

## **Developing Engineering Student Success – A Retention Study at Baylor University**

**Ken Van Treuren, Steve Eisenbarth, Cindy Fry**

Department of Engineering  
Baylor University

### **Abstract**

Faced with an engineering program graduation rate of approximately 22%, Baylor University's Department of Engineering recognized the need to identify the factors that led to student attrition in engineering. By both attracting new students and retaining current engineering students, Baylor University's engineering program seeks to improve this graduation rate in the near term. The engineering program is a small, undergraduate only program with a strong emphasis on teaching and student/faculty interaction. Statistics for the program and freshman sequence are presented as well as the risk factors identified for these students. These retention statistics and risk factors are compared with the literature. Also reported are the work and results from the School of Engineering and Computer Science Retention Committee, which explored factors contributing to the loss of students. Of note is the participation of Institutional Research that helped identify capabilities and limitations associated with institutional data collection and management and the search for relevant data analysis and collection instruments. One outgrowth of this study was the creation of a Freshman Success Task Force, which is charged with generating "a plan and process to increase the success/persistence of freshman computer science and engineering students at Baylor." The retention goals set by the Task Force are discussed and the resulting curriculum initiatives presented.

### **Background**

The engineering program at Baylor University began in 1979 when a faculty committee, at the direction of the University President, created an engineering science curriculum and hired the first engineering faculty member. The engineering science program developed three options targeted to electrical, mechanical, and computer engineering. As more faculty were added the engineering science program was modified to conform to specific ABET accreditation criteria, however, the ABET criteria forced Baylor to seek accreditation under the non-traditional criteria since Baylor did not meet minimum faculty counts. The initial ABET visit did not proceed well and a second visit was requested. Between the first and second visit the three options were reduced to two, mechanical and electrical, and a common engineering core was created for a

general engineering program with options. The second visit resulted in the initial accreditation for the Engineering program.

As the engineering program matured, the students that entered Baylor University to study engineering, for the most part, were first attracted to Baylor by its reputation as a private church related institution and secondarily for engineering. From the mid 80's to the end of the 90's the program was stable with a small growth rate. In 1995, the engineering program, previously a department within a liberal arts college was organized as the School of Engineering and Computer Science. With the higher visibility came pressures for growth and expansion of the engineering programs. Starting in 1999, the Engineering Department developed two new engineering programs Mechanical Engineering and Electrical and Computer Engineering and significantly restructured the existing Engineering program to allow pre-professional combinations. All three programs were accredited in 2001. The addition of two new programs was squarely aimed at increasing Baylor's visibility in engineering and placing it on a growth track. Program growth was sought in two directions, first, attract larger numbers of well-qualified students and, second, increase student retention rates to preserve the front-end recruiting efforts.

### **Retention Taskforce**

A taskforce to study the retention rate problem in the School was initiated by the Dean in the fall of 2000<sup>1</sup>. The Associate Director of Institutional Research and Testing at Baylor University chaired the group. The other members included the Coordinator of Student Retention and two faculty members from the School of Engineering and Computer Science. The mission of the study group was to collect factual data, arrange for subjective information such as focus groups, solicit input from constituents, consider proven strategies, and examine other information as appropriate and needed. Further, the committee was told it could investigate deeper specific problem areas and areas of opportunity.

The questions the group was to address included:

- What is the retention rate for engineering and computer science?
- What are the factors leading to the poor performance of some students, and to the selection of another major for students performing well?
- What are the opportunities and strategies to significantly improve the school's retention rate?

### **Engineering Retention Rate**

Retention data for engineering (all disciplines) was collected for a six-year period. Retention rates from course to course were evaluated, as well as overall engineering graduation rates. The following table contains retention and graduation statistics for students in engineering. The

courses shown in Table 1 were selected since all engineering students took them, regardless of engineering discipline. Each cohort group is defined as those students who took the first engineering course in the fall or spring semester of a particular academic year. These students were then tracked throughout their career at Baylor.

Table 1. Department of Engineering Retention Data

	<b>EGR 1301<sup>1</sup></b>	<b>EGR 1302<sup>2</sup></b>	<b>EGR 2430<sup>3</sup></b>	<b>EGR 3380<sup>4</sup></b>	<b>Engineering Degree from Baylor</b>	<b>Any Degree from Baylor</b>
Fall 94 / Spring 95	81	60.5%	29.6%	21.0%	21.0%	64.2%
Fall 95 / Spring 96	73	67.1%	37.0%	27.4%	23.3%	58.9%
Fall 96 / Spring 97	85	83.5%	55.3%	40.0%		
Fall 97 / Spring 98	85	74.1%	56.5%	45.9%		
Fall 98 / Spring 99	125	70.4%	47.2%	32.8%		
Fall 99 / Spring 00	85	64.7%	34.1%			

1 EGR 1301 is "Introduction to Engineering" usually taken fall freshman year

2 EGR 1302 is "Introduction to Engineering Fundamentals" usually taken spring freshman year

3 EGR 2430 is "Electrical Circuit Theory" usually taken spring sophomore year

4 EGR 3380 is "Engineering Design I" usually taken fall junior year

The first data column, labeled "EGR 1301", shows the number of students enrolled during an academic year. The second column, labeled "EGR 1302", shows the percentage of students from EGR 1301 who subsequently took EGR 1302. The third column, labeled "EGR 2430", shows the percentage of students who then subsequently took EGR 2430. The fourth column, labeled "EGR 3380", shows the percentage of students who then took EGR 3380. The fifth column shows the resulting graduation rates for the students who enrolled in EGR 1301 and graduated with an engineering degree from Baylor University.

The data analyzed shows an overall graduation rate of about 22.1%, meaning that only 22.1% of students who start off taking the first course in engineering will graduate in engineering at Baylor. For comparison, the Higher Education Data Sharing (HEDS) Consortium, a group of private universities that share data between private universities, show the average five-year graduation rate for students entering and graduating in engineering is 42.0%. The 1999-2000 SMET Retention Report contains the retention and graduation rates of 1992-98 entering science, mathematics, engineering, and technology majors in 119 colleges and universities. The study showed that the average six-year graduation rate for the SMET majors from a SMET discipline was 38%. This puts Baylor University's engineering graduation rate approximately half the national average.

## Engineering Risk Factors

The next part of the study sought to determine what the risk factors were for students enrolling in engineering. The risk factors were divided into three groups: faculty, students, and curriculum; based on the source of the potential risk. The following is a summary of the risk factors for each of these groups.

### Faculty

The primary risk factor for engineering retention that affects the faculty is workload. To do the things that should be done is not possible, given the number of engineering faculty employed. At present the department has ten full time faculty members. Of the ten, one is the department chair and another is the associate dean both of which have the commensurate administrative duties further increasing faculty workload. Some of the areas affected include:

- Assessment – assessment tools are not utilized as they should, and even when utilized there is rarely time to adequately analyze the data
- Student Interaction – because of the workload of the faculty, adequate time for student interaction is not available (office hours, outside student activities, advising, etc.)
- Research – research time, especially for new tenure-track faculty members, is inadequate
- Professional Development – again, because of workload, the faculty are rarely able to take advantage of professional development opportunities
- Course Development/Enrichment

### Students

The risk factors for engineering retention that pertain to students include:

- Inadequate preparation prior to matriculation
- Lack of pre-screening of engineering students
- Upper division admission process may allow marginal students to continue in the program (At Baylor, students may declare engineering as early as entry into the university. Engineering students, however, are not “admitted” to the upper division of the engineering program until they have finished a certain number of science, math, and engineering courses, and have maintained a minimum grade point average. This assessment is not usually performed until sometime toward the end of the sophomore or beginning of the junior year.)
- Students’ perceptions of “hard” versus “easy” professors
- Poor work ethic

## Curriculum

Risk factors for engineering retention that pertain to the curriculum include:

- Lack of continuity between the first two engineering courses (these courses were initially developed to be motivational and help with student retention, but have diverged somewhat in time)
- Curriculum changes have confused students
- The new format of the Engineering program (to include pre-professional combinations) has the potential to be an “escape route” for poorer-performing students
- Students are weak in writing
- Department decline in US New and World Report national engineering program rankings for undergraduate only institutions

### **Engineering Retention Study Recommendations**

Most of the recommendations from the Study Group follow logically from the risk factors. Faculty additions are needed to spread the work around. This would keep classes small and give faculty time for assessment, student interaction and involvement, research, professional development, and course development/enrichment. Currently, the department has three additional faculty positions for which the hiring process has been started.

Students need to be screened for engineering earlier in their college career to allow time for changes and to minimize wasted resources. Students who perform poorly should be counseled immediately (students currently have an automatic second chance to do better, and then can be placed on probation, thereby prolonging their participation in the program when they may not be suited to it). The School of Engineering and Computer Science should work with the Student Success Center to develop specific intervention programs for at-risk engineering students.

The curriculum should be studied further to determine where continuity could be improved from course to course. The department should take advantage of faculty who are stronger in teaching and student interaction in the early courses, to further encourage student retention. The conditions for admission to the engineering program should be studied so that exceptions are minimized.

Other recommendations include:

- Do a continuation of this study to investigate the “Freshman Experience” and how Baylor might take advantage of other things that would increase student success
- Investigate how the School’s national rankings can be improved (what are the criteria upon which this assessment is made?)

Many of these recommendations are being investigated further, and the School of Engineering and Computer Science convened a Freshman Success Task Force in September 2001, to continue this study of the “Freshman Experience” and how to increase overall student retention.

## **Retention Focus - Introductory Freshman Course Sequence**

A key element of freshmen engineering retention effort is associated with the introductory freshman course sequence taken by all engineering students. The courses are EGR 1301, *Introduction to Engineering*, and EGR 1302, *Introduction to Engineering Fundamentals*. A more complete description of these two courses can be found in Van Treuren and DeJong (2001)<sup>2</sup>. These courses are a student’s first encounter with both the profession of engineering and the Department of Engineering.

### **EGR 1301 Introduction to Engineering**

The department, since its inception, has always had a course for freshmen in its curriculum taught in the first semester. At first, the freshmen engineering course was a manual drafting course required only of mechanical engineering students. There was concern on the part of the department chair that student retention should be improved and that all incoming freshmen engineering students should have the experience of an introductory engineering course. In the fall of 1986, the course was approved and implemented. The course description was as follows:

EGR 1301: Introduction to Engineering Analysis and Design Techniques. Practice in solving engineering problems. Introduction to engineering graphics and the use of computer work stations. (2-3)

This course was to follow a two-hour lecture and a three-hour lab format. The objectives of the course were as follows:

1. To introduce the engineering profession and its challenges.
2. To motivate freshmen engineering students in their study of science and mathematics.
3. To develop some basic tools of engineering including graphical skills, presentation of engineering results, use of hand-held calculators, engineering applications of microcomputers, design process and systems of units.
4. To introduce several technical subjects engineering students will encounter in their educational program.
5. To provide opportunities for group design experience.

The course was designed to motivate students to make an early commitment to engineering as a career choice. Departmental records are incomplete and it is not possible to determine whether retention improved as a result of the addition of this course.

Through the years the course purpose remained essentially the same, to help students decide on their future in engineering. Changes in course content were introduced to reflect the increasing need for students to learn the skills and tools necessary for a successful professional and academic career. Emphasis was placed on teamwork and communication using a team-based design project as a pedagogic vehicle. More information on the design project is available in DeJong, et al. (2000)<sup>3</sup>.

In 1999, the course description was changed to more accurately describe the intent of the course.

EGR 1301: Introduction to Engineering. Introduction to the Engineering Profession. Topics include engineering disciplines, ethics, the impact of technology on the world, analysis and design using a team project, and computer aided design and problem solving. (2-3)

Much of the new focus incorporated into the course was influenced by the ABET 2000 criteria thereby the course goals changed as follows:

1. To provide career guidance and motivation for new engineering students.
2. To provide a sense of community among engineering students and faculty.
3. To provide students with experience in engineering problem solving.
4. To develop some basic analytical and design skills needed by engineers.
5. To introduce drafting and Computer Aided Design.
6. To develop basic engineering computer skills (i.e. spreadsheets, word processing, etc.)

### **EGR 1302 Introduction to Engineering Fundamentals**

With the perceived success of EGR 1301, in spring 1993 another freshman engineering course was introduced. This course was added to help students better decide whether engineering is a viable major for them by providing an introduction to fundamental aspects of engineering systems and how engineers approach solving problems in those areas. This course was also to assist in student retention by providing direct contact with freshmen students in their second semester of course work. EGR 1301 was a prerequisite course and the course was originally a three-hour lecture course. The original catalog course description was as follows:

EGR 1302 Introduction to Engineering Fundamentals – Introduction to fundamental problem solving techniques in engineering analyses of Mechanical Systems, Electrical Systems, Computer Systems, and Energy Systems. (3-0)

Calculus I was listed as a pre-requisite to ensure the math skills necessary for the analysis of the systems. The goals of the class were to introduce students to several fundamental aspects of

engineering systems and to provide problem-solving capabilities encountered in the design and analysis of those systems. Topics included math (roots of equations, complex numbers, matrices, vectors, dot product, and cross product), mechanical systems (2D and 3D statics principles), electrical systems (analysis of DC and AC circuits using Kirchoff's Voltage Law and Kirchoff's Current Law), mechanical energy systems (potential energy, kinetic energy, and work), and digital systems (number systems, digital circuits, and logic diagrams).

After two years it was obvious that the course in this structure was unacceptable since 28% of the students were earning D's and F's. The intent of this course was not to "weed" out students, and it was clearly not accomplishing its purpose of motivating students to continue in the engineering major. In spring of 1997, two members of the faculty were charged with restructuring the course so the students might have greater success. The "minimum self-paced mastery" technique was adapted to this course and the results were an improvement in retention to the next course. (See Williams and Newberry (1998)<sup>4</sup> for more information on this technique.) Approximately 16% of the students received D's and F's each year in the subsequent two years after the new course was introduced. According to Williams and Newberry, the retention rate of students at the end of the follow-on course, EGR 2320 Statics, also improved. They reported that 63% of the students completing Statics received a "C" or better in the course compared with 49% prior to the "mastery" course technique.

Although the content of the course remained essentially the same, a two-hour problem solving lab session was offered in which the students could ask questions in preparation for their "mastery" test. In fall 2000, the catalog was changed to reflect this lab session and the course description rewritten. The course material at this time was changed to include engineering mathematical concepts and software exclusively. This change was enacted at the request of faculty of higher-level courses who perceived a weakness in their students in these areas. The topics included matrix algebra, linear equations, complex numbers, elementary operations with vectors, scalar product, vector product, set theory, Boolean algebra, and probability. The new description was as follows:

EGR 1302 Introduction to Engineering Fundamentals – Introduction to fundamental problem solving techniques in engineering analyses of mechanical and electrical systems. (2-3)

The goal of this new restructured course was to advance the students' knowledge and skill in their ability to do the following:

1. Apply knowledge of mathematics, science, and engineering.
2. Identify, formulate, and solve engineering problems.
3. Use the techniques, skills, and modern engineering tools necessary for engineering practice.



While the goal of these courses was to help students to understand the engineering profession and make an educated decision about this profession as a life vocation, the result was that about 50% of the students who take EGR 1301 leave the major or do not declare engineering as a major after their freshman year (see Table 1). Approximately 22% of students who take EGR 1301 graduate with an engineering degree. This prompted the School of Engineering and Computer Science to begin a study on retention to determine what factors influence a student to remain in engineering and what can be done to increase retention of these students.

## **Retention Focus – Texas Technology Workforce Development Grant Program**

The State of Texas has undertaken a rather ambitious program to increase the number of engineering and computer science graduates from the State's public and private institutions of higher learning. The State legislature allocated \$5 million in state funds and sought a matching \$5 million from Texas' private/corporate sector to fund the Texas Engineering and Technology Consortium's (TETC) grant program. Texas universities with ABET accredited Electrical or Computer Engineering programs were eligible to apply. Baylor University has sought funding with two proposals, one a joint proposal in collaboration with fourteen other Texas schools and a separate proposal focused on engineering program growth at Baylor.

### **Texas Engineering Education Pipeline**

Fifteen Texas universities lead by Southern Methodists University (SMU) are requesting \$1.075 million to implement the Infinity Project statewide. The Infinity Project is a curriculum reform/development effort designed to place engineering curricula in grades 8 through 12 and first year engineering programs. This program included teacher training and well designed curricular modules that should attract students into the engineering and computer science (ECS) professions. The central program goal is to increase the number of entering freshmen ECS students in Texas institutions from 2900 to 5000 over the two-year grant period.

Each of the fifteen institutions will become a training and support center for high school teachers in their geographic area. In addition to teacher training, funds were requested to support collaboration between university faculty and students and high school faculty and students not only to provide a technical support network, but also to connect each high school student with a mentor from the engineering profession. Presently 24 high schools participate in project with the number to increase to 120 by Fall 2003 if the project is funded.

The Infinity Project also provides the basis for a freshman level introductory course in electrical and computer engineering in both community college and university level engineering programs. The stated goals for this phase of the project include increasing the retention rates for freshman engineering and computer science students to 75%. If funded, Baylor is exploring the possibility of inserting elements of the Infinity curriculum into the freshman-level engineering courses.

## **Strategies to Increase Enrollments**

Baylor has also requested \$175,000 to support a project specifically tailored to increase the number of entering freshman and to reduce the attrition rate for electrical engineering students. The grant would support implementation of four strategies to enhance engineering retention: 1) employing a Retention/Success Coordinator, 2) attracting students from small liberal arts based Texas colleges via transfer agreements and targeted scholarship aid, 3) attracting a greater diversity of well-qualified students from high school using directed recruiting and scholarship incentives, and 4) providing funds for faculty and curriculum development, including areas of mathematics and science that are part of the broader engineering curriculum.

The Retention/Success Coordinator is thought to be an important element in student retention and success. There are indications that the transition from high school to college academics is traumatic for a large percentage of entering freshmen, including those with high achievement records. A significant cause of this trauma is the lack of academic challenge and rigor in most high school programs. Many entering freshmen are shocked that they have to study to learn. The Retention/Success Coordinator will be tasked to identify at-risk students early, hopefully within the first two weeks of a semester, and to marshal counseling and tutorial resources to counter at-risk behavior.

Many aspects of student retention are influenced by the nature of the curriculum itself and in the pedagogic attitudes and skills of the faculty. Retention efforts in engineering can very well be undermined by non-engineering faculty in mathematics, physics, and chemistry as well as the faculty that support the general education portions of the curriculum. To support engineering retention efforts, Baylor is seeking funds to extend the development of “best of pedagogy” concepts to the non-engineering faculty through learning workshops and seminars and to increase cooperative relations between the engineering and non-engineering faculty.

## **Conclusions**

Student retention and success must capture the attention of individual engineering faculty as well as engineering administrators because the causes of student attrition are complex in terms of root causes and the generation of remedies. Attrition can be traced to a wide range of causes including the lack of academic rigor in high school curricula, the inadequacy of university freshman curricula, university faculty that promote the sink or swim version of academic self-reliance, and the lack of support staff. In this light, Baylor is wrestling with the broader implications of student retention and seeking solutions that in combination will create a learning environment that generates success.

## References

1. Baylor University ECS Retention Study Group Final Report, May 2001
2. Van Treuren, K. W., and DeJong, N. C., 2001, "The Evolution of an Introductory Engineering Course Sequence: Responding to Student, Faculty and Industry Needs" Paper presented and published on CD for the ASEE Gulf-Southwestern Section Annual Conference 2001, Texas A&M University, College Station, TX, March 28-30, 2001.
3. DeJong, N. C., Van Treuren, K. W., Farris, D., and Fry, C., 2000, "Using Design to Teach Freshman Engineering." Paper presented at the 2000 ASEE Annual Conference, June 18-21, 2000 St Louis, MO.
4. Williams, S., and Newberry, B., "First-Year Experiences Implementing Minimum Self-Paced Mastery in a Freshman Engineering Problem-Solving Course," 1998 ASEE Annual Conference Proceedings, July 1998.

### KEN VAN TREUREN

Ken Van Treuren is an Associate Professor in the Department of Engineering at Baylor University. He received his B. S. in Aeronautical Engineering from the USAF Academy and his M. S. in Engineering from Princeton University. Serving as USAF pilot, he completed his DPhil in Engineering Sciences at the University of Oxford, UK, and returned to the USAF Academy to teach heat transfer and propulsion systems. At Baylor he teaches courses in laboratory techniques, fluid mechanics, energy systems, and propulsion systems, as well as freshman engineering. His research interests include experimental convective heat transfer.

### STEVEN EISENBARTH

Steven Eisenbarth is Associate Dean of the School of Engineering and Computer Science at Baylor University. He received his B.S. in Mathematics and Physics from Albertson College of Idaho and a Masters and Ph.D. in Physics from Baylor University. He teaches courses in electrical and computer engineering including embedded computer systems design, computer organization, electrical materials, and microprocessor systems.

### CINDY FRY

Cindy Fry is a Lecturer in the Department of Computer Science at Baylor University. She received her B.S. in Industrial Engineering from Texas A&M University (TAMU). After graduation she went to work for NASA's Marshall Space Flight Center in Huntsville, Alabama. While working for NASA, she attended graduate school at the University of Alabama in Huntsville and received her M.S. in Systems Engineering in 1989. She worked on several NASA projects such as the Hubble Space Telescope and was the Science Operations Director for shuttle flight STS-46. She joined the faculty of Baylor in 1997, and teaches courses in computer programming, computer organization and architecture, and freshman engineering.