A literature review of the different approaches that have been implemented to increase retention in engineering programs across the United States

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Abstract

Engineering programs in the United States are faced with the challenging problem of decreased retention rates at the undergraduate level. This paper presents an exhaustive literature review that summarizes the attempts made by several different universities across the United States to increase retention in engineering programs. A common theme between different approaches is developed and presented in a clear and concise manner. The main purpose of this paper is to provide engineering faculty members and administrators that are attempting to increase retention in their programs with a resource that will provide them with a general background idea of the strategies that have already been attempted, enabling them to make informed decisions while attempting to increase retention in their programs.

Keywords

First-Year, Experience, Retention, Engineering, Bridge-Programs

Introduction

The United States is faced with a shortage of qualified engineers. The acquisition of higher education has been positively linked to financial success[1]. Attrition in engineering programs is a well-known issue[1,2]. Student retention rates in engineering fall in the range of 40-60%. It has been observed that students capable of completing an engineering degree are switching from engineering to pursue non-engineering majors[3]. Numerous investigations have been performed to understand the reasons for students opting to transfer out of engineering programs. Hewitt and Seymour concluded that students transferred out of engineering programs because of their inability to cope with problems[1,4]. Other studies stated that inadequate teaching strategies are a reason for students withdrawing from engineering programs. Additionally, students' lack of identification with their area of study results in them transferring out of their degree program[1].

Students are under pressure while undergoing the change from a high school to a university atmosphere because this transition affects their relationship with their family, while simultaneously requiring them to independently manage their time and resources and to meet deadlines without their parental supervision[1]. It has been suggested that this stress is a factor that leads to students' withdrawing from engineering programs. It has also been seen that students withdraw from engineering programs because they are not interested in their chosen discipline[1]. Finally, "literature has identified math and physics aptitude as predictors of academic success in college"[5]. Another reason attributed to the transfer of students out of engineering programs is the difficulty that they have in succeeding with calculus[6,7,8].

Based upon the above discussion, student retention in engineering programs is an important issue that faces the engineering education community in the United States. This paper presents a brief overview of the different techniques that have been implemented in universities across the US to increase student retention in engineering programs. Most approaches that have been implemented fall within 4-5 common themes. A representative technique implemented for each theme is described. The paper concludes by identifying these common themes and recommending best practices for increasing student retention in engineering programs based upon an analysis of the literature provided.

Description of Strategies Implemented to Increase Student Retention

Strategies that have been employed and have proven to be successful in increasing retention in engineering programs can be broadly classified as 1) Strategies focused on improving math (specifically, calculus) and physics skills of incoming freshman; 2) Strategies focused on enhancing the sense of community and support (both academic and social) for incoming freshman students and creating a strong identity among students as engineers, and in providing encouragement and support to underrepresented groups; 3) Strategies focused on improving the teaching techniques employed in engineering programs, such as developing an active learning environment, increasing the use of technology in the classroom, and using peer mentors to better relate to challenges freshmen face in understanding classroom material; 4) Strategies focused on retaining student interest in their chosen discipline by incorporating modules into the courses involving solving practical engineering at the freshman level, to demonstrate the application of classroom concepts to real-world problems, thereby enabling students to appreciate the significance of the material and the potential benefit that they can provide to society as engineers; and 5) Strategies focused on incorporating more hands-on components into the classroom.

Search method: The systematic review was conducted through a detailed search of the ASEE.org website and google scholar. The key words used in the search included freshman engineering, retention in engineering, freshman bridge courses, and first year experience.
Representative examples of retention strategies falling within the aforementioned themes are presented below.

Improving math skills, sense of community among students, introducing active learning environment and practical engineering problem solving by Neubert: Neubert et al.[9] proposed an approach to increase retention rates in engineering programs by providing an enhanced calculus experience to the students at the University of North Dakota. A unique feature of the proposed curriculum modification is that the recommended enhancement can be easily incorporated into the program of any institution with a very small amount of required institutional change and at a low cost. The proposed approach involves improving the existing calculus coursework by linking calculus to the real-world and demonstrating their application in solving practical engineering problems. Additionally, they recommend a strategy to increase the level of commitment that students feel toward completing their chosen engineering program by creating an environment in which students feel a sense of belonging to engineering and feel that they are part of a supportive community. They recommend that Calculus 1 and 2 be modified with 30 “modules”, one per week, requiring groups of 3-4 students to apply the classroom concepts to solve engineering problems. Groups would be selected to ensure that underrepresented students are not

outnumbered by traditional students and would be formed so that students with similar majors and schedules would be able to meet outside the discussion groups and form a community. The discussion groups would be mentored by junior or senior level engineering students trained to promote an active learning environment in the classroom and provide students with real-time feedback in a safe environment. Traditional homework assignments would be completed in isolation and feedback would be provided about a week after the submission. Students would not be penalized for incorrect answers; instead, they would be penalized for not attending the group discussion sessions and for not participating in the discussions when present. The mentor would select a student in the group to present the solution to the problem. Everyone would participate in the discussion process and at the end of this, the optimum solution to the problem is arrived at. Each module would take about one to two hours for the average student to complete and be comprised of background material and practical industry-based problems encompassing all engineering disciplines, exposing freshmen to the different engineering fields. The problems would also highlight ways in which engineers can positively contribute to society.

Development of learning community by Kline: Kline et al.[10] implemented a strategy called the "Science Talent Expansion Project (STEP)" to increase retention of first-year students in the engineering program at the Western Michigan University. The strategy involved combining first-time, first-year STEM students into discipline – specific learning community cohorts during over the entire duration of their first year. An "Engineering House" was developed that offered tutoring services for freshmen in their residence halls. Academic and career mentoring and advising was improved. Underperforming students were assisted and supported by timely interventions by faculty and tutors. Faculty learning communities were established to facilitate the transfer of knowledge among faculty regarding teaching best practices. Interaction and coordination with other programs in the university focused on increasing minority participation and organizing freshman/parent orientation were also enhanced. The STEP program increased freshman retention at Western Michigan University from 57% to 65%, which is greater than the 62% retention rate recorded at peer institutions. Additionally, 4th year retention for students that were enrolled in the learning communities increased from 33% to 46%. The STEP project successfully led to the implementation at the institution level of "best practices" concerning the monitoring and evaluation of student success.

Improvement of math skills and development of learning community by Rawn and Bennett: Rawn and Bennett[11] at the University of Tennessee, Knoxville focused on increasing the low retention rates among two groups of engineering students: 1) students performing poorly in math and consequently being unable to enroll in engineering fundamentals, and 2) freshmen women students in the different honors programs. They introduced interventions to deal with the low retention rates among these groups, in which they developed pre-calculus sections solely for engineering students that incorporated visits from engineering faculty and students, and provided the students underperforming in math with the option of availing of a learning community to get support. The learning community included a peer mentor that resided with the students and guided them toward successful navigation of the social and academic transitions that they were undergoing. Additionally, a summer preparatory camp for students with low math ACT scores was introduced. The camp extended over a duration of ten days and was offered before the fall semester commenced, and helped students improve their math skills while also obtaining an idea of the nature of university life. During the week, a lecturer from the math department taught the

students pre-calculus for four hours per day. The students were introduced to university life by visits from staff members that represented different support organizations on campus, as well as from faculty. Participation in a course involving low-ropes activity helped in building a sense of community among the students. Finally, Undergraduate Research Assistantships were offered for the female honors students to increase their retention. This was done because it was learned that female student attrition was linked to their concern about the social benefit of their chosen careers. Performing undergraduate research in a collaborative environment involving interactions with faculty and other researchers helped female undergraduates learn about the benefits of engineering to society. It was concluded that retention of female students that participated in the undergraduate research assistantship program was greater than 85% and it laid the foundation for them to participate in other research endeavors in the future. Finally, retention percentages for incoming freshmen over four years from (2012, 2013, 2014, 2015) were 63%, 41%, 78%, and 90%. It was concluded that the participation in the program was increasing and that the program positively influenced the progress of students in the college of engineering.

Improvement of math skills, development of learning community, and introducing technology into the classroom by Citty and Lindner: Citty and Lindner[12] at the University of Florida describe a dual model first-year summer bridge program involving a residential component on campus during the summer to foster a sense of community on campus, and a non-residential component over fall and spring semesters. It focuses on underrepresented student groups and addresses several issues that affect student retention by strengthening students' calculus skills, providing them with a sense of community via a mentor, exposing them to the use of modern technology and computer tools that engineers use, and introducing them to the engineering design process. The bridge program, mentored by an upper level student, served about 120 students per year and introduced freshman to the engineering experience over the duration of a six-week summer course encompassing classes in calculus, chemistry, computer programming, AUTOCAD, engineering design, student success, and introduction to engineering. Students met every day over the summer course, and continued to meet through the fall and spring semesters on a weekly basis. An evaluation of the program showed that it was successful in retaining less-prepared students. 88% of the students that completed the freshman bridge program were retained, as opposed to 84.1% for non-participants. Hence, the program proved to be so successful that underprepared students that completed the program showed a higher retention rate that their better prepared peers that did not participate in the program.

Development of learning community by Robinson and Collofello: Robinson and Collofello[13] at Arizona State University developed an Undergraduate Teaching Assistant (UGTA) Program that incorporated existing ideas that have proven to improve student retention such as building a sense of community among freshman, fostering meaningful relationships between students and faculty, promoting active learning environments, and assisting freshman in developing an identity as an engineer. The UGTA program is unique because it is institutionalized and involves a formalized, consistent UGTA training program which is implemented across all the departments in the entire engineering school. The program hires a diverse group of sophomore and upper – level UGTA's and trains them primarily in the implementation of active learning techniques in engineering courses and team based classroom activities.
UGTA's are beneficial because they are young and energetic, can relate to their peers and promote learning via peer mentoring, and, having recently completed the concerned course, are

more familiar with difficulties and challenges that their peers might be facing in understanding hard classroom concepts. They assist freshmen in the transition from high school to college, provide them with confidence by directing them to available resources, and act as positive academic role models. It was concluded that the UGTA program was beneficial for everyone concerned. Students valued the fact that they had a peer mentor, UGTA's benefitted by gaining experience on their resume, developed their leadership and communication skills, felt a sense of satisfaction in helping their peers, and formed meaningful relationships with faculty members. Faculty members benefitted due to the availability of an additional resource.

Use of technology in the classroom by Lewis and Hieb: Lewis and Hieb[14] explored the use of technology based approaches to improve student learning and success. It was found that the electronic collection of students' digital work of in-class problems took less time collecting and returning papers and encouraged students to use their tablet PCs. They also began the adoption of Pearson's MyMathLab™, an online multimedia textbook with active content, including algorithmic problem generators and computer grading. MyMathLab was used to create homework problems algorithmically and create quizzes and tests that could be graded automatically. This technology was used to also deliver and grade daily in-class problems in their introductory Engineering Analysis I course. The benefits of using this technology were: (a) attendance data was collected and stored with little effort by the professor; (b) the use of MyMathLab in-class problems helped reinforce course learning concepts with immediate feedback; and (c) students had a structured environment to practice exam-like problems. The technologies were evaluated in Engineering Analysis I which had about 186 students in the semester. Problems that would normally have been done on paper were done on tablets using DyKnow electronic ink and stored in DyKnow panels one per student accessible by the instructor for grading the problems. Additionally, software was developed to extract content from the electronically submitted problems to help with scoring. Using this technology required that students attend class to submit in-class problems electronically which was assumed would improve their grades. It was shown that students attending class 89 -100% of the time had an exam average at least 10 points higher than those attending 74 to 89% of the time which had an exam average at least 10 points higher than those attending 29-74% of the time.

Improving math skills and incorporation of hands-on work by Ni: Ni et al.[15] under an NSF sponsored consortium A National Model for Engineering Mathematics Education added real-world problems into the learning of trigonometry a basic engineering math skill to improve retention in engineering. The introduced into the classroom 1) trigonometry calculations with robotic welding operations on an automobile assembly line, 2) a programmable humanoid robot trigonometry experiment where students needed to specify joint angles, and 3) a surveying experiment to enhance students experience in learning trigonometry. Students enthusiastically embraced the new approach with active classroom participation. Student performance data also showed improvement related to the trigonometry skills where the class average on trigonometry problems improved by 22%. They subsequently saw significant improvement in retention in Civil Engineering, Electrical & Computer Engineering, and Mechanical Engineering programs.

Improvement of math skills and development of learning community by Kukreti: Kukreti et al.[16] used a NSF project funded by the Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) to improve retention of engineering students by introducing cohort building, networking, and defining a pathway to graduate school. A total of 218 students

participated in the program. Cohort building included a Summer Bridge Scholars Program, cohort course scheduling; and freshman supplemental collaborative learning of math and science courses. The major objectives of the Summer Bridge course was to prepare students for their math and science courses taken in the freshman year. During exit interviews, students were given specific information about their placement in freshman year Calculus and English courses in which they pre-enrolled as a cohort for each class. Networking strategies included creating academic relationships among students, between students and faculty, and between students and the university administration. The networking strategies attempted to create a professional network starting in their freshman year with all the people they met within their education experience such as advisors, faculty members from whom they had taken classes, professors in their major, internship supervisors, employers or administrators, people they met through volunteer and community activities, seminars/workshops, and conferences. Finally, the pathway-to-graduate school is made clear to encourage promising undergraduate students to apply for graduate school and assist them in creating a portfolio which would make them competitive to receive financial support. It was found that retention was 12.7% higher than the goal set for the program for the freshman year.

Introducing hands-on work in the classroom Ray: Ray[17] introduced hands-on projects with the goal of improving quantitative and qualitative problem solving skills of freshman students by introducing an Introduction to Engineering Technology course. The hands-on projects focused on introducing the concepts of engineering design, prototyping, and testing. Soft skills such as formal report writing, team work, and orientation to the engineering profession and industry were components of the course. Hands-on projects included 1) building the tallest possible tower with an 8.5”x11” sheet of paper and 20 inches of tape, 2) prototyping and testing a music-engine printed circuit board by soldering through-hole components, 3) the design, prototype, and test a 40-kHz infrared wireless remote controller, and 4) building a bridge from spaghetti and glue/epoxy. Assessment data indicated that even though students consider the introductory course demanding and challenging, they do benefit from the course’s analytical rigor which is essential to performing well in subsequent math, science, and engineering technology courses. Course-embedded direct and indirect student assessment data confirmed that the main objectives of the course were met.

Conclusions

Engineering programs in the United States are faced with the issue of falling student retention rates. Most students withdraw from their chosen program by the end of the first or second year. The reasons for this attrition encompass a lack of preparation in calculus and physics, pressure due to the transition from a high school environment to a college environment, a lack of interest in the chosen major, and inadequate teaching techniques. Strategies that have been employed and have proven to be successful in increasing retention in engineering programs can be broadly classified as being focused on improving math and physics skills of incoming freshman, on enhancing the sense of community and support for incoming freshman students, on improving teaching techniques employed in engineering programs, on retaining student interest in their chosen discipline, and on incorporating more hands-on components into the classroom.

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