AC 2011-1862: UNIVERSITY PARTNERSHIP WITH HIGH SCHOOL TEACHERS TO INCREASE STUDENT AWARENESS OF ENGINEERING

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University Partnership with High School Teachers to Increase Student Awareness of Engineering

Abstract

Multiple approaches to achieve increases in college enrollment and retention in engineering were explored under the first four years of a National Science Foundation funded program (grant number 0652982). The initial approach during the first year was to form a team in each of the seven engineering departments consisting of a high school teacher, a faculty member and five undergraduate students. The objective was for each team to work with the teacher to develop engineering-based curriculum modules and class demonstrations that the undergraduate team would implement in the teacher's classroom. The modules/demonstrations would then be revised as appropriate and offered to other teachers. Assessment during the first year determined that this initial approach was not as effective as desired due to an inadequate fit between the focus of the specific department and the specific teacher. A new approach was tried the second year. Seven teachers were invited to a daylong workshop where each student team presented the demonstrations and modules developed during the first year. Each teacher filled out a worksheet for each team identifying where in their curriculum specific activities would fit and also suggesting where that teacher could work with that specific team for class visits and further module development. This modified approach resulted in improved partnerships with teachers and greater opportunity for each teacher and class to become more familiar with multiple engineering fields.

The successful approach of the second year was expanded for the third and fourth years with greater than 30 teachers representing more than 20 schools attending the teacher workshop each year. This resulted in many more requests from teachers for teams to visit classrooms. To accommodate these additional requests, the undergraduate teams were increase from five students to as many as 14 for one team. This addressed another objective of the program, retention. Assessments during the first two years clearly showed that outreach participation and mentoring by college students plus the team and faculty interaction significantly increased undergraduate excitement in engineering and had a positive effect on retention.

The paper provides specific examples of the experiences of the first four years of the program regarding both recruitment and retention, describes the level of interaction with teachers, describes some of the successful modules/demonstrations that have been developed, and presents detailed quantitative assessment results.

Introduction

Utah and other states have faced an increasing shortage of engineers in recent years. A group of faculty representing the seven different engineering departments at the University of Utah met along with the Associate Dean and the Director of Outreach and Diversity in the College of Engineering (COE), a faculty member from the College of Education and a specialist in the Center for Learning Excellence to discuss this issue, explore possible reasons, and to brainstorm possible solutions. Part of the outcome was a proposal to the National Science Foundation (NSF) that resulted in a five-year grant (award 0652982) "Utah's Engineers: a Statewide Initiative for Growth", which is now in its fourth year. Another outcome that has evolved during the past four years has been a close working partnership of the NSF program team and the COE outreach team with a goal of integrating successful processes developed under the NSF program into the ongoing COE outreach activities. The following paragraphs describe the approach and progress of the NSF grant and especially some of the lessons learned that may be helpful to other universities for their outreach, recruiting and retention efforts.

NSF Grant Initial Approach

A key objective of the program was to increase awareness of high school students and teachers about engineering as a potential career and about the exciting things engineers do in each of the engineering disciplines. Figure 1 illustrates the approach that was pursued during the first year. Specific tasks included the following:

- Establish a team in each engineering department consisting of four University of Utah undergraduate students, a faculty advisor, one Salt Lake Community College (key feeder to the University of Utah engineering departments) undergraduate, one high school teacher and multiple high school students.

- Conduct a nine month effort with each team to design, construct, de-bug and demonstrate in multiple high school venues one or more curriculum modules and/or demonstrations that provide a hands-on engineering experience for high school students.

- Explore interactions with different demographics of high school students through visits to regular public school classes, a charter school focused on underrepresented students (Academy for Math, Engineering and Science - AMES), MESA clubs (also focused on underrepresented students and ethnic and gender diversity), the relatively new pre-engineering technology program Project Lead the Way (PLTW) and International Baccalaureate groups.

- Plan and implement a summer camp.

- Establish links/partnerships with community organizations to increase communications and help in the process of building a sustainable pathway of students into engineering.

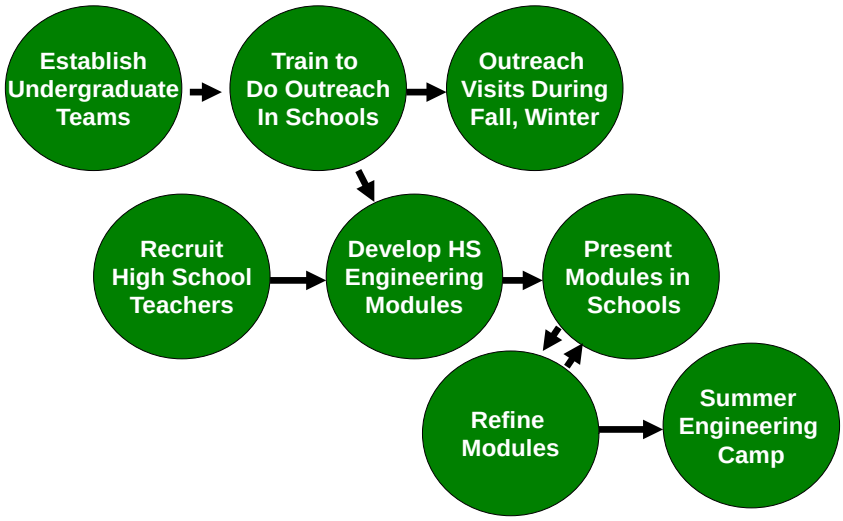

Figure 1 First year approach for engineering outreach to high school students and teachers

The first year was a learning experience. Most of the professors and students were not experienced with outreach and not aware of the curriculum requirements in the high schools. The teachers helped, but likewise lacked experience in working with university teams. High school students had difficulty working with teams because of time and transportation constraints. As a result, most of the departmental teams took some time to become effective. However, as the year progressed and everyone gained experience, progress accelerated. By the end of the school year, every team had succeeded in preparing at least one module or demonstration and had visited at least one group of high school students. Some teams developed multiple modules/demos and visited many high school venues. High school students participating in a couple of the most popular demonstrations are shown in Figures 2 and 3.

The high school students visited filled out a questionnaire (part of the assessment process) that provided feedback to the teams on the response of the students to the visit to help the teams plan and improve future visits. Some of the questions were designed for answers “strongly agrees, agrees, neutral, disagrees and strongly disagrees” so that the responses could be evaluated statistically. A few of the questions, such as goals after high school, allowed written answers to provide a more subjective and personal insight into the students’ career planning. A third portion of the survey included demographics information such as gender, ethnicity, professions of parents, and where the students go for information about colleges. The enthusiastic high school student responses showed that the teams were on the right track. Specific assessment results are discussed later in this paper.

Figure 2 High school students exploring the bounce behavior of vulcanized rubber compared to non-vulcanized rubber

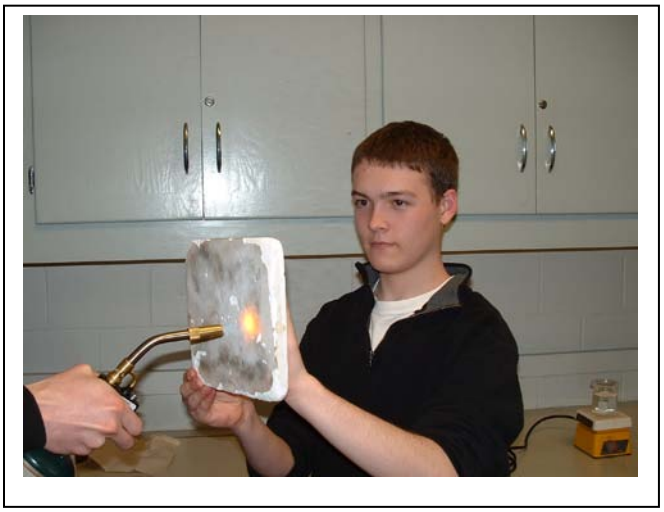

Figure 3 High school student exploring the thermal barrier effectiveness of a ceramic Space Shuttle tile

Besides the challenges of team building and training, other challenges were encountered during the first year. One of the most difficult was scheduling visits to classrooms. The class schedules of the undergraduates often (and usually) conflicted with the high school class times. However, even more significant than this was the perception of teachers. As it probably is in other states, the curriculum (standards, outcomes, etc.) for math, chemistry and physics is quite rigid in Utah such that many of the teachers that were approached were reluctant to give up any class time for a visit from a university team. In fact, even some of the seven teachers on our teams did not invite a team to visit any of their classes. The best results were with MESA clubs that met outside of normal class times and with the AMES charter school, which had a much more flexible curriculum.

Although the first year was challenging, there were some excellent highlights. One was the partnership that the Chemical Engineering Department team established with a team of about 12 juniors at AMES to conduct a year-long design project. This involved nearly weekly mentoring by undergraduates, visits by the high school students to the university, joint design project brainstorming and selection, and team implementation of the project by the high school students. The challenge that was chosen was to design an alternate cleaner (compared to diesel) mode of powering snowmaking machines for a local ski resort. The high school students formed smaller teams to compete with each other for designing the best concept. Each team then gave a formal presentation at the end of the year. The high school students loved the project and the engineering experience, and most of them entered engineering or science programs at universities after graduation. Assessment interviews revealed that the undergraduates, through their mentoring, enhanced their engineering experience and their commitment to continuing to

graduation in engineering. This partnership with AMES is an excellent model of an activity that was effective both for recruitment and for retention.

Another highlight from the first year was the summer camp. Rather than just calling it a "summer engineering camp", it was identified as a "Youth Summit on Bio Innovation". Sixty-eight high school students attended this three-day event. They got to spend about 1.5 hours in each of the seven engineering departments learning about each engineering discipline, participating in hands-on engineering activities, and especially learning what each department was doing in bio innovation. They got to meet and have lunch with graduates who were working in biotechnology and had made major inventions. Near the end of the summit, the high school students divided into three teams, met with severely handicapped individuals, and prepared their own recommendations for directions for development in biotechnology. Figure 4 shows some of the students with one of the severely handicapped individuals who was using advanced engineering technology to cope with the handicap and to live a somewhat normal professional life.

Figure 4 High school students meeting with a severely handicapped person during the summer Summit on Bio Innovation

Modifications for the Second Year of the NSF Grant

Much was learned the first year regarding what works and what does not work. The faculty principal investigators and the undergraduate teams now had a year of experience and all of the demonstrations and activities developed during the first year as a starting point. Several of the teachers identified that they had ideas of how to work engineering into their curriculum and requested to continue as part of a team. In addition, more people in the community (especially

the State Office of Education and other teachers) were now aware of the program and had heard good things about what the program had to offer. As a result, departmental teams were ready and available to visit schools much earlier in the school year, and teachers were more willing to have teams visit their classes.

A very important decision was to implement a better way of getting teachers involved in the program and at the same time become more comfortable with engineering. As in the first year, seven teachers were selected to participate. Instead of assigning one to each department team, though, the teachers were invited to a one-day workshop to become knowledgeable about all of the engineering departments and teams. Specifically, each team gave a 20-minute presentation telling about their department and conducting some of the demos/activities that had been prepared the first year for taking into classrooms. Each teacher was given a worksheet where he or she could tell which demos/activities would work in particular classes, when those classes were taught, how much class time would be made available for a team visit, and also if the teacher would like to work with a specific team to prepare a new curriculum module or demo. The teacher response was overwhelming compared to the experiences with teachers during the first year. Every teacher gave great feedback and requested multiple visits from multiple teams to fit into well-defined portions of their curriculum. This resulted in a large increase in the number of classes visited and the number of high school students exposed to engineering.

Based on the success of the Chemical Engineering team project with AMES, an effort was pursued in the second year to expand this approach. "Alternative Energy" was selected as the theme. The idea was to form teams at high schools in the Salt Lake area to each explore (and become experts on) different aspects of alternative energy while being mentored by university undergraduates on the program. Eleven teams were formed and selected the topics solar, solar thermal, wind, geothermal, tides and waves, coal, alternative fuels, nuclear, transportation alternatives, car of the future, and fuel cells. The objective was for each team to learn everything they could about the topic and the engineering needed for success in the marketplace and to prepare to lead a workshop on the topic at the second summer camp "Youth Summit on Alternative Energy". The concept of this was good. More high school students became involved for an extended time (rather than just through a class visit). However, not enough undergraduates and faculty were available on a regular basis to provide effective mentoring for each high school team. Some of the high school teams lost interest after a couple meetings, but most continued effort intermittently during the year and participate in the summer summit, which was equally as successful as the first summer summit.

Another objective of the second year of the program was to strengthen partnerships with the College of Engineering (COE) outreach team and with community partners. A number of collaborative events/activities were planned with COE including "Engineering Day" and "Meet an Inventor Day" at the university and several engineering days at various high schools. The role of the NSF teams was typically to set up demonstrations, talk with high school students individually and in small groups, and lead tours. Other collaborations with COE included a

week-long summer engineering course for teachers and the Youth Summit on Alternative Energy.

Ties to the community were strengthened during the second year as part of the long-range plan of establishing increased communications about engineering careers to k-12 teachers and students. The MESA coordinator, the secondary math specialist and the technology specialist (responsible for implementation of Project Lead the Way pre-engineering curricula) for the State Office of Education all participated on the External Advisory Board of the program. So also did the Education Director for the Governor's office plus a couple key individuals from other State universities. The Program Manager of the NSF grant was active in the key working group "Engineering Education Partnership" and was a member of subcommittees that prepared a dvd on engineering pathways and drafted a plan for a high school technical communications class that was implemented in less than a year in several school districts. The goal of these involvements has been to tie the university into an effective network of educators, business persons and government decision makers that will help in establishing and sustaining the desired engineering education pathway. The Program Manager also was invited to prepare a white paper on STEM education for the Governor's office and to present it to the Governor's Scientific Advisory Council, again strengthening the network.

Modifications for the Third Year of the NSF Grant

Further lessons were learned during the second year that prompted changes in the approach. The updated approach is illustrated in Figure 5. The major lesson learned during the second year was the teacher workshop. The third and fourth years 30-40 teachers were invited to the teacher workshop and paid a stipend to attend. All of these were new teachers that had not previously participated in the program. As during the second year, each team highlighted demonstrations/activities they could bring into classrooms and each teacher filled out worksheets for each departmental presentation identifying items the teacher would like to see brought to their classrooms. As in the second year, the response of the teachers was overwhelming. To help accommodate all of the requests, the undergraduate teams have been expanded to as many as 14 in one of the most-requested departments. Even with the increase in the size of the teams, the teams have not been able to meet all of the requests of the teachers. The big challenge has been availability of students at the times the high school classes are offered. However, by the end of the Fall Semester, as many class visits had already been conducted as for the complete previous year.

Collaboration with the College of Engineering Outreach Team

The key long range goal is to introduce children to engineering and science at an early age and nurture them throughout k-12 so that they are aware of the opportunities of a career in engineering and STEM fields and have taken the right courses to be prepared to enter a college engineering or STEM curriculum. The NSF grant specifies focus on high school students. The

COE outreach team previously emphasized high school recruiting. Having the NSF grant has allowed the COE outreach team to substantially expand into middle and elementary schools. Each year they select elementary, middle and high schools as partner schools for a whole series of activities. This leverages what can be done under the NSF grant and *visa versa*. Even more important is that the collaborations are greatly increasing the awareness and comfort zone of teachers at all levels regarding engineering. These teachers will tell their students that engineering is an exciting career and will guide their students to taking the necessary preparatory classes. These teachers also will know who to contact to bring visitors and programs to their classes.

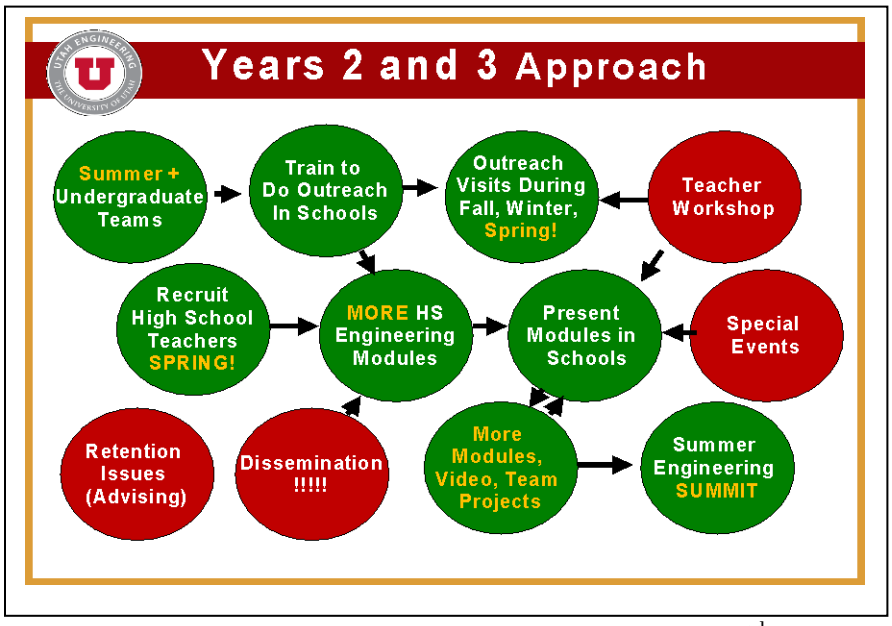

Figure 5 Modified outreach approach initiated during 2nd year

Assessment

The whole team has been involved in the assessment process. The faculty Principal Investigator (PI) from each department worked with one co-PI from the College of Education (Dr. Amy Bergerson) and one from the Center for Learning Excellence (Dr. Stephanie Richardson) to prepare the assessment plan and questionnaire. The undergraduate students then administered the questionnaire during the class visits, reviewed the responses to help improve subsequent visits, and delivered the completed questionnaires to the assessment team for statistical analysis by Dr. Bergerson and Dr. Richardson and a couple of their graduate students. For further assessment, Dr. Bergerson interviewed the undergraduate students on the teams, high school students that participated on the special projects (the Chemical Engineering project and the alternative energy project), faculty PIs, and high school teachers that attended the workshops and invited teams to their classes.

During the first three years of school visits, 56.8% of the students that filled out the questionnaire were male and 43.2% female. This was not surprising since most of the classes visited were physics, chemistry and math and had a larger male population. MESA clubs, which by nature have a larger population of underrepresented students, typically had a higher ratio of females. Ethnicity was quite mixed as shown in Table 1, although the majority was white Caucasian.

Table 1 Ethnic Distribution of High School Students Responding to Questionnaire

Student Ethnic Background	**% of High School Students Surveyed**
American Indian/Alaska Native	0.8
Asian	6.6
Native Hawaiian or other Pacific Islander	2.5
Black or African American	2.9
White	71.0
Hispanic/Latino/Latina	8.3
More than one race	5.7
Unknown/not reported	2.1

In an effort to understand a little of the family background of the high school students, one question asked for the highest level of formal education completed by each parent. The results of this are summarized in Table 2. The majority of parents were high school graduates and most had college/university experience. The primary differences were that more mothers attended two-year colleges and more fathers completed post-graduation studies. Not surprisingly, since 81.7% of the fathers and 80.1% of the mothers had college experience, the majority of high school students indicated that they planned to attend college.

Table 2 Highest Level of Education Completed by Parents of High School Students Surveyed

Level of Education Completed	% of Responses for Father	% of Responses for Mother
No high school	1.9	2.4
Some high school	3.9	2.6
High school graduate	12.6	14.9
Some college/university	18.3	22.6
2-year degree	6.7	12.6
4-year degree	35.0	31.7
Post-graduate study	21.7	13.2

A primary objective of the visits with high school students was to increase their awareness of engineering as a potential career. 74% of the students responded in the questionnaire that they were now more familiar with engineering, 68% that they could see how their high school classes related to engineering, 62% that engineering now seemed exciting, 48% that they now knew the requirements for an engineering major, and 42% that they were more likely after the presentation to choose engineering. Figure 6 compares the responses of male versus female students of all ethnic backgrounds to the survey item "I am now more familiar with engineering as a college major and career." The responses are statistically the same for male and female students. The analysis also compared the responses for males and females of each ethnic group. The results for white students were the same as shown in Figure 6. The results for all other ethnic backgrounds were similar, but did include a few more responses in the "disagree" and "strongly disagree" categories.

The same assessment survey was filled out by students attending the summer camps during registration and after the camp. The results are summarized in Table 3. Many of the students that attended the 2008 summer camp heard about the camp during class visits, which probably explains why the ratings at registration were so high. Major effort was expended for the 2009 summer camp to recruit high school students whose class had not been visited and also to include more underrepresented students. According to the registration survey, their knowledge of engineering was lower. The key point, though, is that the summer camp was very effective at giving all the attendees a much better understanding of engineering and an increased interest in choosing engineering as a major in college.

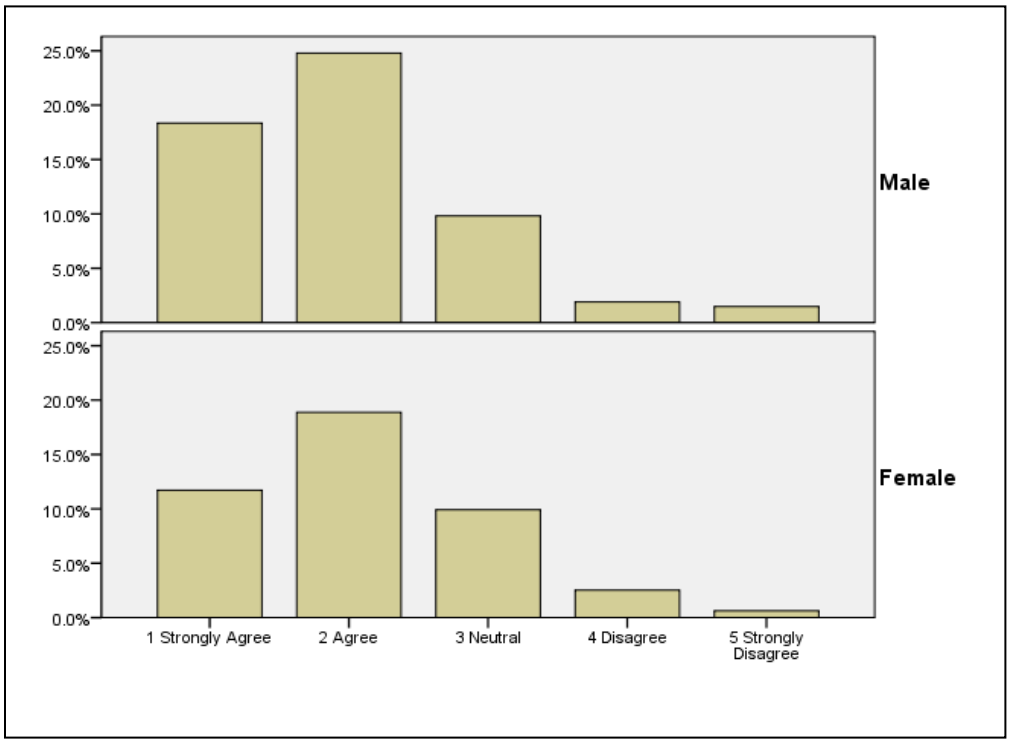

Figure 6 Comparison of the responses of male versus female high school students to the survey item "I am more familiar with engineering as a potential college major and career"

Table 3 Assessment Survey Results for Students Attending the Summer Camps

Year/Question on Survey	Response at Registration (% who agreed)	Response after Summer Camp (% who agreed)
2008—Familiar with engineering	72	100
2009---Familiar with engineering	59	92
2008---Likely to choose engineering as a major and career	59	90
2009---Likely to choose engineering as a major and career	53	67

A couple other items on the survey provided additional insight into the response of the high school students to the class visits and the information presented. To the survey item "The presentation was interesting", a large majority of the high school students listed "strongly agrees" or "agrees". This was good validation that the undergraduate teams were effective in their presentations. To the question "Would you now consider engineering as a career?", most of the students took time to write a thoughtful response. This was a good indication that the students really were listening and appreciated the opportunity to learn more about engineering as a potential career option. Some students responded enthusiastically and even identified a particular engineering field of interest. Others stated engineering was not right for them, and many students clearly identified the field they already were planning on pursuing.

Another important aspect of assessment was interviews. Teachers were interviewed after the workshops and also after teams visited their classes. Physics and chemistry teachers were delighted. They loved the hands-on activities, the linkage of the demonstrations and presentations to the core curriculum, and the interaction of the undergraduates and faculty with the high school students. These teachers stated that they were much more comfortable with engineering and integrating engineering into their classroom, as well as recommending to their students to consider engineering. One physics teacher was so energized that he trained a team of his high school students to visit elementary and middle schools to get those students excited about physics and engineering.

Math teachers were more of a challenge. They had difficulty seeing where the engineering demos and presentations would fit into their classes. The solution to this was to link teams, professors and individuals with the teachers to work together to devise lesson plans that did meet the teacher's needs. This is still a work in progress.

Interviews with high school students were conducted by Dr.Bergerson during summer camps and with students involved in the special long-term projects (ski lift power project and the alternative energy teams). All of the students responded that the involvement in projects and the mentoring of college students increased their interest in engineering as a career.

Interviews with undergraduate team members revealed a very strong impact on retention that can best be related through direct quotes. The team interaction helped students connect better with faculty. One student stated "I didn't know the kinds of things our professors were involved in until I worked with the team. They are doing really cool stuff, and important too." A second recurring theme was better connection with course concepts. "I like the opportunity to do hands-on things. It helps ideas we're talking about in class come to life and makes me more excited about what we are learning." Preparing demonstrations and presentations for high school students also increased commitment to engineering. "Talking about engineering with high school students has made me more excited about engineering." Finally many of the undergraduate students stated that the program had a strong impact on their career plans. A significant number of students who had not planned on attending graduate school changed their

minds and are now working on advanced degrees. One student confided "The experience has increased my interest in going to graduate school and becoming a teacher myself."

Summary of Impact on Recruitment and Retention

Firm statistics are not yet complete enough to conclusively show that the program has met the objectives for recruitment and retention, but all the preliminary information is pretty encouraging. Table 4 identifies the increase in number of high school students and teachers that received engineering experiences during the first three years of the program through outreach by the teams. This was leveraged by a parallel large increase in outreach by the College of Engineering. Table 5 shows the College of Engineering enrollment for the 2004/2005 through 2010-2011 school years. The numbers were up and down in the range 2000 to 2134 students during the three years prior to the NSF program, but have shown a steady increase since the program started at the beginning of the 2007/2008 school year with a substantial jump for 2010-2011. The number of BS graduates also has increased from 360 in 2007 to 377 in 2008 to 407 in 2009. Currently efforts are in progress to better track individual students and better understand which factors of our recruiting and retention approach have been the most effective.

Table 4 Increase in High School Students and Teachers Contacted Under the NSF Grant During the First Three Years

	2007-2008	2008-2009	2009-2010
Students	389	1197	>2500
Teachers, Principals, Counselors	32	97	>150

Table 5 College of Engineering Enrollment

School Year	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011
Undergraduate Enrollment	2134	2000	2099	2047	2167	2298	2615

Conclusions

Government programs can be a great aid in exploring ideas for improving engineering education and a catalyst for quickly implementing the best practices that are identified. Much has been learned under the NSF grant "Utah's Engineers: a Statewide Initiative for Growth". High school students responded favorably to visits by undergraduate engineering teams presenting upbeat activities, "wow"

demonstrations, and discussions about how things important to high school students work. Surveys, interviews and enrollment numbers indicate that the outreach activities are having a positive effect on recruitment, although we need two more years of data and student tracking to be sure. In addition, high school teachers are gaining comfort in their knowledge of engineering and in inviting engineering teams to present core curriculum topics in the classroom. Workshops for teachers have been an effective venue for increasing awareness of teachers and helping these teachers become an important link in efforts to better inform high school students about engineering and engineering careers. Finally, the participation of university undergraduates on teams to prepare outreach modules and present them to high school students and teachers has clearly increased the excitement of the undergraduates in engineering and benefited retention.

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