Assessment Strategies for Student Recruitment and Retention in Engineering

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***Abstract*— A recruitment and retention program is developed and assessed for undergraduate engineering students. The goal is to recruit students with academic talent and to provide the financial, academic and social network supports that prepare these students to graduate in the field of engineering. The program has three main components: (1) A pre-collegiate summer workshop designed to introduce engineering concepts to high school students through a new multidisciplinary precollegiate summer course; (2) Scholarships for full-time students enrolled in the program who demonstrate financial need and academic achievement; (3) A network of academic and social support that will help students persist in their studies at a high level of achievement, complete their baccalaureate in a timely manner, and pursue careers and educational opportunities in the field. By focusing the program within the college of engineering we are able to facilitate the institution of a program-centered community of learners whose members share common goals, interests, and identity that are associated with achievement and persistence toward graduation. During a four year period we were able to recruit and retain 25 students in four engineering majors.**

***Index Terms*— Undergraduate; Engineering; Retention Recruitment; Assessment**

I. Introduction

The importance of higher education in science and engineering (S&E) is increasingly recognized for their impact on innovation and economic development, providing advanced skills needed for a competitive workforce and the research necessary for innovation in graduate education [1]. During the last 20 years, the undergraduate degrees in S&E have constituted about one third of all baccalaureate degrees awarded with only a narrow fluctuation. The exception is an increase in degrees in psychology and a decrease in engineering from 7% to 5% [2]. The share of the US general funds devoted to higher education has decreased tremendously in recent years. At the same time that the state funding for higher education absorbed severe cuts the student enrollment has grown at increased rates. This combination of enrollment increases and funding cuts has caused a dramatic decrease in the state funding per resident student. The biggest change is the proposed budget reduction for FY 2011-2012 hitting public schools and cutting additional fund from state support for higher education and colleges [3]. The decline is even more dramatic when adjusted for inflation [4] and current economic conditions.

In this paper, we describe strategies in developing a coherent program for talented engineering students with financial need in which they receive the mentoring, support, and networking they need to successfully matriculate in their selected majors. This program is supported by a grant from the National Science Foundation, which made it possible for us to provide scholarship to qualifying students. In the remaining of this section, we describe the university and the college and describe our motivation for implementing the ReACH program. We will present the design strategies and supporting literature in implementing the program for our specific environment in Section II. This section also includes the specific pre-collegiate program that we designed to support our recruitment efforts. Section III describes the four-year period program progress and the results achieved. Our observations and concluding remarks are presented in Section IV.

The University of Colorado Denver offers education in an urban downtown location. The College of Engineering and Applied Science offers four degrees in both undergraduate and graduate programs in Civil, Mechanical, Electrical, and Computer Science and Engineering disciplines. The undergraduate programs are suited to the needs of practicing professionals as well as full-time students. Our school attracts urban students from diverse backgrounds, many with financial need. For the College of Engineering and Applied Science (CEAS) the year-to-year retention rate for the first-time degree seeking freshmen was 56% in 2003 and 76% in 2004. Figure 1 shows the student credit hour enrollment (SCH) at CEAS from 2002 to 2010.

A study of success and failure in engineering colleges with potential enrollment increase is discussed in [5]. The critical engineering students' first year experience is reviewed and discussed in a study by [6]. Academically focused retention programs such as our "Recruiting Engineers to ACHieve (ReACH)" described in this paper, are based on the assumption that the higher a student's academic competence is, the better the performance and the greater the likelihood of [7]. The college retention and performance are also influenced by non-academic factors, such as academic self-confidence, achievement motivation, institutional commitment

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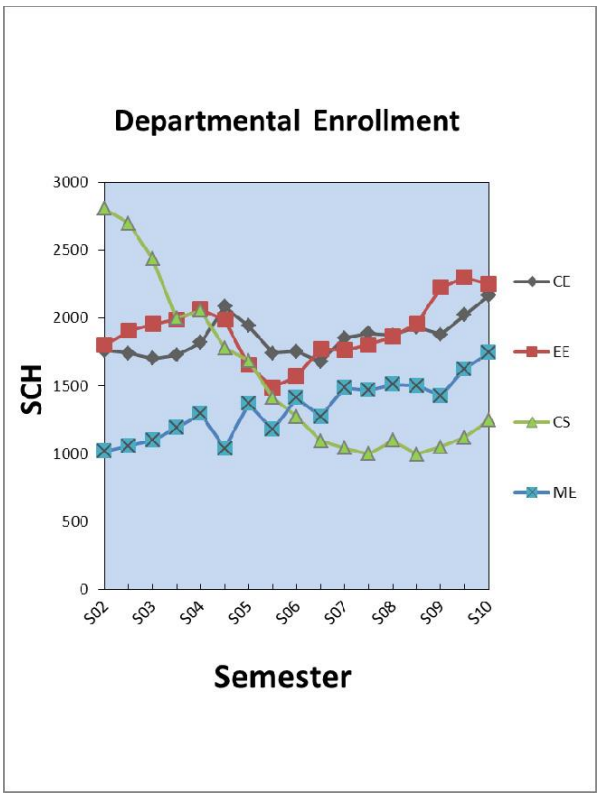

Figure 1. College of Engineering credit hour enrollment

staying in school and social support. New theories to explain models for academic achievements have been developed. Results of several reviews of the motivational literature highlight the need to integrate non-academic and academic models [11-13].

The variety of support offered through a well-designed program will help students develop a strong affiliation with the college academic environment both in and out of classroom. These supports feature learning-centered interaction with faculty and academic peers, mentoring relationships with faculty, involvement in student activities, and career counseling and job placement [14]. The intent of support services is to create a social and learning community that fosters a shared consensus regarding program goals that promote academic achievement and persistence to graduation. Faculty student mentoring, academic counseling and advising, and peer tutoring help improve levels of student involvement, motivation and academic self-confidence and in turn increase levels of institutional commitment and engagement [15, 16].

Our project intended to focus on increasing the number of engineering graduates through the provision of financial assistance and supports that build persistence toward degree completion, and through the introduction of a pre-collegiate program that strengthens current recruitment efforts. By focusing the program within the College of Engineering we were able to facilitate the institution of a program-centered community of learners whose members share common goals, interests, and identity that are associated with achievement and persistence toward graduation. The first year of our program was dedicated to planning. Various members of university organizations were invited to join our ReACH Steering Committee during the planning year. The members represent crucial components of the institution to provide support for outreach and recruitment, student advising, student services, financial aid support, and curriculum development and mentoring.

II. Design Strategies and Retention of the ReACH

ReACH consists of three components: (A) Pre-Collegiate summer workshop designed to recruit students into the engineering college and the ReACH scholars program; (B) Scholarships that will provide up to $7,600/year for fulltime students enrolled in the college who demonstrate financial need, academic achievement, and commitment to pursue a science, technology, engineering, and mathematics (STEM) career; (C) Academic Networking where a network of academic and social support will help ReACH scholars to persist in their studies at a high level of achievement, to complete their undergraduate degree in a timely manner, and to pursue careers and educational opportunities in the field. The components of the ReACH program are further described as follows:

A. Pre-Collegiate

Most standard high school curricula do not provide students with much exposure to engineering disciplines [17]. The pre-collegiate program is a great way to introduce the concepts of engineering to high school students and build a pipeline of high school students who are interested in enrolling in engineering and becoming ReACH scholars. The pre-collegiate program at the University of Colorado Denver provides financial support for first generation college-bound high school (HS) students to take specially designed university level courses during the summer of their HS junior and senior years [18,19]. The recruitment process for HS students is that the Pre-collegiate personnel present the specially designed summer programs to students nominated by their teachers and counselors who meet the program criteria, hand out applications to those who show interest; interview those who turn in completed applications. Selected students are then admitted into various summer programs.

During the first year of our project we designed a new multidisciplinary "*Topics in Engineering*" pre-collegiate summer course and offered it for the first time during summer 2007. Students participating in this five-week program completed two parallel engineering projects: *Game Software Automata*; *Earthquakes & Engineering* taught be a team of three instructors. The course strategy for Game *Software Automata project* is to lead students to conceptualize and analyze an interactive puzzle solving simulation system.

The premise is that this process will lead students to a greater intuitive understanding of a moderately complex system as well as an understanding of the methods of computer simulation. Weekly class periods introduce the necessary engineering concepts, any corresponding model, relevant algorithms, programming strategies, and methods for analyzing the results. The puzzle programmed is Dan Gilbert's

Table 1. *Make up of students in Pre-Collegiate "Topic in Engineering" summer course*

Year/ Ethnicity	Asian	Black	Hispanic	Native American	White	Other	Male	Female
2007	1	3	8	1	2	3	1	8
2008	0	1	3	1	3	2	6	5
2009	8	1	7				1	6
2010	3	3	6			1	7	6

The second course, *Earthquakes & Engineering*, was designed with the following engineering concepts and design objectives:

- *Prediction:* Understanding the problem and the difficulty of engineering seismicity,
- *Avoidance:* The effects of ground shaking and failure, such as motion amplification and soil liquefaction, on structures and avoidance mechanism,
- *Prevention:* Analysis of the performance of structures under strong seismic events and affordable
- destruction prevention measures,
- *Projection:* Projections of potential loss of lives and injuries, structure destruction, ground failures, and associated social, economic, and political impacts,
- *Planning:* Development of action plans to minimize all the ill impact of a strong seismic event.

Table 2. *Related family role models: Did participants have an engineer in their mediate family?*

Year	Engineers in Family	
	Yes	No
2007	1	12
2008	0	11
2009	1	16
2010	1	12

Triazzle [20] chosen especially for its combinatorial properties, within *Microsoft's XNA* [21] game programming framework. The puzzle is designed to operate in four different interactive modes, from fully automatic to fully interactive. This program flexibility shaped the design of the course by exposing multiple engineering tradeoffs involved in the building of a software solution.

II. Recruitment Data and Analysis

The makeup of the students in our Pre-Collegiate summer courses is shown in Table 1. Almost none of the students in our engineering pre-collegiate courses had an engineer in their immediate family as role models, shown in Table 2. These data show that students in the program did not have any prior exposure to engineering in their high school curricula. It was important to offer the summer program to introduce the concepts of engineering to the students.

A questionnaire to evaluate the impact of the summer course was administered at the end of the semester. A summary of the questionnaire with key responses is shown in Table 3. The data show that our class offering, in terms of content and motivating the students to consider pursing engineering disciplines improved during the four years from 38% in 2007 to 61% in 2010. Similarly we were able to better help students in their decision making on pursuing a degree in engineering from 46% in 2007 to 69% in 2010. Of interest is that at this stage many students do not consider the financial affordability of going to college as an obstacle. Our data shows that less than half of the students, considered the award of scholarships to be relevant to their decision to pursue an engineering degree in three out of the four years that the questioners were administrated. This is encouraging in the sense that introducing the right curricula and providing role models can be the an effective way to increase interest and motivation of students to consider pursuing engineering disciplines, while financial aid at the right time will enable them to follow through and complete their education.

B. Scholarships

The scholarships are awarded to fulltime students enrolled in engineering who demonstrate financial need, academic achievement, and the commitment to pursue STEM careers. In the process, students submit an application providing their transcripts and high school credentials, along with financial aid eligibility. As part of this program the university's *Financial Aid Office Representative* helps coordinate assistance to eligible applicants in completing and evaluating the *Free Application for Federal Student Aid (*known as the *FAFSA).* Moreover, the university's *Experiential Learning; Internship and Career Center Services* help with career planning, internship, Co-Operative education, and employment.

Table 3. *Impact of "Topics in Engineering "course; sample questionnaire Results*

Number of students considering…	2007 Total =13	2008 Total =11	2009 Total =17	2010 Total=13
A degree in engineering after taking this class	5	7	10	8
This class helped them to make a decision about pursuing a degree in engineering	6	6	11	9
A degree in engineering if they had scholarships	5	5	5	11

C. Academic Networking

Academic networking and social support are crucial components of the program to help ReACH students strengthen their academic and non-academic life during their college experience. Such networking and support have positive impact on the college retention and performance as well [7-10, 22, 23]. All ReACH students have access to and benefit from the following academic program supports: (1) Academic advising and orientation; (2) Faculty mentoring and advising; (3) Peer mentoring.

1) Academic Advising and Orientation.

The study has shown that an engaging and comprehensive program orientation will cultivate students' identification and connections to the academic and social culture of the college [24-26]. The *College of Engineering and Applied Science Students Services* provides specialized student advising, orientation, and services for engineering students. Furthermore, at the beginning of each semester we hold a special orientation for our scholarship students where they are introduced to their faculty mentors, the program director, and their peer mentors, each other and the university resources. As part of the ReACH program, we hold several meetings and seminars on topics related to students' interests and concerns during the academic year. The orientation reinforces students' academic goals and aspirations, emphasizes to students that they matter to the institution and will be supported as they proceed toward completion of their degrees.

2) Faculty Mentoring and Advising

Research shows that faculty-student mentoring, academic counseling and advising, and peer tutoring help improve students involvement, motivation and academic self-confidence and in turn increase levels of institutional commitment and engagement [15, 16, 27]. Our ReACH students are assigned a faculty mentor from each of the four departments in the College of Engineering from the start of their program. The students get to know a faculty member in their academic discipline where they can always seek advice on academic and related issues. The faculty member, a familiar face where students can go to when they need help, is crucial and invaluable resource for academic advising and mentoring.

3) Peer Mentoring

There is abundance of literature that supports the importance of peer mentoring and supplemental instruction. Supplemental Instructions (SI) for *Freshman* and *Sophomore* scholars focus on courses that historically have been high-risk in terms of retention [28-31]. The SI structure also provides students with a framework for studying together, recognizing that peer support can be an important long-term strategy for academic achievement. Studies indicate that across institutional types, disciplines, precollege student preparation levels, and ethnic groups, those who participate in supplement instruction consistently outperform their peers who attempt similar courses on their own [28-31]. Several of our academically outstanding student scholars take on additional responsibility for being designated ReACH mentors. These scholars provide student leadership, organization, and academic support for the entire group. They help facilitate networking among their peers and group them based on their similar classes and help them network and study together to achieve better performance toward their undergraduate study at engineering level.

To help students engage in academic activities, a dedicated website for the ReACH program has been designed. The site provides links to the ReACH program, application, summer programs, campus resources, student resources and ReACH contact information. The website provides many campuses and external resources and current events to students. ReACH scholars are featured on this website. A list of activities to choose from is provided to scholars and they are asked to participate in several of these activities. They are encouraged to complete an *industrial internship* where they can take advantage of the opportunity to apply academic knowledge to real world situations. *Undergraduate Research Opportunities* enable students to learn first-hand the underlying methodology of research and its capabilities and limitations in solving current problems. Student scholars are invited to contribute and participate in the university *Research and Creative Workshop held annually*. All ReACH scholars are encouraged to participate in *student organizations* and affiliated *professional Society*.

III. Retention Data Analysis

The status of the program through the first four years of the implementation is summarized in Table 4. The table summarizes the number of student scholars, their majors, and their undergraduate status for each year. Table 5 shows the makeup of ReACH students during the same time period.

Table 4. *The number of scholarships awarded in AY 07-8, 08-09, 09-10*

Major /2007	**Total**	**Freshman**	**Sophomore**	**Junior**	**Senior**	**Transfer**	**Status**
Mechanical Engineering	3	3					1 dropped
Electrical Engineering	2	2					1 dropped
Civil Engineering	1	1					1 changed major
Computer Science and Engineering	0						
Summary'07	**6**	**Returning: 4**					
Major /2008	**Total**	**Freshman**	**Sophomore**	**Junior**	**Senior**	**Transfer**	**Status**
Mechanical Engineering	8	3	2	3		2	1 changed major
Electrical Engineering	6		4	2		3	
Civil Engineering	4	4					
Computer Science and Engineering	1	1					
Summary'08	**19**	**Returning: 18**					
Major /2009	**Total**	**Freshman**	**Sophomore**	**Junior**	**Senior**	**Transfer**	**Status**
Mechanical Engineering	7		3	3	1		
Electrical Engineering	9		1	6	2	1	2 graduated December '09: 1 in industry; 1 in grad school
Civil Engineering	3		1	2			1 changed major
Computer Science and Engineering	2		1	1			1 dropped
Summary'09	**21**	**Returning: 18**					

Table 4. *Continued…*

Major /2010	**Total**	**Freshman**	**Sophomore**	**Junior**	**Senior**	**Transfer**	**Status**
Mechanical Engineering	6			2	4		3 graduated, all in grad school
Electrical Engineering	7	1	1	3	2		2 graduated, 1 industry, 1looking for job and plans to go to grad school
Civil Engineering	2			1	1		1 graduated, 1 industry
Computer Science and Engineering	4		2	1	1		1 graduated, 1 industry
Summary'10	**19**	**Returning: 12**					

In AY 2007-08, six students met the eligibility requirement of the program and were recruited into the engineering at different disciplines. Despite promising high school records, two of the ReACH students did not participate in the mentoring sessions, did not respond to calls for meetings, and did not meet with their faculty mentors. These two students did not perform well during their first semester and were put on academic probation and dropped out of the program. The other four students did participate and were able to benefit from the program tremendously. Of the remaining four, one changed major to Architecture and Planning. During this first year experience, we learned that students do not in general seek academic advising unless they are required to. Students seldom took advantage of available SI. To address these issues and to make sure students understand the availability of the resources, we started requiring that students read and sign a list of activity requirements at each orientation meeting in order to earn scholarship. Part of the agreement is regular meetings with faculty advisor, participation in mentoring sessions, and response to calls for meetings.

In AY 2008-09, a total of 19 scholars were admitted into the program in the four engineering departments. Eight of these students were first year (freshman) students. Two highly motivated returning scholars with outstanding academic performance were asked to become "*Peer Mentors*". Through close monitoring students' progress we noticed that two of the new recruited students were struggling in their courses and needed additional help to improve their performance. One of the two decided to change his major to *History* after his 2nd year in engineering. The rest of the students continued in good academic standing. Four of our returning scholars became peer mentors for the next academic year.

In AY 2009-2010, we had a total of 21 students. Among this group, one decided to change major to *Psychology*, one decided to drop out of ReACH and was undecided as which major to continue but stayed in school. Two students graduated, one pursing graduate school and one joined the workforce in industry. Five of our returning scholars have become peer mentors. In AY 2009-2010, we had a total of 21

Table 5. Ethnicity and gender makeup of the students in the program

Ethnicity	Number of Students	Gender	Number of Students
Asian	5	Female	3
Black	2	Male	22
Hispanic	4		
Caucasian	11		
Unknown	3		

students. Among this group, one decided to change major to *Psychology*, one decided to drop out of ReACH and was undecided as which major to continue but stayed in school. Two students graduated, one pursing graduate school and one joined the workforce in industry. Five of our returning scholars have become peer mentors.

In AY 2010-2011, the program consisted of 19 students. Three of the students were new to the program. One student changed his major to *Business School*, the remaining students continued. Seven of our scholars graduated this year. Four of these students have been admitted to graduate programs and will pursue advanced degrees. Three already had job offers before their graduations and one is searching for a job. As the program has matured and our students have reached the graduation point, it is encouraging to see these results and their success in the program.

IV. Observations and Conclusion

For ReACH program a rigorous recruitment strategy was developed that included the financial, academic and social network supports in the field of engineering. Furthermore, a pre-collegiate program was developed for high school juniors and seniors interested in entering engineering disciplines. The summer program has been an effective way to introduce engineering concepts to high school students through summer courses on engineering topics. Designing innovative summer projects at appropriate levels in each discipline or in multidisciplinary areas to augment and complement the high school curricula is effective.

There have been valuable lessons learned and important challenges faced through the design, development, and implementation stages of our program as summarized below:

- It was observed that students appear to have a different perception of what some of the engineering disciplines are. The extensive math and science requirements seem to surprise and at times disappoint them. Although this is not a general observation, it comes from counseling students who declared their majors and then decided to change majors within one to two years to non-STEM disciplines.
- The summer courses to introduce high school students to engineering projects should be encouraged and become available to a wider group of students.
- Students do not in general seek academic advising unless they are required to. Having a dedicated faculty mentor to provide academic advising and mentoring is invaluable to a student and should be implemented in each major.
- Students seldom take advantage of "Peer Mentoring" on their own; a form of community of learners that is a coherent part of their education is needed to provide a natural networking mechanism for students. When students take on the role and responsibility of being a "peer mentor", they develop a sense of leadership resulting in assuming responsibility for the success of the entire team.
- The *university steering committee* and its make-up is a natural way to organize the academic units to provide communication and coordination among different entities within the university.
- During a four year period the researchers were able to recruit and retain 22 students in four engineering majors. It is anticipated that a much higher number of students can be recruited and retained in the program if more funding becomes available.

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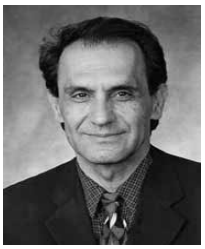

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Gita Alaghband is Professor, chair and co-director of the CSIS-PhD program in the department of Computer Science and Engineering at the University of Colorado Denver (UCD). She a senior member of IEEE Computer Society. She has been a visiting scientist at NASA, ICASE, a visiting professor at Rensselaer Polytechnic Institute, a visiting scientist at Centre European De Recherche Et De Formation Avancee Ec Calcul Scientifque, CERFACS, and a consultant with QWEST Information Technologies. As the principle investigator on the NSF ReAch (Recruiting Engineers to ACHieve) grant, she maintained an active program where she mentored and provided scholarship and networking support for over 30 academically talented engineering undergraduate scholars majoring in the four disciplines in the College of Engineering and Applied Science. She works in partnership with many local industry representatives such as Oracle, Raytheon, Avaya, IBM, Microsoft with special interest in higher education to offer cutting edge programs at the CSE Department to enhance exposure between students and industry and the program. Her research interests in parallel processing and distributed systems include application programs and algorithm design, computer architectures, operating systems, performance evaluation, and simulation.