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A Project-Based Engineering and Leadership Workshop for High School Students

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ABSTRACT

Summer outreach programs provide pre-college participants an introduction to college life and exposure to engineering in an effort to raise the level of interest and bring more students into engineering fields. The Junior Engineering, Mathematics, and Science (JEMS) program is a project-based summer workshop in which teams of high school students complete a design project on a topic such as robotics, rockets, or alternative fuel vehicles. The summer workshop includes courses that integrate learning about science, mathematics, engineering, technology, leadership, and teamwork within the context of the design project. Students also participate in engineering laboratory tours in order to expose them to a variety of engineering disciplines and possible careers. In this article we describe the program structure and findings from ten years of student questionnaires.

Key Words: Pre-engineering education, design project, teamwork and leadership.

INTRODUCTION

Since the publication of "A Nation at Risk" [1], schools have reinforced the curriculum to include more science and mathematics. In response to the rapidly growing imbalance between supply and demand of technically skilled workers [2], colleges are attempting to attract more and more of the brightest students to STEM fields in order to meet the demands of American industry. As the generation educated in the 1960s and 1970s prepares to retire, our colleges and universities are not graduating enough scientific and technical talent to replace them [2]. In 1980 the United States held 73 million tertiary degrees or about one third of the world's degrees broadly equivalent to a U.S. baccalaureate. By 2000, the U.S. held 194 million tertiary degrees, but this translates to only a one-quarter share of the world's tertiary degrees [3].

Today's engineering employers are not only requiring technical skills, but also highly value teamwork capabilities in new hires. A study conducted by the American Society of Mechanical Engineers (ASME) found that mastery of teamwork and communication skills were the top desirable attributes of graduating engineering students [4]. Similar professional skills are outlined in the Accreditation Board for Engineering and Technology *Engineering Criteria 2000* [5]. These include the ability to function on multidisciplinary teams, an understanding of professional and ethical responsibility, and the ability to communicate effectively [6]. In Martin's [7] study based on self-efficacy of currently employed chemical engineers, "half of the participants described teamwork as a major part of their jobs, with time spent in teamwork ranging from 60 to 80% of the working day." According to Adams [8], "When utilized effectively teamwork has been shown to lead to an increase in productivity, a reduction in costs, a rise in employee involvement, and a flattening of the organizational structure." Employers report that most engineering graduates, although astute and well prepared technically, lack the ability to function effectively in teams [9].

The National Science Board (NSB) sponsored workshops in the fall of 2005 and 2006 focusing on improving engineering education. One of the key challenges identified was retention of engineering students in college programs. The board recommended that the NSF should consider supporting programs that inform pre-college students about engineering [10]. Pre-engineering summer programs provide students interested in Science, Technology, Engineering, and Mathematics (STEM) related fields an opportunity to explore a number of topics in engineering. Programs that expose students to engineering experiences and/or projects early might have a greater chance of both enticing students to persist and interesting them in specific sub-fields of engineering [11]. In an editorial in the Journal of STEM Education Watkins [12] wrote, "A strong workforce in science and engineering and literate citizens in a technological-based society begin with pre-college education." High school summer programs may help incoming college freshman make a more "educated" choice when selecting their major area of study.

The University of Idaho's Junior Engineering, Mathematics, and Science (JEMS) program is a project-based summer workshop in which teams of high school students in grades 11 and 12 complete a design project on a topic such as robotics, rockets, or alternative energy vehicles (http://www.uidaho.edu/engr/jems/fast-facts). JEMS provides pre-college students an introduction to engineering through the study of real-world problems within their technical and social contexts. The summer workshop includes courses that integrate learning about science, mathematics, engineering, technology, leadership, and teamwork within the context of the design project. By working in teams on the design project students build peer relationships and learn teamwork and leadership skills integral to the engineering field as well as overall college and career success. JEMS allows students to experience life as a college student and become more informed about college major choices and eventual career choices in STEM fields.

Previous summer engineering programs for high school students have primarily focused on exposing students to engineering in order to increase recruitment into engineering fields [13, 14]. This program provides a unique approach by incorporating a team-based design project along with specific attention to STEM content and teamwork/leadership skills in order to recruit students to engineering while better preparing them for participation in the discipline. In this article we describe the program structure and findings from ten years of student questionnaires. By analyzing the results of the student questionnaires we provide a students' perspective of their experiences and the impact of the workshop on their learning and future college and career choices.

PROGRAM DESCRIPTION

The JEMS program started by Ron Byers in 1967 at the University of Idaho, College of Engineering in Moscow, Idaho is one of the longest running K-12 outreach programs in the country. Initially the program was affiliated with the Junior Engineering Technical Society (JETS) and focused on computer science. During the 1980's the program was expanded to include the application of engineering principles, offering courses in engineering design, computer-aided drafting (CAD), human factors, and leadership training. Starting in 1996 JETS evolved into the JEMS Summer Workshop. The goals of the summer program are to improve student understanding of engineering and related fields of study as well as improve leadership and teamwork skills. The two-week summer program is designed to expose students to engineering problems within technical and social contexts and attract students into university engineering programs ultimately facilitating a career choice in an engineering field. The summer JEMS workshop integrates engineering design projects with STEM content courses, leadership classes, and lab tours focused on different engineering disciplines.

The engineering design projects are the primary component of the workshop bringing the entire two-week program into focus and allowing students to see the connection between engineering and solving real world problems. Student teams work on design, construction and testing of an assigned project to meet a need. A design project is chosen for the challenge it will provide and the high level of interest it holds for the students. Past projects have included robotics, alternative energies, bridges, turbines, trebuchets, rockets, and alternative energy vehicles (Figures 1–3). During the design process students use computer programs such as modeling software to assist with their project design as well as preparing visual aids and posters for their final project presentation. A different project is chosen each year to prevent a student from having to repeat a project if attending in consecutive years. Some projects are used in multiple years, but are redesigned in order to take advantage of new technologies and innovations available or to address an engineering problem in a new and different way.

At the conclusion of the design project students test their designs to determine which team's project best meets the design criteria. For example, during a rocketry design project students' rockets were required to carry a set payload to a specific height. Students developed their own test parameters to evaluate and improve on their rocket's performance culminating in a competition to demonstrate their rocket's ability. Following this, each group makes a presentation to the other workshop participants, faculty and staff, and invited guests including parents. This presentation consists of a demonstration of their project and a poster or other visual aids to explain their design process, rationale for the particular design selected, and final results of the design project (Figure 4).

The summer workshop includes STEM content and leadership courses designed to support students' successful completion of the engineering design project. Workshop courses integrate science, technology, engineering, mathematics (STEM), teamwork, and leadership and are taught by a collaborative group of faculty, staff, graduate students, and undergraduate engineering student mentors. Course topics include engineering design, engineering physics, computer-aided design, mathematics, science, problem solving, and introductory engineering. Each year additional courses

Figure 1. Rocket Engine Design Project.

Figure 2. Alternative Energy Vehicles Design Project.

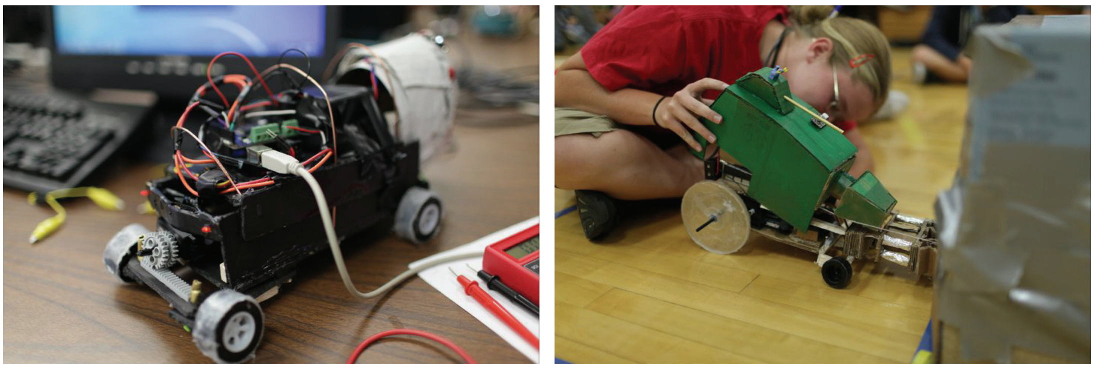

Figure 3. Crash-worthy Intelligent Vehicles Design Project.

are added that specifically relate to the design project such as environmental engineering, computer programming, or robotics. For example, when the design project was a trebuchet, the content classes addressed mathematics and science concepts such as projectile motion, inertia movements of levers, engineering methods and ideas like structural analysis of loads and forces, technological ideas of wood construction, connectors, and the use of computer-aided design software. These courses highlight how engineering problems require use of mathematical techniques, scientific theories, and technological innovations that in turn inform each other.

Leadership courses focus on teamwork, collaboration, communication, responsibility and trust. While working on design projects students are required to cooperate and problem solve as members of a successful team by applying techniques they have learned in leadership courses. Students

Figure 4. Design Project Presentation.

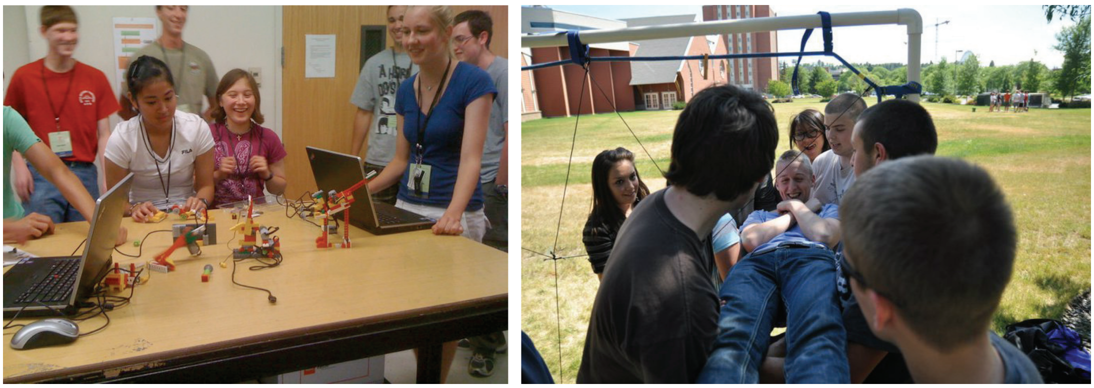

Figure 5. Teamwork and Team Building Activities.

participate in team building exercises as they attend leadership classes to help them understand the importance of different roles within a group (Figure 5). They learn about the various roles required of team members, why these roles are important, and how they help to create a successful team. Teamwork and leadership skills help students to reinforce the engineering principles learned during the workshop and help their team work more effectively.

Students also participate in lab tours in which professors and graduate students provide an introduction to each specific field of engineering, possible career opportunities, and the types of college courses required for a degree. Lab tours consist of a tour of the facilities, demonstrations, and hands-on lab work where students work at computers or carry out experiments related to the research conducted in that lab. For example, in an electrical engineering lab, students rotated through an interactive lab station making a light show circuit, while in a chemical engineering lab they used silicone to make a glowing bouncy ball.

The two-week residential workshop includes living in the dorm, eating meals in a campus dining hall, and learning what life might be like as a college student, all the while being supervised by university faculty and counselors. Extracurricular activities allow participants to socialize and enjoy meeting other students with similar interests while participating in barbecues, pizza parties, field trips, and having access to university recreational facilities.

Figure 6 shows a typical schedule during the two-week workshop. The STEM content courses and associated labs, leadership classes, lab tours, and components of the design project are integrated throughout the two-week schedule. Also included in the workshop schedule are design project work periods, field trips, and social activities to offer a balanced agenda of work and study for a fun and memorable camp experience.

FINDINGS FROM TEN YEARS OF STUDENT QUESTIONNAIRES

Data collection took place through student questionnaires administered to participants at the end of each summer workshop. This paper presents results from ten years of student questionnaires collected from 1998 through 2008. A total of 356 students responded to questionnaires over these ten years. The questionnaires were designed to assess student perceptions of the workshop, including what the students felt was worthwhile, what they would change about the workshop, and what they liked or didn't like about the design project. They also asked students to identify how the workshop impacted their teamwork and leadership skills and intended college major choice. The questionnaires consisted primarily of single response or yes/no questions, followed by prompts for students to explain their answers. The prompts were used to allow participants to describe their experiences and perceptions in detail. The open-ended responses were compiled, coded and analyzed for trends. Due to slight changes to the questions in the questionnaires over the 10 years and some data that was not archived, not all data is available for all questions for all of the years between 1998 and 2008. This is noted in the following discussion where appropriate.

Student Feedback on the Design Project

An overwhelming majority of the students reported that the design project was a worthwhile, rewarding experience. Between the years 1998–2007[1] the JEMS participants were asked to identify whether or not they found the design project to be interesting. Ninety-two percent of the

[1] Data was unavailable for this question for 1999, 2000, 2003, and 2008.

Date/Time	Activity
Monday, July 13	
8:00 – 8:20 a.m.	Welcome & Program Overview
8:20 – 8:40 a.m.	Group Photo
8:45 – 10:00 a.m.	Project/Class Overview
10:05 – 10:40 a.m.	Intro to Engineering
10:45 – 11:20 a.m.	Alternative Energies
11:25 – 12:00 p.m.	Computer Modeling/ CAD
12:00 – 1:00 p.m.	Lunch
1:15 – 2:25 p.m.	Leadership
2:35 – 3:45 p.m.	Introduction to the Library
3:55 – 4:40 p.m.	CAD LAB
4:45 – 5:30 p.m.	Electrical Lab
5:30 – 7:00 p.m.	Pizza Party
Tuesday July 14	
8:15 - 9:25 a.m.	Intro to Engineering
9:35 – 10:45 a.m.	Alternative Energies
10:55 – 12:00 a.m.	Computer Modeling/CAD
12:00 – 1:00 p.m.	Lunch
1:15 –4:45 p.m.	Leadership
5:00 - 6:00 p.m.	Team Work Time
6:00 – 7:00 p.m.	BBQ
Wednesday, July 15	
8:15 - 9:25 a.m.	Intro to Engineering
9:35 – 10:45 a.m.	Alternative Energies
10:55 – 12:00 a.m.	Computer Modeling/CAD
12:00 – 1:00 p.m.	Lunch
1:15 – 3:00 p.m.	Electrical Lab
3:30 – 4:45 p.m.	Gear Lab
5:00 – 6:00 p.m.	Dinner
Thursday, July 16	
8:00 - 9:05 a.m.	Intro to Engineering
9:15 – 10:20 a.m.	Alternative Energies
10:30 – 11:35 a.m.	Computer Modeling/CAD
11:45 – 12:00 p.m.	Project Assignment
12:00 – 1:00 p.m.	Lunch
1:00 – 2:30 p.m.	Transportation Lab
2:30 – 4:00 p.m.	Project Design Time
4:00 – 5:00 p.m.	Group Work Time
5:00 – 6:00 p.m.	Dinner
Friday, July 17	
8:15 - 9:25 a.m.	Intro to Engineering
9:35 – 10:45 a.m.	Alternative Energies
10:55 – 12:00 a.m.	Computer Modeling/CAD
12:00 – 1:00 p.m.	Lunch
2:00 – 3:30 p.m.	Field Trip to Schweitzer Engineering
4:00-5:00 p.m.	Group Work Time
5:00 – 6:00 p.m.	Dinner
** Preliminary designs and list of materials due by 5:00 pm*	

Date/Time	Activity
Monday, July 20	
8:00 – 9:45 a.m.	Computer Modeling/CAD
10:00 – 11:45 a.m.	Start Building Vehicle
12:00 – 1:00 p.m.	Lunch
1:00 – 2:15 p.m.	Lab Tours
2:30 -3:45 p.m.	Lab Tours
4:00 – 5:00 p.m.	Team Work Time/ Building Vehicle
5:00 – 6:00 p.m.	Dinner
** Rough draft of presentation due at 5:00pm*	
Tuesday July 21	
8:00 – 9:45 a.m.	Computer Modeling/CAD
10:00 – 11:45 a.m.	Start Building Vehicle
12:00 – 1:00 p.m.	Lunch
1:00 – 2:15 p.m.	Lab Tours
2:30 – 5:30 p.m.	Team Work Time/ Building Vehicle
6:00 – 7:00 p.m.	BBQ
** Rough draft of poster & final report due at 5:00pm*	
Wednesday, July 22	
8:15 - 9:25 a.m.	Intro to Engineering & Alternative Energies- Tests
9:35 – 10:45 a.m.	Computer Modeling/CAD - Test
10:55 – 12:00 a.m.	Final Vehicle Build/ Testing
12:00 – 1:00 p.m.	Lunch
1:00 – 5:00 p.m.	Final Vehicle Build/ Testing
5:00 – 6:00 p.m.	Dinner
5:00-7:00 p.m.	Vehicle Testing & Modeling
Thursday, July 23	
8:00 – 11:45 a.m. Report,	Adjust Vehicle for Testing, Finalize, Poster, & Presentation
12:00 – 1:00 p.m.	Lunch
1:00 – 4:00 p.m.	Alternate Energies Vehicle Competition
4:00 – 5:00 p.m.	Evaluations
5:00 – 6:00 p.m.	Dinner
6:30 – 10:30 p.m.	Finish Presentations
Friday, July 24	
7:00 a.m.	Final Report and Poster Due
8:00-9:30 a.m.	Check-out
9:30 – 10:00 a.m.	Vehicle Demonstrations & Poster Fair
10:00 – 11:20 a.m.	Presentations
11:30 – 12:30 p.m.	Graduation
12:30 – 1:30 p.m.	Picnic
1:30 – 2:30 p.m.	Optional Campus Tour

Figure 6. Sample Two-week Schedule for JEMS Workshop.

students responded positively to this item on the questionnaire. These predominantly positive evaluations provide encouraging feedback and describe a motivating and engaging learning environment.

Starting in 2005, students were asked to explain why they did or did not find the design project interesting. Common themes that emerged from the analysis of these responses included (a) the ways that the design project increased their understanding of engineering and provided a real application of what they had learned, (b) the opportunity that the project provided to design, build, test, and revise, and (c) the value of the challenge and competition that was a part of the design project. Students also described some challenges and frustrations related to specific design projects.

Understanding and Application

In their responses, students often discussed how the design project allowed them to learn more about engineering and involved an actual application of what they were learning. For example, one student stated, "I liked the fact that it taught us what was involved in engineering" (Rockets, 2008). Other students described specific ways that they were able to apply learning from their classes, "The design project tested a group's knowledge to manipulate slopes, learn new technologies, and cope with challenges" (Robots, 2007). Students also described the ways that the project brought together the various things they had learned, such as one student who stated how the project had "Helped pull all concepts together" (Trebuchets, 2005). Students who participated in the workshop in 2006 when the design project was related to alternative energy vehicles also commented on how what they learned was relevant to real world issues, "the project is a modern day issue that we as engineers may have to face in our future" (Alternative Energy Vehicles, 2006). Finally, one student summarized the learning that occurred with the design project as follows, "It made us the engineers and let us learn the processes in a way that applied the things we'd learned in other classes" (Robots, 2007).

Design, Build, Test, and Revise

Each year students were provided with a design challenge that required each team to design a solution to the problem, build and test their designs, and redesign in order to improve their designs. Students often commented about the value of being able to actively engage in each of these aspects of the design process. In regard to design, one student stated, "I liked rockets because it's the first time I could actually play with them to create my own design" (Rockets, 2008). Students also enjoyed the opportunity to actually engage in the hands-on aspects involved in building the projects, "I liked the fact that I was able to use my hands" (Rockets, 2008). Finally, many of the students described the value of having an end goal that they were working towards and getting to test their designs and see how well they accomplished that goal, whether it was how well their rockets flew or how far they could launch a three-pound ball with their trebuchet. As one student stated, “It was nice to have an ultimate goal in sight and to see how the different parts of the project came together” (Trebuchets, 2005).

Challenge and Competition

Each design project involved a design challenge and resulted in a final competition among the teams to determine whose design best met the criteria of the challenge. Students often commented about the value of the challenge involved in creating a design to meet specific criteria. One student stated, “Working on a team to accomplish a goal by a deadline was very fun” (Trebuchets, 2005). Students involved in building robots in 2007 also described how the competitions challenged them to problem-solve, “Competitions were challenging which was great – I love to use creativity to solve a complex problem” (Robots, 2007). Another student described how the project, “presented many new challenges and encouraged me to view the situation in new ways” (Robots, 2007).

Dislikes Regarding the Design Project

The JEMS design projects often involved a large amount of problem-solving and real-world constraints, such as time and materials. Although students generally enjoyed the design projects, their comments revealed some frustrations and challenges that they experienced in regard to particular projects. For example, in 2008, students made their own rocket engines rather than using commercial engines. This presented students with a challenge when some engines repeatedly failed or exploded. Approximately 29% of the students cited inconsistent materials as an issue, while another 17% expressed a need for more time to better address potential problems. In 2007, the robotics design project consisted of a large amount of programming leading to 35% of students saying the program was too difficult or they were frustrated. The alternative energy vehicles of 2006 and the trebuchet project in 2005 were very popular, well-liked projects with few negative comments related to these design projects.

In planning the design projects for the JEMS workshops and reflecting on the successes of each year’s project it was important to examine the student comments related to the level of challenge and time constraint the students expressed. When designing such a project it is necessary to find the right balance in regard to these issues. Material limitations and time constraints are part of the realities of engineering design that are important for students to experience. However, if the requirements of the project become too difficult, the materials too unreliable, or the time limitations too constraining, then students may not be able to fully experience all aspects of the design process and they may miss out on seeing the application of the concepts they are learning to the project itself.

Impact on Teamwork and Leadership Skills

Overall data compiled from 1998 to 2007 showed that the majority of students felt that the JEMS program improved their ability to work as a team member, their understanding of leadership skills,

Question	Years data collected	N	% positive response
Has JEMS improved your ability to work as a team member?	1998, 2000-2002, 2004-2007	271	80
Did JEMS change the way you will interact with people in the future?	1998, 2000-2002, 2004-2007	263	60
Has JEMS improved your understanding of leadership skills?	2006-2007	50	80

Table 1: Impact of JEMS on Teamwork and Leadership Abilities.

and changed the way that they will interact with people in the future (Table 1). In addition, when asked to describe the most valuable piece of information that they received from the JEMS workshop as a whole, 20% of the students stated that what they had learned about the role of teamwork in engineering was the most valuable thing they had gained from the workshop.[2]

Between 2005 and 2007 students were also asked to explain their responses to these three questions and the responses were analyzed to identify the specific ways in which students described the impact of JEMS on these professional skills. The ideas that students discussed in their responses to these questions often overlapped and therefore were examined together for this analysis. Student responses suggest that involvement in the group project and the associated leadership classes provided an important learning experience that resulted in growth in a variety of teamwork and leadership skills.

Students described how their experiences at JEMS supported their development of teamwork and leadership skills by placing them in a context in which they were required to work with others. As one student stated, “I had to do group tasks where efficient teamwork was an absolute necessity, an experience I hadn’t had previously.” Another student described how the experience of living on site during the workshop also encouraged them to interact and support others as they worked on their design projects, “Living in a dorm was weird but awesome for socialization. Sharing, lending other groups a hand or ideas or materials, working together.” Student comments also suggested that things they learned in the leadership classes directly supported development of these skills. One student described how she used what she had learned in the leadership classes to address specific issues she encountered, “I related some problems to simple issues I learned in the leadership classes.”

Examination of the students’ comments also shows the specific ways in which the JEMS project impacted students’ teamwork and leadership skills. Through the JEMS project students

[2] Data from 1999, 2003, and 2008 was unavailable for this question.

learned the importance of communication, the value of recognizing the similarities, differences, and strengths that each group member brings to the task, and the complexities of teamwork and leadership.

Communication

Students described how JEMS improved their abilities to communicate, made them more aware of various forms of communication, and more willing to make the effort to communicate effectively. Some commented, "No one is the same, communication is vital", "I learned to shut up sometimes and listen to others ideas and try them", and "I take more effort to communicate effectively with others." A number of students also described how their experiences in JEMS made them more confident and able to speak up for themselves in group-settings. For example, students stated that, "You have to speak up when you want to be heard" and "It made me more comfortable sharing my ideas". When asked about the most valuable piece of information that they received from the JEMS project one student stated, "As an engineer, communication is important. Without effective means to communicate, problems of society would not be solved."

Drawing on the Strength's of Group Members

Students also described the importance of being open-minded to other's ideas and recognizing the strengths that each group member brings to the task. This involved learning to trust in others' abilities and recognize that group members might be able to contribute something that the individual can't. Students stated that, "I will try better to find the strengths in people to work better with them" and "Sometimes you have to realize that someone has a better understanding than you in certain areas." One student described how he/she benefitted from working with other students that had similar interests, yet also acknowledging each other's individualism:

> Here we all thought math and science is fun… It was wonderful to know there are others like you. At the same time we were different enough to feel original. We achieved the highest level of social interaction; we were individuals in a group.

Recognizing the Complexities of Teamwork and Leadership

Student comments showed that participation in the group projects in JEMS helped them better understand the complexities involved in working in teams. Students described how they learned to take responsibility and yet also distribute and share responsibilities with other members of the group. For example, students described this in the following ways, "It has helped me learn to step up or step back and keep giving full effort, even when terribly exhausted", "I learned to depend on someone besides myself to work and participate", and "I've learned to ask for help if I need it." Students also described how they had learned that part of teamwork and leadership involves flexibility in regard to leadership roles. As the following students stated, "I learned that sometimes you need to let someone else take control", "It has helped me learn when to lead and when to follow, as well as to improve my compromising skills", and "You can't automatically take charge of a situation, but have to work with your teammates to lead."

Students also recognized that teamwork would not always be easy and through this experience they learned how to work through difficult situations that may arise when working in teams. This is evident in the following student comments, "Experience how to handle other people at bad times", "I am more patient with incompetence", and "Taught me that not all people will be easy to get along with and how to deal with them." Overall, these comments show the students' understanding of the complexities of teamwork and leadership. Students' experiences in JEMS helped them see that teamwork requires a delicate balance of leadership, communication, collaboration, and compromise.

Impact of JEMS on College Major Choice

On the questionnaires, students were asked what their college major choice was at the beginning of the JEMS workshop and then what it was at the end of the workshop. Each participant's response was coded into one of three categories: some type of engineering, a field other than engineering, or "undecided." Chi-squared analysis was then computed, to test for an association between participants' aspirations for undergraduate majors before JEMS versus after JEMS. Results indicate a statistically significant pre-post change ($\chi^2(4, N = 263) = 123.576, p < 0.001$) with participants' interests trending toward pursuing degrees in engineering. The majority of participants (N = 173) began JEMS indicating a desire for an undergraduate major in some type of engineering. Of these, 155 (89.6%) still indicated a desire to major in some type of engineering after participation in JEMS, 9 (5.2%) changed their response to a major other than engineering, and 9 (5.2%) changed their response to "undecided." A substantial number of participants (N = 44) began JEMS indicating a desire for an undergraduate major in an area other than engineering. Of these, 25 (56.8%) still indicated a desire to major in an area other than engineering after participation in JEMS and 2 (4.5%) changed their response to "undecided." However, 17 (38.6%) of those students who initially indicated an interest in a field outside of engineering changed their response to indicate an interest in pursuing a degree in some type of engineering after participating in JEMS. A substantial number of participants (N = 46) began JEMS indicating they were "undecided" with respect to undergraduate major. Of these, 19 (41.3%) still indicated they were "undecided" after participation in JEMS and 6 (13.0%) changed their response to indicate an interest in a field other than engineering. However, 21 (45.7%) of those students who initially indicated they were "undecided," changed their response to indicate an interest in pursuing a degree in some type of engineering after participating in JEMS. Overall, the substantial majority (N = 193, 73.4%) of participants indicated interest in pursuing a degree in engineering after JEMS and a significantly greater proportion of participants changed their degree interests to engineering from undecided or some other field (N = 38, 14.4%) than vice versa (N = 18,

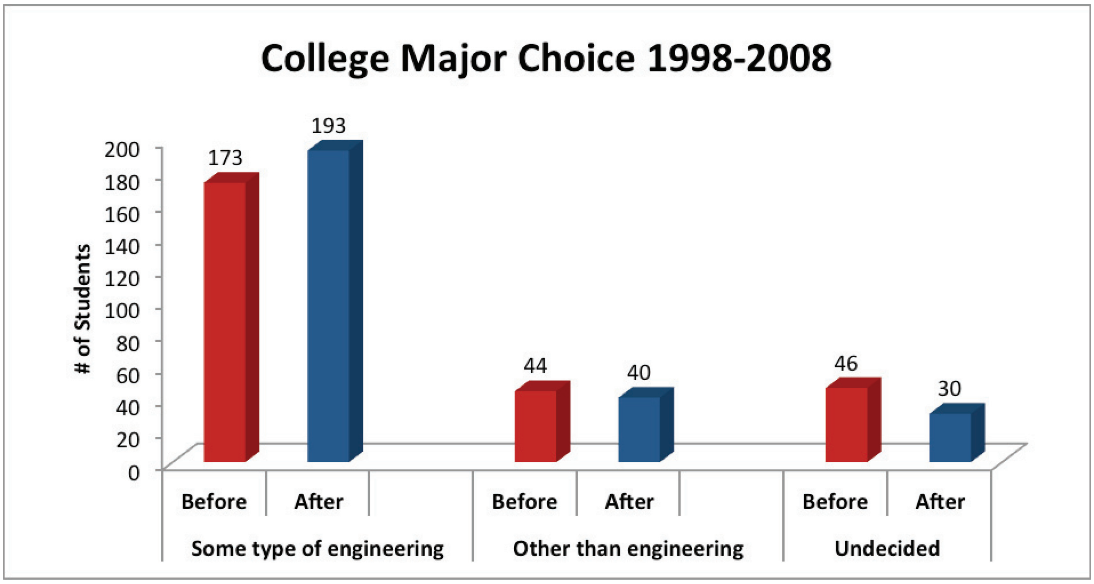

Figure 7. College Major Choice 1998–2008.

6.8%). Figure 7 shows the cumulative data collected between 1998 and 2008 indicating students' intended choice of college major before and after the workshop.

On the questionnaire, students were also asked to explain their choices for their intended college majors. Students' comments on the questionnaires indicated that their experiences in the workshop, including the lab tours, gave them a clearer picture of what engineering is, what their possible engineering career options might be, and how engineering applies to the real world. The lab tours, projects, and classes encouraged a number of students who were undecided about a college major when they came to JEMS to pursue engineering. For example, one student who changed from undecided to electrical, civil, or mechanical engineering stated, "I liked these labs and really enjoyed the projects we did in these labs." Another student who started out undecided and after the workshop decided to pursue chemical engineering stated that his decision was "not set in stone, some other types of engineering we experienced here were fun and interesting."

While the majority of the workshop participants already had an interest in engineering, not all of these students were still interested in an engineering major at the conclusion of the program. Of the 173 students who were planning to major in engineering prior to the JEMS workshop, 4.5% (n = 8) changed to another major. One participant who changed to a major in math education commented, "I discovered engineering didn't work for me. There wasn't enough of it that interested me." Another 4.5% (n = 8) of these students left the workshop undecided as to a college major choice.

One stated, "Probably not engineering, it wasn't really what I thought it was." For these students the experience of JEMS helped them determine that engineering was not the correct path for them and they left the JEMS workshop with a better understanding of what engineering entailed and how it matched with their interests.

For many students who came to JEMS already interested in engineering, the workshop helped clarify, change, or reinforce their decisions about what areas of engineering to pursue. For example, a student who was initially interested in mechanical engineering changed to electrical engineering and stated that "Well, the EE lab was really cool and I like how things worked in there. It made sense to me. I could picture myself doing it." Another student who changed from engineering in general to computer engineering stated, "JEMS has helped to focus my broad aspiring to be an engineer to the type of engineer I want to be with the microcontrollers." A student who entered JEMS interested in mechanical engineering stated that at the end of the project, "my interests in it are still the same if not stronger."

Impacts on Student Learning, Understanding of College, and Personal Growth

In order to further understand what students gained from their experiences in JEMS, the questionnaires asked about what students found worthwhile and valuable about their experiences and things that they would change. Ninety-six percent of students who participated in JEMS between 1998 and 2007 felt that it was a worthwhile experience.[3] When asked what they felt was worthwhile and what was the most valuable piece of information they received from the JEMS workshop, student responses included discussion of things they had learned, increased understandings they now had about college, and impacts of JEMS on their personal development.

A majority of the students described learning about engineering careers, STEM concepts, the design process, and skills related to engineering and teamwork. For example, one student stated, "I understand more of what the work of an engineer is like". Another student commented "JEMS improved my team-working skills, discipline, social skills, and even helped me with critical thinking and various math and science skills." Students also identified things that they felt that they learned at JEMS that they would not have been able to learn in school, "I learned aspects of engineering I would never learn in a classroom such as leadership and AutoCAD" and "I learned more in two weeks than in two months of high school".

A number of students also stated that JEMS taught them a lot about college. Students said, "it helped me experience what studying engineering at college would be like, and I found it both tough and fun", "it was great fun, helped you to know what to expect from professors and college life", and it "hardened my desire for college".

[3] Data from 1999, 2003, and 2008 was unavailable for this question.

Students also reported developing personally as a worthwhile outcome of their participation in the JEMS workshop. The following comments attest to the personal development that was taking place:

"It took me down a notch. There are things I still need to learn, and I got to meet some very cool people."

"I have gained more confidence in myself and realized that I can be competent so I'll be able to come out of my 'shell' more easily."

"I learned what it is like to fail and how to learn from failure."

"I learned how to conquer more stress than I thought I could ever have."

"I learned that there are other people in this world like me."

Student Recommended Changes

The JEMS workshops are designed to engage students in an engineering design project, provide them with an overview of various engineering disciplines, and provide a college-like experience. Student comments on the questionnaires regarding what they would change in the JEMS workshop often highlighted the challenges of balancing all of these workshop goals. For example, students discussed desires for more time to work on the design project, more exposure to different types of engineering through the lab tours, and less homework.

As part of providing a college-like experience, students received college credit for the courses they took as part of the workshop. These courses were graded and based on students' completion of homework and tests. Many students commented that they wished there had been less homework or more time for completion of projects. Many of the students felt that the amount of homework created a stressful environment and limited the time for other activities. Some students also commented that they had not expected the workshop to include homework and tests and that they would have preferred if it was not so much like school. Some students also suggested that the workshop focus less on grades. For example, one student requested that JEMS should "remove the grading system; I came to learn, not stress about a grade." However, other students recognized that this was all part of the college experience, as one student stated, "Maybe give less homework. However, that's what it's like in college." These comments suggest the challenges of providing a college-like experience within a summer program where students may be coming in with differing expectations.

Some students also commented that they wanted more opportunity to learn about different types of engineering and other students responded that they wanted more time to work on the design project. For example, one student stated, "Get more time for special lab classes. I didn't get a good idea of what things you actually do in a specific field," whereas another student in the same year requested, "More time to work on our rockets." These comments highlight the challenges associated with finding a balance between a survey approach that exposes students to a variety of areas of engineering and the in-depth engagement in a design project that provides an authentic experience in one area of engineering.

CONCLUSIONS

The JEMS Summer Workshop provides students with a pre-engineering experience in a college setting. The goals of JEMS are to improve student understanding of engineering and related fields of study as well as improve leadership skills. By engaging students in a team-based engineering design project, integrated with content courses, leadership training, and hands-on lab tours of different engineering departments, the workshop provides an informative, fun and exciting experience for the student participants while meeting the program goals. Data collected from the questionnaires show student evaluations of the workshop to be overall positive and indicate the program goals have been met for a large majority of the participants.

The engineering design project provides focus to the summer workshop through which students learn about engineering, science, mathematics, teamwork and leadership. The design project allows students to develop a better understanding of what engineers do and the components of the engineering design process. The design project also allows students to directly see how mathematics and science concepts are involved in engineering design [15].

The team based aspect of the design project and the associated leadership courses support students in developing teamwork and leadership skills. Engineering graduates and employers have identified teamwork, leadership, and communication as important competencies for engineers [7, 16]. In order to address this need engineering educators are designing more and more courses around teams [17]. These project-driven classes provide students with the opportunity to experience team design work from idea conception to completion [17]. The team concept of the JEMS design project provides students with a comprehensive experience simulating a real-world engineering task including working with available resources, time constraints, and working as a team member. Student comments on the questionnaires provide evidence that the JEMS program has been successful in enhancing students' understanding of the complexities of teamwork and leadership, the importance of communication, and the value of recognizing the various strengths that team members bring to the task.

Participation in the JEMS workshop allows students to become familiar with the university, the engineering department, and faculty while earning two engineering college credits. Many students commented that learning about college life was one of the most worthwhile aspects of their experiences during the workshop. Although, some students leave JEMS still undecided about their college major choice, the majority report coming away with a better understanding of the field of engineering, their possible career paths, and what to expect when they get to college. This appears to be a positive outcome for the JEMS program, but future research is needed to determine whether students who are more informed about engineering majors are more likely to enroll in engineering programs when they get to college.

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