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How Important is the WOW Factor in First Year Engineering Courses?

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Abstract

This paper discusses the effectiveness of using projects with a "wow factor," that is, engaging and challenging hands-on projects, in a freshman engineering course to excite students about engineering and to motivate student retention and persistence. The course, offered at San José State University, enrolls approximately 700 students per year in a lecture/laboratory format. Projects include a solar cell evaluation, and the design, construction and testing of a scaled wind turbine and an autonomous robot. Impact of the course content on students' knowledge and attitudes about engineering is compared with an assessment done in 2002 using the same instrument. Impacts of these particular projects on students' excitement about engineering and motivation to pursue engineering were measured with a new instrument. A large majority of the students report that the projects got them excited about engineering and motivated them to continue.

Introduction

As has been documented in many studies[1, 2, 3, 4, 5, 6, 7], persistence of students in engineering relies on a complex set of interrelated issues including demographics, high school preparation, self efficacy, motivation, commitment, academic performance, satisfaction with curriculum, interaction with faculty, financial difficulties, and others. Of particular interest is that students' expectancy for success as well as their identification with, and interest in, engineering decrease during their first year[6.] Questions remain about the predominant causes of students' reduction in enjoyment and value of engineering over the first year. One suggestion is that aspects of the curriculum are contributing to this phenomenon[6].

San José State University (SJSU), a large comprehensive public university in California, has been making efforts to improve engineering student retention for about 20 years through advising, curriculum reform, early intervention, and faculty development. At SJSU, no one strategy can be identified as a "magic bullet" because the study of retention is complicated by changing characteristics of the student body, the curriculum, and the university experience. This study attempts to look at one element of the freshman engineering experience and better understand its influence on student attitudes about engineering and retention.

The College of Engineering has offered the required freshman introduction to engineering course (ENGR 10) since 1992. The course enrolls approximately 700 students per year from all of the engineering disciplines in a lecture/laboratory format. The course meets twice per week for 50 minutes in a large lecture (about 175 students) to teach some basics of engineering principles and ethics. Students also attend a three-hour lab once a week, where they design, build, and test solutions to engineering problems in a series of projects. The labs are limited to 24 students. The goals of typical first-year engineering courses fall into several general categories with the aim of retaining students in engineering[8]:

- Demonstrate the diversity of engineering
- Give students a simplified and exciting view of what the engineering process includes
- Teach basic skills and concepts

Basic skills included in typical introduction to engineering courses include introductory computer programming, CAD, simple data analysis, teamwork, and written and oral communication. Basic concepts depend on the discipline focus of each the course, but often they are basic science concepts applied to engineering problems. Examples are Ohm's Law to analyze a simple circuit, energy transformation and conservation for projects involving dropping objects or projectile motion, or chemical reactions to evaluate soil or water contamination. The goals of this class are similar to those of other first-year engineering courses:

- Summarize the steps of the engineering design process
- Apply basic physics concepts to the design and analysis of built systems
- Apply teamwork skills and resolve team conflict
- Write a simple engineering report and present the report orally
- Use tools such as spreadsheets, programming, and CAD software to support engineering design and analysis
- Use ethical reasoning to address to evaluate ethical dilemmas
- Explain principles of sustainability and how they affect engineering design
- Recognize the value of participation in professional activities

When the course was developed in 1992, it was part of a lower division engineering core required of all engineering majors, and focused on computational skills (spreadsheets and MATLAB®). In 1997, in response to faculty and student feedback, a task force was formed to redesign the course. The goal was to make it more motivating for first year students, incorporate projects that introduced students to the design process, provide opportunities to practice teamwork and communication skills, and provide support in academic success and professional development. The redesigned course included three design projects, but most of the design work and teamwork was done outside of class. Projects included disassembling a household object and describing the components, and designing a penny launcher, a rubber band-powered flying machine, and a balsa-wood bridge. These projects all used materials that students could easily find around the house or at a local grocery store, making the projects easily accessible. On the other hand, many were similar to projects students had done in high school science courses. Assessments showed gains in student knowledge about, and positive attitudes towards, engineering as a career[9]. Gains were significant in knowledge areas (ranging from 1 to 1.6 on a five point scale for most areas); however the changes in attitudes were very modest (1 to 5 percentage points in many areas). There was virtually no impact on students' perceptions about engineering as an a) exciting profession, b) challenging profession, c) profession that contributes to society, or d) profession in which people design products.

In 2007, a new task force was convened to redesign the course. At the time 20% to 50% of our engineering freshmen (depending on gender and ethnicity) were not persisting in engineering into the sophomore year. Furthermore, the course was not filling its intended purpose, as 30% of the students in the class were students who had waited until their junior or senior year to take it. A multi-disciplinary team of faculty designed a series of projects that engage students in multiple steps of the design cycle including brainstorming, conceptualizing, building, testing, evaluating, revising, and finally, communicating their design outcomes both orally and in writing. Concurrently, the College of Engineering received a large donation from an alumnus that was used to renovate two rooms specifically for team-based projects in the freshman course. This enabled the college to expand the scope of the projects to team-based, multi-week, multi-disciplinary, challenging projects that students work on in a well-equipped, dedicated lab. The goal of this study is to assess the impact of this new version of the course.

Project-based Introduction to Engineering

Presently, the course includes three projects that are progressively more complex and challenging. The first project requires students to wire a group of solar cells in series and parallel and investigate the impact on the output power. Then students use that knowledge to configure the solar cells with a motor and spool to lift an object from the ground. Students have to choose between motors with different gear ratios and spools with different diameters to assemble a system with the greatest efficiency. In the second project, students design a 3D solid model of a rotor/blade assembly for a wind turbine and build it using a rapid prototyping machine. They mount the blade assembly and a small dc motor, which serves as generator, on a tower that they also have designed and fabricated. They must experimentally determine the stiffness of the tower, and measure the power output of the turbine under different electrical loads (Figure 1).

Figure 1. Wind turbine project. Students design, fabricate, and test a small-scale wind turbine. Photo insets show students fabricating the support tower (left), measuring the stiffness of the tower (center), and measuring the wind speed and power output (right, top and bottom). Power is measured by connecting the output of the turbine generator to an in-house designed power meter. The maximum power output is determined by varying a load resistance (potentiometer shown in the lower right).

In the third project, students build a circuit board to detect infrared signals from a beacon, and then design, build, and program a robot that completes a specified set of tasks and finally captures an infrared beacon using feedback from sensors on the circuit board (Figure 2). This mechatronics project requires students to bring together mechanical design, circuit board assembly, and programming as well as effective teamwork. Teams must brainstorm, learn about mechanical elements (i.e. motors, gears, clutches, sensors) and electrical components (i.e. sensors, resistors, capacitors, LEDs, integrated circuits), learn how to solder, and translate mechanical specifications into programming commands to complete a specified problem statement. Students find this culminating class project quite challenging, but also consider it the most rewarding of the projects in the course. More information about these projects is available on the course web site[10].

These projects introduce what we call the WOW factor. Most students have never soldered, used a drill press, anemometer, tachometer, or dial meter, or even sawed a piece of wood. Most have never seen a rapid prototyping machine and are very excited about actually touching and using an object that they designed on the computer. While an ever increasing number of students have done some robotics in high school, few have ever built and programmed a circuit board to control their robot. Students also enjoy working with solar cells and discovering their low efficiency rating. In 2010, the College was awarded an NSF grant to add aspects of sustainability to the class. The course now puts more emphasis on energy sources, life cycle analysis, recycling, and the water-energy nexus.

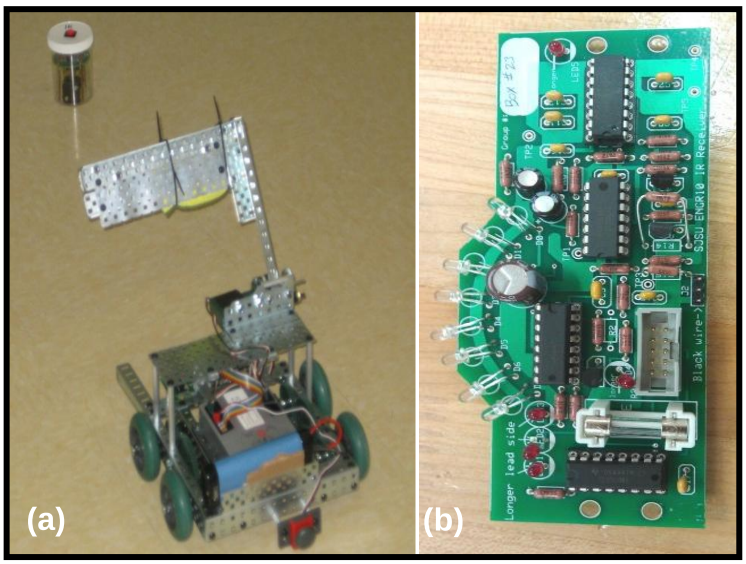

Figure 2. Robot Project. In this project, students design, fabricate, and test a robot that autonomously locates and turns off a flashing IR beacon (inset (a)). Part of this project entails the fabrication of an in-house designed pc board that is used to detect the IR beacon (inset (b))

Students' Assessment of Their Learning

Currently, engineering retention rates in the College of Engineering from freshman to sophomore year have increased to approximately 87%, and the College wanted to investigate factors that are contributing to this gain. While the hypothesis is that ENGR 10 contributes to retention, a number of other factors may be contributing as well. A five-year NSF STEP grant (2006-2011)[11] added "supplemental instruction" workshops to math and physics courses that all engineering students take, and which for years have had low pass rates. These weekly workshops have increased the pass rate in each of these classes by 9 to 15 percentage points. For example, before the workshops were available, the pass rate was 62%. After the workshops were implemented the pass rate increased to 75%. As part of the NSF STEP grant, the College has added intrusive advising and extensive tracking, thus facilitating early intervention for students who are struggling. Finally, over the last two years, budget constraints have required the College to be much more selective about the students it admits, thus incoming student demographics are changing with respect to the extent of their high school preparation. The GPAs and SAT scores of incoming freshmen are higher. A larger percentage of entering freshmen have taken advanced math and science, and even pre-engineering courses in high school, which may be contributing to their confidence and persistence in engineering. Gender and ethnicity were not specifically addressed in this study but it should be noted that females dropped from 21.3% to 13.6% of undergraduate engineering students from 2002 to 2012 and minorities increased from 18.4% to 20.8%. Most of the growth was in the Hispanic population. However, even with these confounding factors, it is still useful to understand the impact of ENGR 10 on their attitudes about engineering and self-efficacy.

For comparison purposes, this study used the same pre-post assessment used in 2002[9] to evaluate student gains in *knowledge of course components*, as well as gains in *attitudes and knowledge about engineering as a career*. The survey is based on the Pittsburgh Freshman Engineering Attitudes Survey (PFEAS) developed at University of Pittsburgh[12]. Students were asked to rank their understanding of 13 topics on a four-point scale (1 – no understanding, 2 - little , 3 - some, 4 - great understanding). Figure 3 summarizes the results from the 2012 pre- and post-course survey using a weighted average of the responses. The largest gains were in the understanding of engineering ethics (+0.88), how to write engineering reports (+0.95), how to give engineering oral presentations (+1.38), understanding of the engineering design process (+0.78), and understanding of SolidWorks® (a 3D solid modeling software we use) (+0.82). The smallest gains were in how to work effectively on teams (+0.13), understanding of learning styles (+0.13), understanding of what it takes to do well on exams (+0.02), and understanding of Excel® (+0.08).

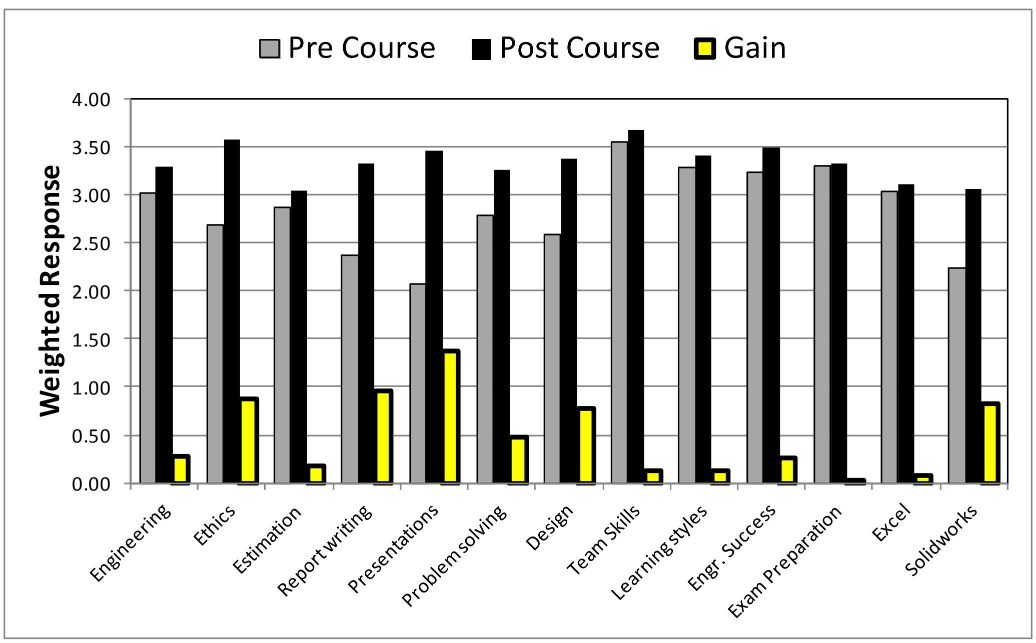

Figure 3. Students' 2012 self-assessment of knowledge of course content (n_{pre}=203, n_{post} =320). The largest gains were in the understanding of engineering ethics, how to write engineering reports, how to give engineering oral presentations, understanding of the engineering design process, and understanding of SolidWorks®.

Some of these are not hard to understand. For example most students have had no exposure to CAD, so it is not surprising that they show higher gains with respect to using SolidWorks®.

While many students have given oral presentations or written reports in high school, they have not had experience with communication in the format typically required of engineers. The multiple project reports and presentations throughout the semester reinforce these skills. Therefore they experience and report larger gains in the areas of communicating like an engineer. As discussed in the 2002 study[9], sometimes the gains are small because of students' preconceived notions. The example given was, *"my way of preparing for exams has worked well all these years, I don't need to change it now"*.[9] Prerequisite knowledge is also a factor. Over the last few years the incoming freshmen have shown more proficiency with Excel® than in the past, so they do not perceive the Excel® exercises to be as challenging as previously. The ENGR 10 team plans to revise the Excel® content to better match the skills of current incoming students.

Figure 4, taken from the 2002 study[9], summarizes the responses from the same survey, with one exception. The current course does not use MATLAB® but instead requires students to do 3D solid modeling using SolidWorks®, so the 2002 question about understanding of MATLAB® was replaced with a question about understanding of SolidWorks® in the 2012 survey. The 2012 gains on average are actually smaller than 2002, but the 2012 students are beginning at much higher levels and ending a higher levels. This reinforces the thesis that current students are different than 10 years ago. For example the 2002 students gained 0.62 in team skills, with a final self-assessment of 3.51. In comparison, 2012 students are starting at 3.55 in team skills and reporting a gain of 0.13. One explanation is that students are participating in more team projects in the high schools today than 10 years ago, therefore students feel more confident about their teamwork skills. In another example, we find that students who have taken pre-engineering courses often have experience with 2D drawing in CAD, typically using AutoCAD® software. On the whole, students report that they are learning the course content. These results combined with authentic assessments of student work, indicate the course is meeting its learning goals.

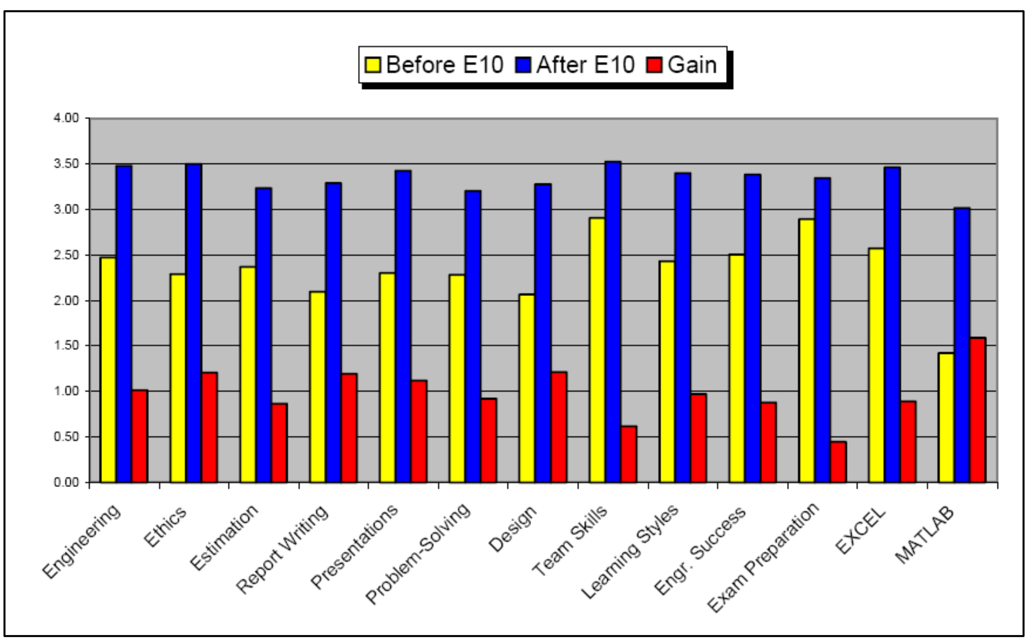

Figure 4. Students' 2002 self-assessment of knowledge of course content (n=174)[9]. The largest gains are in the areas of engineering ethics, engineering report writing, engineering oral presentations, the engineering design process, and MATLAB®.

Students' Attitudes about Engineering

Again for comparison purposes, changes in student attitudes were measured using the same instrument as in 2002. Table 1 compares results from the pre- and post- surveys from 2002 and 2012. As with skills self-assessments discussed in the previous section, 2012 students' attitudes about engineering start from a different place than the 2002 students. A larger percentage of 2012 students reported *positive attitudes* about engineering at the beginning of the semester, and the changes in the two cohorts over the semester are comparable. Two exceptions are attitudes about salaries and engineering as a challenging career, where 2002 students report a decrease and 2012 students reported an increase. A welcome result is that a larger percentage of 2012 students agree or strongly agree that engineering offers ample opportunities for women and minorities. The data indicate a small decrease in the percent of students that perceive engineering as an exciting career, but this result is inconsistent with the data described in the next section in which 70% to 80% of student indicated the ENGR 10 projects were exciting and made them want to continue in engineering.

Table 1: Students' Attitudes about Engineering Before and After ENGR 10

Survey Questions	% Students Who Agree or Strongly Agree					
	2002[9]			2012		
	Before n=514	After n=399	Δ%	Before n=203	After n=320	Δ%
Positive Attitudes about Engineering						
Most engineers are well rounded people	17	27	11	47	57	10
There are ample career opportunities in engineering for women	51	57	6	72	86	14
There are ample career opportunities in engineering for minorities	53	59	6	69	86	17
Engineering is a prestigious profession	68	72	4	90	94	4
Engineers have lots of opportunities to be creative	74	78	4	95	95	0
Engineers have secure jobs	39	43	3	67	70	3
Engineers make important contributions to society	80	81	1	98	98	0
Engineering seems like an exciting career	71	69	-1	92	88	-4
Engineering seems like a challenging career	89	86	-2	91	97	6
Engineers make good salaries	74	68	-5	87	91	4
Knowing What Engineers Do						
Most engineering is done in teams	66	75	8	88	93	5
There is little difference between engineers and scientists	19	24	5	26	30	4
Engineers are involved primarily with military and defense work	10	15	4	19	24	5
Engineers design and create products	67	65	-2	91	89	-2
Desire to Pursue Engineering						
I would rather be an engineer than a scientist	65	70	6	75	76	1
I think I have what it takes to be a successful engineer	77	74	-3	93	86	-7
I hope to be an engineer someday	90	83	-8	97	90	-7

Similarly, a larger percentage of 2012 students report knowing what *engineers do* than 2002 students. Interestingly the same misconceptions about engineers being primarily involved in defense work and there being little difference between engineers and scientists were reinforced during the semester in both cohorts. Consistent with the literature, on average students' attitudes about their *desire to pursue engineering* decreased. This decrease in desire to pursue engineering is consistent with the literature[6], but contrary to data described in the next section in which students indicate that the course is effective in exciting them about engineering.

This comparative analysis summarized in Figures 3 and 4 and in Table 1 strongly suggests that the 2012 students are different than the 2002 students. The students come to the university knowing more about what engineers do and having more developed teamwork and technical skills. This is an important consideration in evaluating the importance of the wow factor on overall retention rates.

Assessment of the "Wow Factor"

A survey was administered to students who completed ENGR 10 during the previous 18 months, which explicitly explored why students originally chose engineering as a major, whether they intend to continue in the major, and what factors were important in their decisions. The survey was founded on work done by the NSF-funded *Assessing Women and Men in Engineering Project*[13] (AWE). The AWE project has developed assessment instruments for K-16 educators involved in formal and informal educational outreach activities. Specific questions from the *AWE Students Leaving Engineering Survey*[14] were used. Additional questions specific to this course and its projects were also developed by the authors.

Table 2: Factors That Influenced Student's Decision to Persist in Engineering

Factor	Significant
My personal abilities/talents "fit" the requirements in engineering	83%
Confident of succeeding in future engineering classes	79%
Positive interactions with other engineering students	69%
Positive experiences in design teams or other collaborative learning experiences in engineering*	64%
The projects in the ENGR 10 class got me excited about engineering as a career*	64%
Satisfactory performance on my grades in engineering/math/science	63%
The projects in the ENGR 10 helped me gain my confidence in my abilities as an engineer*	62%
Good teaching by engineering faculty, instructors or graduate assistants	56%
ENGR 10 motivated me to continue in engineering*	53%
Effective academic advising by engineering faculty or advisors	48%
Ability to find satisfactory Co-Ops and / or internships	47%
Friendly climate in engineering classes*	46%
Faculty help me understand what practicing engineers do	46%
Reasonable workload in the engineering/math/science classes	37%
Engineering faculty/departmental personnel showed an interest in me	32%

*questions related to ENGR 10 or engineering classes

One hundred forty six students responded to the survey of which 132 indicated that they plan to continue in engineering, 9 indicated that they plan to pursue a different career and 5 did not answer this question. Table 2 summarizes the responses for students persisting in engineering, in the form of the percent of students that reported a factor was somewhat or very significant. All of the options that students were given are listed, and those that are specifically related to ENGR 10 are marked with a *. Students who indicated they do not plan to continue in engineering were also asked to indicate the reasons for their decision to leave. Only 2 of the 9 students indicated that ENGR 10 did not motivate them to continue in engineering, the other 7 indicated that the class was not a factor in their decision the change majors. The main reasons they reported they are leaving engineering is because of the unreasonable workload and their lack of confidence in succeeding in future engineering classes.

In an attempt to evaluate the importance of wow projects relative other factors influencing student persistence, Figure 5 compares responses where more than 50% of students reported the factor was somewhat or very significant in their decision to persist in engineering. Black bars are specifically related to ENGR 10, and gray bars are factors that are impacted by ENGR 10 but also from other experiences students have during their first year. The factor "Positive experiences in design teams or other collaborative learning experiences in engineering" was included in ENGR 10 factors (black) because this is the first engineering class students take and is prerequisite to all other engineering classes. Impacts outside ENGR 10 include participating in a variety of student success programs at University A, such the summer two-week project-based engineering orientation program (EXCEED), the engineering learning and living community (CELL), or the MESA engineering program for underrepresented students. The survey did not explore the impact of pre-college pre-engineering programs. Students are also impacted by math and science courses they are taking, their academic advising, and student clubs they participate in. The top two factors students reported are both related to self-efficacy: 'my personal abilities/talents "fit" the requirements in engineering', and 'I am confident of succeeding in future engineering classes'. However, factors related to ENGR 10 are comparable to other factors that influence students' decisions to persist.

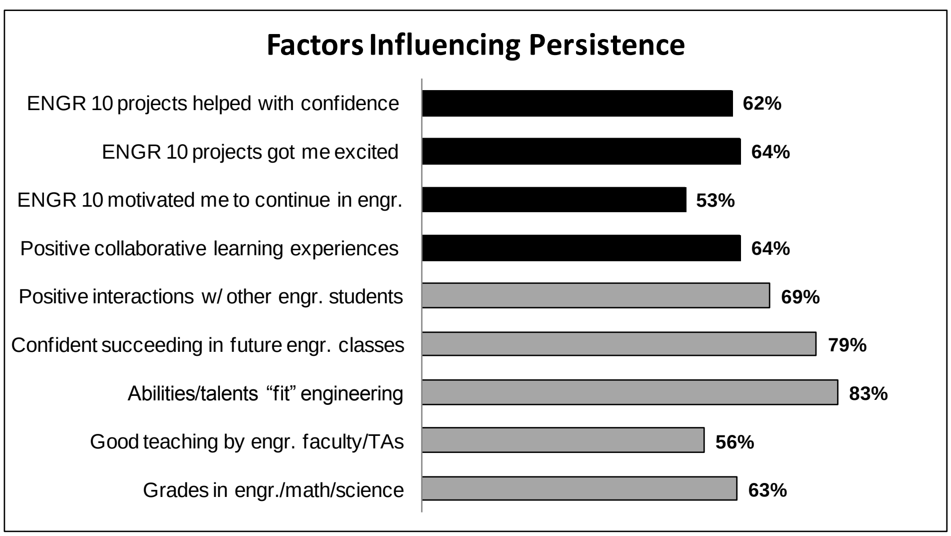

Figure 5. Factors that more than 50% of students reported were somewhat or very significant in their decisions to persist in engineering. The black bars (factors specifically related to ENGR 10) are of nearly equal magnitude to three of the five gray bars.

Figure 6 summarizes responses to questions specifically about course content. Three questions were related to excitement about engineering:

1. Designing the robot and seeing it accomplish a specified set of tasks got me excited about engineering.
2. Designing the turbine blade in CAD and having OUR DESIGN made on the 3D-printer got me excited about engineering.
3. Learning skills such as programming, soldering, CAD and working with hand tools got me excited about engineering.

Two questions were related to persistence:

4. Designing, building, and testing a project in the lab motivated me to continue in engineering.
5. The sustainability content in the ENGR 10 class motivated me to continue in engineering.

Because the solar project contains minimal design content, it is not really a wow project, so no questions were asked about it. In retrospect, this was an oversight.

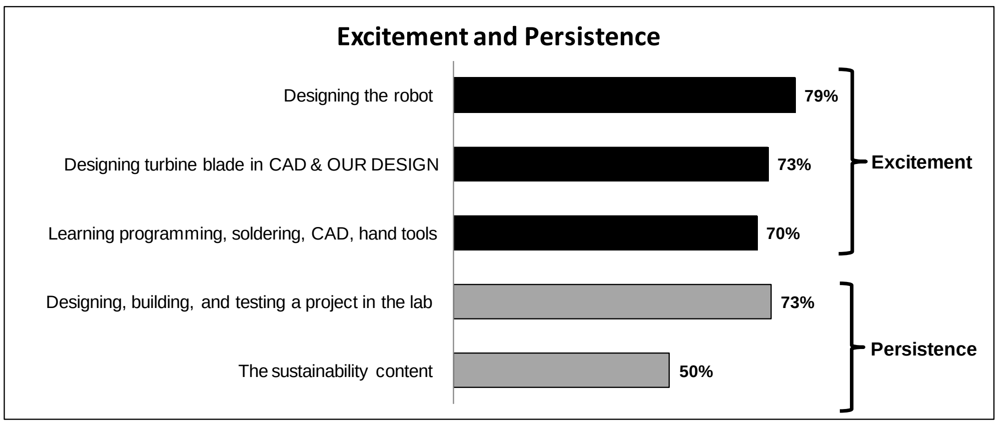

Figure 6. Influence of ENGR 10 content on excitement and persistence. Students find the ENGR 10 projects exciting with 70% to 79% of respondents indicating that the activities and projects got them excited about engineering. The projects were an important factor in motivating to them to persist in engineering. To a lesser extent, the sustainability lectures and videos also motivated students to persist.

The robot and the turbine blade clearly excited students about engineering. Only 8% to 10% disagreed or strongly disagreed with statements 1 through 3, and 12% to 22% were neutral. The projects were also important in terms of self-efficacy, as 87% of students reported that the projects gave them a sense of accomplishment. Designing, building, and testing projects were every effective in motivating students to persist, with 73% agreeing or strongly agreeing and only 6% disagreeing or strongly disagreeing. The sustainability content was reported to be less effective, but the students may be thinking about lecture content on energy sources, recycling, efficiency, and life cycle analysis, rather than the projects on wind and solar. However, 73% of students reported that sustainability content helped them realize that engineers contribute to improving society (an implicit goal of the class).

When asked which their favorite project was, students listed the robot twice as often as the turbine project. No one indicated that the solar project was their favorite. Though the solar project is hands-on, it has a very limited design component and likely feels more like a science experiment. It really doesn’t have the ‘wow’ factor of the robot or the turbine. When asked what the students liked about the projects as open-end questions, 43% of students mentioned making new friends, and 40% mentioned that building something was exciting, challenging, and fun.

"On the first day of class, I didn't know anyone, but after the projects that we did throughout the semester, I made many new friends."

"I became good friends with my teammates. It was the first class I've taken that is actually exciting, because instead of doing problems out of the book or something similarly stale, we got to create working engineering models! By far, one of my favorite classes to date!"

"I had so much fun designing the wind turbine blades for the Wind Turbine project that I decided to go ahead and design my group's entire wind turbine in SolidWorks® on my laptop."

"The engineering projects were everything I expected plus a ton more. The experience of being in a team, working together, was the greatest thing about the ENGR 10 projects. The whole semester was pure fun, because it was exciting to learn about new technologies and how to design and test as an engineer. I learned new social and engineering skills with real equipment and software. Overall, this course was both the most enjoyable and the most important one I took this semester."

Other students indicated that they enjoyed the teamwork (24%), that the class helped them better understand what engineers do (29%), and that the class got them excited and motivated about becoming an engineer (24%).

"I really liked that I felt part of a whole that was doing something. I felt like I was an important member of a team that was actually building something."

"Worked on team dynamics . . . brought out the true leader in me."

"I enjoyed how the projects gave us a small push into the engineering field. Just enough to either realize this is what I want to do, or this is something that I' m not going to enjoy. And I'm very glad I enjoyed them."

"I am very excited about engineering and have motivation to try hard in my classes to graduate with a BSEE."

"The projects have definitely excited me to stick with engineering, but most of all they gave me a wider perspective of how crucial and important engineering is to our future."

Conclusions

While a study of this type cannot fully evaluate the effectiveness of this course as a factor in the overall increase in the College of Engineering retention rates, it does provide some insight into the effectiveness of engaging and challenging hands-on projects with significant design content ('wow' projects) in exciting and motivating students about engineering. Students find them fun and look forward to meeting with their teams to discuss design decisions and test their solutions. Many students reported that making friends was one of the positive outcomes of the class. Feeling connected is an important factor in student retention. Students spend hours in the lab beyond the required three-hours per week. The "open lab" periods, staffed by undergraduates who have taken the class previously, are packed several weeks before each project is due. Open labs have only been available since the course was redesigned in 2007. Students indicate that the projects are "hard" but that they felt a sense of accomplishment when they were done.

These projects with a 'wow factor' appear to be equally important to other factors such as quality of teaching, grades in STEM classes, and interaction with other engineering students in influencing students' decisions to persist in engineering. The college recognizes the importance of scheduling enthusiastic committed faculty to teach the lecture and lab, and some instructors have been teaching the class for 15+ years in its many incarnations. In addition, clickers and active learning techniques are used during lectures to keep students engaged while sitting in a large lecture hall. When considering whether or not to add such projects to the curriculum it is important to know that operating a lecture/laboratory class of this type is resource intensive. The two 175-student lectures each semester feed into 14 labs. In addition to the lecture and lab instructors, a team of paid student assistants help with lab set-up, grading homework, and mentoring students through their projects. Lab fees are used to offset the costs of the materials and supplies such as building materials, robot parts, 3D printer supplies, and tools. While more costly than a lecture-based introduction to engineering course, the positive impacts on the students strongly suggest that the benefits outweigh the costs.

A number of questions remain about how to perfect the class in achieving its goals. A future survey will be used to explore more deeply what difference the projects make. For example, we might ask a question such as, "How much of a difference would it make in your decision to continue in engineering if there were no hands-on projects?" or "What types of projects would help you better understand what engineers do?" It would be interesting to better understand how the use of groups affects retention by asking "If ENGR 10 used *individual* design projects (instead of group projects), how do you think that would affect your experience?" The difference between the 2002 and 2012 cohort is also intriguing. While we know that the 2012 cohort has higher GPAs and SATs, it would be useful to gain a better understanding of why a higher percentage of freshmen come in with positive attitudes about engineering. No questions were asked about engineering experiences in high school or whether students participated in EXCEED, CELL or the MESA program. These are factors that could and should affect attitudes and knowledge. It would also be helpful to explore how to best address concerns that some students have expressed. For example, in open-ended responses, some students indicated that members of their teams did not pull their weight. Others indicated that more guidance on the robot programming would be helpful.

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