52%
2015/16	114	93 (82%)	21 (18%)	35 (31%)	37 (32%)	3.26	54%
2016/17	147	132 (90%)	15 (10%)	39 (27%)	54 (37%)	3.16	35%
2017/18	108	94 (87%)	14 (13%)	36 (33%)	47 (44%)	3.24	39%
Average	118	102 (86%)	16 (14%)	33 (28%)	42 (35%)	3.23	45%

Note: Underrepresented students includes women, Hispanic and African American students.

Participation

Figure 4 shows the participation in each cohort over the four years of the program. The 2016/17 cohort is significantly larger than the other cohorts. Participation in the LLC increased significantly after the first-year due to the implementation of an Opt-out approach to participation in the program. Participation in the Summer Bridge program increased steadily.

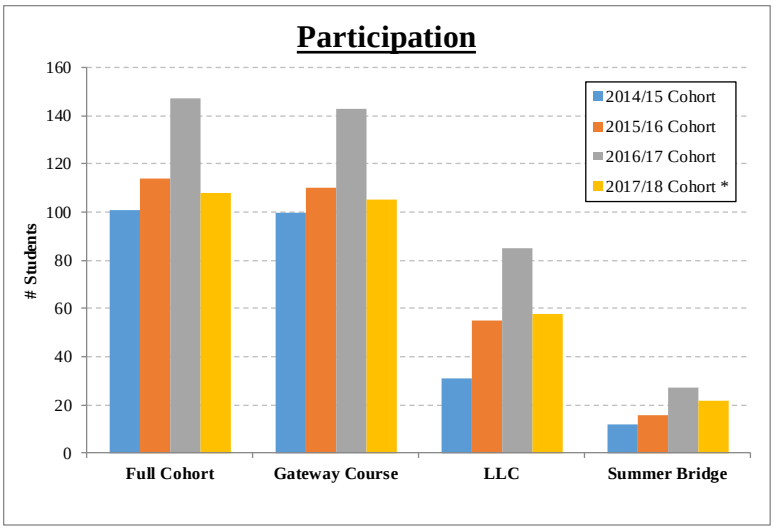
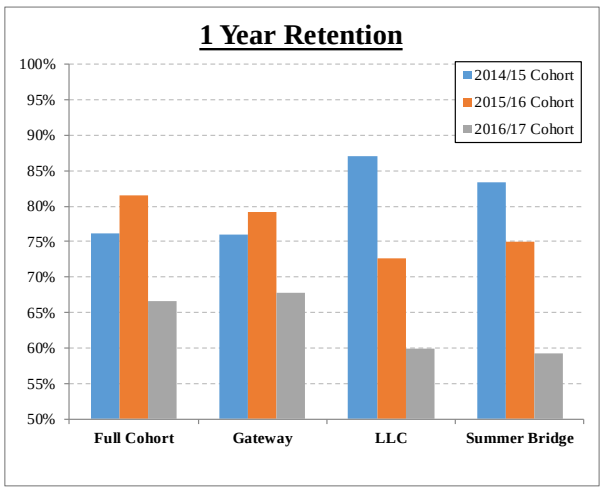


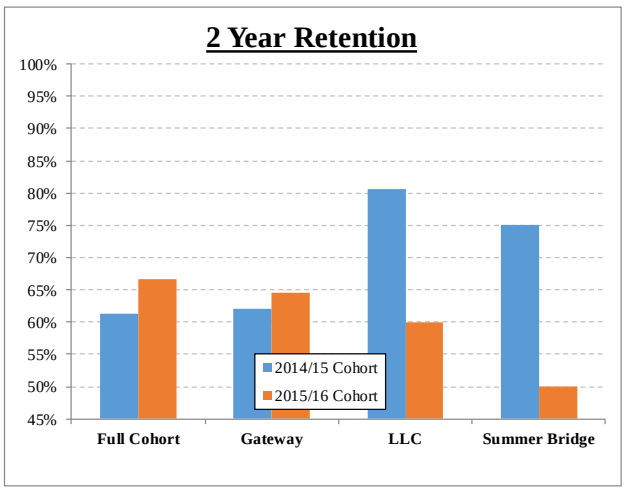
Figure 4 Participation in each cohort and the initiatives

Retention

Figure 5a shows the one-year retention rates of the first three cohorts broken down by initiative. The first two cohorts shows a step forward in retention, from 76% in the first-year to 82% in the second year. Both of these values are measurably ahead of our baseline of 67%. However the third cohort retention dropped to 67%. This figure also shows that the retention for the LLC and summer bridge of the second and third cohorts was noticeably below the retention rate of the full cohort. This is a contrast from how the LLC and bridge performed in the first-year. This change is believed to be due to several factors including a significantly reduced tutoring participation rates observed in the second year and the weaker math background of the third cohort. This may also be due to a change in the manner in which students are selected into the LLC. The first cohort utilized an "opt-in" approach where students must choose to participate in the LLC. The second and third cohorts utilized an "opt-out" approach.



a) One Year



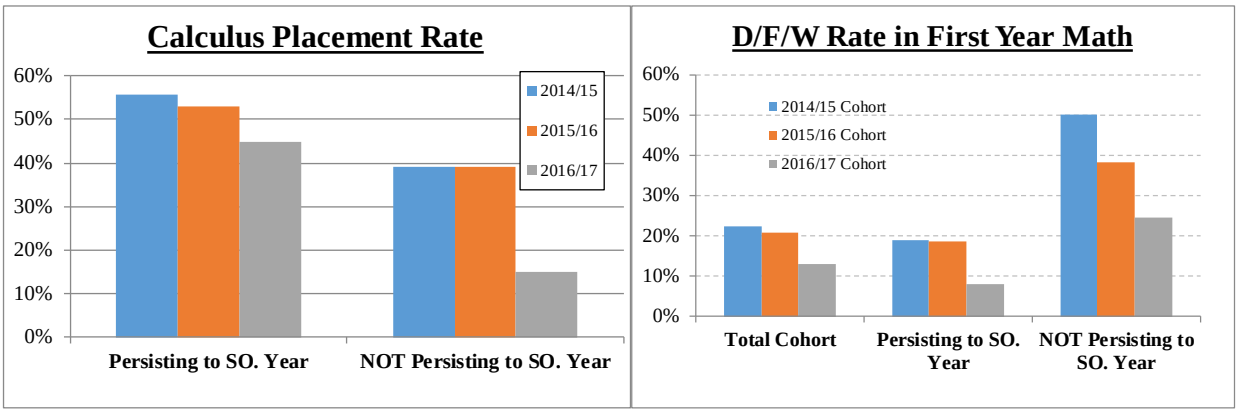
b) Two Year

Figure 5 Retention

Figure 5b shows the two-year retention data for the 2014/15 and the 2015/16 cohorts. The retention rate for the full cohort indicates modest improvements with an increase from 61% to 67%. The baseline in the proposal was 57% so the full cohort suggests an improvement from the past year. The retention rates of the LLC and the Summer Bridge show significant differences however with 2014/15 cohort retention rates of 80% and 75%, respectively, and the 2015/16 cohort dropped to 60% and 50% for the LLC and Summer bridge, respectively.

Relationship of Math and Persistence

Figure 6a compares the Calculus placement rate of students who persisted to sophomore year and of students who did not persist to sophomore year for the first three cohorts. For the first two cohorts (i.e. 2014/15 and 2015/16) this figure indicates that more than 50% of the students who persisted to sophomore year placed into Calculus, while 40% of students who left the target majors placed into Calculus. This suggests that students who place into Calculus are more likely to stay with engineering/CS into their sophomore year. The trend is similar for the first two cohorts, but this does not appear to be a very large effect. One can also read this data and say that nearly 50% of students who persisted to sophomore year placed into Pre-Calc or lower. For the third cohort (i.e. 2016/17), Figure 6a indicates that 45% of students who persisted placed into Calculus, compared to only 15% of students who did not persist. This is a 30 point differential and strongly suggests that the student's math backgrounds impact their likelihood of persisting in engineering/CS.



a) Calculus Placement Rate b) D/F/W Rate in 1st Year Math Course

Figure 6 Impact of Calculus Placement and D/F/W Rates on Persistence to Sophomore Year

Figure 6b compares the DFW rate in first-year math courses of students who persisted to sophomore year to students who did not persist to sophomore year. Students who persisted to sophomore year received poor grades (DFW) in first-year math on average 15% of the time (i.e. 15 in 100 math courses). Student who did not make it to sophomore year received poor grades on average 38% of the time. Students who receive a DFW in their first-year math course are more than twice as likely to drop out of the major after one year. This has a stronger impact on retention than simply placement into Calculus, and it highlights the importance of academic

support services that are relevant to first-year math courses, such as study skills training and tutoring.

Implementation Challenges and Strategies to Address These Challenges

The FS^2 team confronted a few implementation challenges including (1) coordination with other business units on campus, (2) competition with other affinity housing options for first-year students, and (3) low participation in the affinity house despite an opt-out approach.

Coordination with other business units. Small liberal arts colleges must compete in an evolving higher education landscape. Consequently the admissions process is often critical to the financial stability of a small college and is highly streamlined and efficient. This admissions process must include a transition with residential life personnel to coordinate housing of the first-year students. New initiatives that target first-year students must coordinate with both admissions and residential life personnel. To ensure a smooth transition into the critical admission/res-life process requires a thorough understanding of the important stages. Continuous communication and coordination between all parties is essential.

Our team addressed this challenge by organizing regular internal advisory board (IAB) meetings early in the admissions process. The objective of these meetings were to ensure all partners across the college understood: (1) the importance of the FS^2 program, (2) and the various initiative within the program, and (3) the target audience for each initiative. These IAB meetings fostered a collaborative environment by opening lines of communication between all parties and reinforcing informal meetings between personnel.

Competition with other affinity house options for first-year students. Several programs across the college have recognized the importance of affinity houses, and there are a variety of options for first-year students including an Honors LLC and a Women in STEM LLC. The result is that a number of top engineering and CS students choose not participate in the iTEC LLC. These top students are often leaders and good role models, and their absence can impact the culture and motivation of the remaining group of students.

Our team addressed this challenge by working with residential life staff to locate potentially competing LLCs near the iTEC LLC. This strategy is a middle ground that allows students the option to choose between several good residential life options and to participate in multiple programs simultaneously.

Residential life logistics and low iTEC LLC participation. Housing is limited on small campuses so it is important to fill all possible rooms in the dormitories. Balancing this need with the desire to fill a residential unit with only engineers/CS majors can be challenging. The first iTEC LLC cohort utilized an Opt-in participation approach which resulted in only 31% of the full cohort participating in the LLC and necessitated populating half of the dormitory floor with non-engineering/CS students.

Our team addressed this challenge by changing the participation selection approach to the iTEC LLC. In subsequent years the iTEC LLC utilized an Opt-out approach to participation in the program. This change in approach was encouraged by the significant improvement in retention of LLC participant in the first cohort and a desire to encourage as many students as possible to participate in the iTEC LLC. In addition, student who requested to opt-out of the program solely because they wished to room with a specific student who was not an engineering/CS major were allowed to remain on the iTEC LLC floor.

Conclusions

This paper describes the four initiatives of the Foundations for STEM Success project, the current status of the project, and the preliminary results. This is a 5 year project and aims to increase the retention and graduation rates of engineering and computer science majors. Preliminary conclusions are listed below and are based on data from three of the four cohorts of the project.

- Students who earn a D, F, or W in a first-year mathematics course are three times more likely to change out of an engineering or CS major.
- Average one year retention rate is 75%, which is an increase from our baseline of 67%
- Average two year retention rate is 64%, which is an increase from our baseline of 57%.

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