Experience Engineering: An Engineering Course for Non-Majors

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Abstract

The engineering profession continues to struggle to attract new talent, in part because it is not well understood by the general public and often viewed in a negative light. Therefore, engineering professionals have called for new approaches promote better understanding and change negative perceptions. One suggested approach is for engineering professors to create and teach courses for non-majors, perhaps as an option to fulfill general studies requirements. This paper describes one such course developed and offered at Elon University. The "Experience Engineering" course features hands-on, interdisciplinary team experiences that result in a tangible product: a remotely operated vehicle (ROV). Students are guided through the fundamental principles of physics, engineering, and electronics that govern the basic system components and operation. Teams are then challenged to integrate these basic components into a system design that is capable of achieving simulated real-world tasks within the confines of the materials provided, allotted budget, and available class time. In addition to discussing the course content in greater detail, this paper describes the assessment methods and outcomes from the first offering of the course.

Introduction

It is well known that recruitment and retention have been a problem for Science, Technology, Engineering, and Mathematics (STEM) professions for many years. More specifically, data indicate downward trends in the number of American students who select STEM fields as a major and those who successfully complete the degree program (Science and Engineering Indicators, 2004, 2006). Dr. Shirley Ann Jackson, President of Rensselaer Polytechnic Institute and Building Engineering and Science Talent (BEST) Board Member, has termed the growing disparity in the number of scientists, engineers, and technically skilled workers needed in the field and the number of new graduates in these areas "the quiet crisis" (Jackson, 2002). This is quite a paradox in a world filled with technology, infrastructure, and conveniences directly attributable to expertise in STEM fields. There is substantial evidence that these fields are perceived as too difficult, too boring, and unattainable.

The American Society for Engineering Education (ASEE) and National Science Foundation (NSF) have called for engineering professors to create classes and other opportunities for liberal arts majors and non-engineers to study engineering (ASEE Project Report, 1994; Restructuring Engineering Education, 1995) to address the aforementioned issues. The belief is that this exposure will promote technological literacy and change the negative perceptions, provided that such a course focuses on real-world applications and how engineers make a difference (Changing the Conversation, 2008). The chair of the Committee on Public Understanding of Engineering, Dr. Don Giddens, Dean, College of Engineering, Georgia Institute of Technology, says, "Improving public understanding of engineering will enable people to make more informed decisions about technology, encourage students to consider engineering careers, and ultimately sustain the U.S. capacity for technological innovation" (The National Academies, 2008, para. 4).

It is also recognized that particular care must be taken to ensure that positive messages are conveyed since many of the targeted students may already have negative or erroneous beliefs about engineering. First, instead of characterizing engineering as a career for those who love math and science, help non-engineering majors gain a better appreciation for how math and science are applied to impact their lives (Changing the Conversation, 2008; ASEE Project Report, 1994). Second, emphasize that much can be learned from engineers' approach to solving problems, for creative problem solving is a skill transferrable to any discipline (Changing the Conversation, 2008; Styer, 2002). Third, show that engineers shape the future by illustrating the role of engineering in history (Changing the Conversation, 2008; Halford, 2004). Last, illustrate that engineering is necessary for health, happiness, and safety by simply imagining life without engineering contributions (Changing the Conversation, 2008).

Although engineering has historically been excluded from liberal arts education because it is more practice- than holistically-oriented, there is compelling evidence for its inclusion (Ettouney 1994, Turbak & Berg, 2002, and Christ 2008). A liberal education is widely known to encourage students to explore and find connections across a range of disciplines, ideas, and thoughts. Engineering is complementary to a liberal education because it inherently requires an interdisciplinary approach. Turbak & Berg (2002) have explored this topic and state, "any given engineering task almost always involves solving problems in multiple disciplines, typically including not only math and the natural sciences but also human factors, sociology, economics, politics, and art" (p. 238).

Exposure to engineering can have a positive effect on liberal arts students as well by enhancing their understanding of their major subject. Carol Christ, President of Smith College, noted in her speech to the Mellon Symposium on Engineering and Liberal Education, "Just as the study of literature and art enriches and deepens the education of scientists and engineers, so the study of science and engineering should enrich and deepen the education of historians and poets" (Christ, 2008, para. 18).

Cross-disciplinary colleagues of engineering faculty are known to look to the constructionist approach of the engineering design project to improve learning in their classes by introducing design and to build opportunities related to their subject matter (Turbak & Berg, 2002; Christ, 2008).

Engineers have responded to the charge and engineering courses for non-majors have been offered at a number of schools, including University of Illinois (as cited in Halford, 2004), Princeton (as cited in Halford, 2004), University of Colorado—Boulder (as cited in Halford, 2004), Wellesley College (Turbak & Berg, 2002), Michigan Technological University (Sorby, Oppliger & Boersma, 2006), Lake Superior State University (Mahajan, McDonald & Walworth, 1996), and Miami University—Oxford (Ettouney, 1994). Course goals and content vary considerably among the aforementioned schools, with some centered on a single design project, and others run more like a traditional science laboratory with smaller hands-on explorations. Some are exclusively for non-majors, while others are for a mixed population. Regardless, all cover the engineering design process and give students an opportunity to use it to develop solutions to a problem or explore the evolution of big ideas in engineering.

I created a course for non-majors to explore engineering at Elon University as an option to partially fulfill a general studies science elective. Elon is a private, liberal arts institution with a Dual-Degree Engineering Program that currently has affiliations with nine traditional engineering schools. Students typically spend three years at Elon and two at an engineering school. Elon engineering students have a breadth of courses and experiences that set them apart from typical engineering students. The most unique aspect of the program is the freshman, sophomore, and junior level engineering courses taught by engineers during the years of study at Elon. These characteristics make Elon an ideal setting for a non-majors course.

The course is called Experience Engineering and is centered on the design and building of a remotely operated vehicle (ROV) to complete tasks that simulate the work of current professionals in ocean-related fields. Using ROV design and building in the classroom is an idea inspired by Bohm & Jensen (1997) and taught at the Marine Advanced Technical Education (MATE) Center Summer Institute (http://www.marinetech.org/education/institutes.php). The design and building of such a vehicle "involves a practical, working knowledge of math, physics, electronics, hydraulics, and engineering. It also requires budgeting, setting deadlines, documenting procedures and results, project management, communication, teamwork, critical thinking, continual problem solving, and producing deliverables on time—just like the real world" (Zande, Michel & Sullivan, 2005/2006, p. 112). Therefore, the course also provides students with an opportunity to build life skills.

In designing the course, much care was devoted to providing an experience that would help students 1) to gain a better appreciation for how much science and engineering influence life—past, present, and future, 2) to understand that the methodical problem solving approach is a transferrable skill, 3) to realize that science and engineering are not beyond their capability, and 4) to improve technological literacy. The remainder of the paper is devoted to describing the course and discussing assessment outcomes in the context of the above four areas.

The Course

Experience Engineering is offered during the Winter Term (January term) and meets three hours daily for approximately 14 days. Students are guided through the fundamental principles of science and engineering that govern the components and operation of a basic ROV. Most classes begin with a short lecture and an overview of the tasks to be completed during the period. The remainder of the class time is devoted to directed designing and building. Lecture topics mirror ROV components and emphasize the science behind them (see Table 1). Students are assigned to teams by the instructor at random, with the exception of some consideration of gender and prior experience working with tools. Enrollment is limited to allow for a maximum of seven three-member design teams. Teams are challenged to integrate the basic components into a system design capable of achieving the tasks within the confines of the provided materials, allotted budget, and available class time. They are also challenged to research two current uses of ROVs, then design mission tasks and test modules for possible use in future offerings of the class.

The first class meeting differs from the aforementioned typical format because it is focuses on entrance assessment and orientation. A variety of assessment methods are used, all of which are discussed later in the paper. Also, to facilitate team assignments, students are

Lecture Topics	ROV Component
Engineering Mechanics (forces, moments, free body diagrams, determine the center of gravity mathematically and physically)	Structure—what holds it all together
Electrical Circuits (types and sources of electricity, series and parallel circuits, circuit diagrams)	Power—energy source for the vehicle Control—used to direct the vehicle
Fluid Dynamics (thrust, moments, Bollard test to inform propeller selection)	Navigation and Propulsion—devices that transform electrical energy to motion
Buoyancy	Floatation and Ballast—what allows the vehicle to float and sink
Chemistry (chemical bonding, polymers)	Sensors—camera
Engineering Design Process	Tools—what you need to complete the task at hand

TABLE 1: Experience Engineering Lecture Topics and Corresponding ROV Component

given a brief questionnaire about their previous team experiences and tool use. The initial class culminates with an orientation to ROV general uses and their components given in the context of a discussion of the history of ROVs.

The second class meeting prepares students for executing the engineering design process. A basic 6-step process is used: define the problem, acquire pertinent data, identify constraints and criteria, develop alternative solutions, analyze alternatives, and communicate the results. Each step is explained in the context of a practical example such as is given in most introductory engineering textbooks. Then, instructor-assigned design teams meet for the first time and begin to form as a team using published techniques (Csernica et al., 2002). Next, student teams are asked to practice this new material by discussing design practice problems and informally presenting their solutions at the end of class. Last, students are assigned an engineering discipline to research and teach the class about at the beginning of the next class. Both of these short assignments are intended to give the teams some practice working and presenting together.

The third class meeting marks the transition to the lecture/lab class format and complete focus on the ROV design and building. Therefore, following the teams' engineering discipline presentations, the mission tasks are distributed and discussed. A total of five mission tasks are given: three that reflect ROV use in ocean-related fields and two that are just for fun. For example, ROVs are often used in deep sea pipeline repair operations, so a pipeline test module was built that requires teams to close a valve to stop the fluid flow, patch the "hole" in the pipeline, and reestablish fluid flow. Note that this and the other real world mission tasks are completed in the deep region of the campus pool with subsea vision limited to the area visible by an on-board waterproofed camera, which the teams construct. A fun mission task might be a relay race completed in the shallow region of the pool.

An example of the typical short lecture and lab class format is the unit on electrical circuits and ROV control. Students are given a brief lecture that covers basic terminology, simple series and parallel circuits, and circuit diagrams. They are then presented with the circuit diagram for the ROV control box and a discussion ensues about how it relates to the theory just presented and to other practical applications, such as decorative string lights or circuitry in a building. Teams then spend the remainder of the class period constructing their control boxes and I visit each team to address additional questions.

The course also requires individual students to maintain a journal and design notebook. The journal is intended to capture students' thoughts as they reflect upon their experiences in class. While many entries in the journal are in response to directed prompts, there are several opportunities for free writing. The design notebook is a medium for documenting team work throughout the class. It includes daily jottings as the team works each day in class and a second directed reflective writing on their accomplishments or challenges in each class and goals for the next class.

Student Assessment and Outcomes

Students enrolled in the course are assessed using three approaches. At the beginning and the end of the class, a tailored Student Assessment of Learning Gains (SALG) is administered to evaluate students' confidence in their ability to do science and engineering, their interest in science and engineering, and the integration of science and engineering into other aspects of their lives. SALG is an online, customizable instrument for assessing student learning in a course (http://www.salgsite.org/). Much to their surprise, the students are also given crayons, markers, and blank sheets of paper on which to draw pictures of an engineer at the beginning and end of class to evaluate their perception of engineers and the profession. The aforementioned journal is a useful means of assessing their confidence, interest, and perceptions throughout the course.

SALG

Analysis of the SALG data was done using the methods typically employed in the behavioral sciences. This approach was most logical because it was necessary to evaluate students' cognitive responses to this new course.

There were twenty questions in the pre- and

Item	t-Value	Mean Difference (Post – Pre)	Standard Deviation	p-value
C1: Discuss scientific or engineering concepts with my friends or family	3.99	1.11	1.18	< .01
C2: Think critically about scientific findings I read about in the media	3.73	1.00	1.14	< .01
C3: Determine what is—and is not—valid scientific evidence in the media	4.37	1.00	0.97	< .01
C4: Make an argument using scientific evidence to friends or family	3.80	.94	1.06	< .01
C5: Interpret tables and graphs	2.06	.33	0.69	.06
C6: Understand mathematical and statistical formulas commonly found in scientific texts	2.72	.72	1.13	.02
C7: Find scientific journal articles using library/internet databases	3.31	1.00	1.28	< .01
C8: Extract main points from a scientific article and develop a coherent summary	5.58	1.06	0.80	< .01
C9: Give a presentation about a science topic to your class	3.51	1.22	1.48	< .01
C10: Obtain scientific data in a laboratory or field setting	3.07	.83	1.15	< .01
C11: Understand how scientific research is carried out	2.44	.78	1.35	.03
C12: Pose questions that can be addressed by collecting and evaluating scientific evidence	3.20	.72	0.96	< .01
C13: Organize a systematic search for relevant data to answer a question	4.19	.89	0.90	< .01
C14: Write reports using scientific data as evidence	4.24	1.06	1.06	< .01
C15: Work with others collaboratively to solve a problem	2.03	.50	1.04	.06
C16: Apply theoretical scientific information to real applications	3.83	.83	0.92	< .01
C17: Understand scientific processes behind important scientific issues in the media	5.50	1.22	0.94	< .01
C18: Understand the science content of this course	5.10	1.50	1.25	< .01
C19: Distinguish a scientist and an engineer	8.42	1.83	0.92	< .01
C20: Perform the same tasks as a	4.91	1.44	1.25	< .01

TABLE 2: Significance of Increases in Confidence Ratings

post-SALG directed at student confidence in doing science and engineering. Students were to respond using a five point Likert scale from "not confident" to "extremely confident." Mean pre- and post-SALG student responses were statistically analyzed using a t-test. It explores whether the mean difference (post mean response minus pre mean response) is statistically significant. Any positive or negative deviation from zero indicates a shift in student confidence over the course of the term. Positive deviations denote increases in student confidence, negative deviations denote decreases in student confidence, and zero deviations denote no change in student confidence. an item is considered significant if its p-value is less than or equal to 0.05.

The twenty SALG questions and their respective statistical data are provided in Table 2. It is also important to note that with eighteen students responding, there are 17 degrees of freedom for each question. As the data show, the students' responses indicated an improvement in confidence on all but two items upon completion of the course. Each of the questions yielding insignificant improvement in student confidence (questions C5 and C15) had a p-value of 0.06. These results are not surprising. First, due to time constraints, tables and graphs were not covered during propeller selection as planned. Secondly, Elon University has received recognition for its engaged learning approaches in Newsweek-Kaplan in 2006 and 2010. Engaged learning frequently requires collaboration, so it can be assumed that Elon students are very comfortable in that role. More importantly, of course, are the eighteen measures that indicate significant student gains in confidence in areas ranging from performing scientific- and engineering-related tasks to interpreting scientific and engineering material to understanding and applying scientific and engineering principles. This is sufficient evidence that the course goal of helping students realize this material is not beyond their capability was achieved.

A similar analysis was completed for measures of interest in science and engineering in the SALG. However, of the eleven questions, only three yielded significant gains (I2, I4, and I10), as shown in Table 3. Again, some of these results are not surprising. First, several questions probe interest in pursuing science or engineering as a major, in graduate study, or as a career (I5, I6, I8, and I9). Although there was one student, a math major who comes from a family of engineers, who took engineering courses after completing Experience Engineering, this was a unique case largely influenced by other factors and it is not likely that this would happen for most students. Second, the remaining questions may be summarized as interest in science- or engineering-related extracurricular activities (I1, I3, I7, and I13). With many students being so tentative about this subject matter already, expecting them to engage in these activities outside of a structured academic setting is also a bit unreasonable. On the other hand, it is encouraging to see that the students did gain some interest in reading about science-related topics in the context of civic issues. Perhaps this is an indication that the course did successfully demonstrate how

Item	t-Value	Mean Difference (Post – Pre)	Standard Deviation	p-value
I1: Discussing science or engineering with friends or family	1.05	0.28	1.13	0.31
I2: Reading about science and its relation to civic issues	2.65	0.61	0.98	0.02
I3: Reading articles about science in magazines, journals, or on the internet	1.46	0.33	0.97	0.16
I4: Taking additional science courses after this one	2.47	0.89	1.53	0.03
I5: Majoring in a science-related field	0.40	0.11	1.18	0.70
I6: Exploring career opportunities in science	-0.25	-0.06	0.94	0.80
I7: Joining a science-related club	1.05	0.28	1.13	0.31
I8: Attending graduated school in a science-related field	0.48	0.17	1.47	0.64
I9: Teaching science	1.00	0.22	0.94	0.33
I10: Socializing with scientists and/or engineers	2.15	0.56	1.10	0.05
I11: Learning how things work or how things are made	-0.20	-0.06	1.16	0.84

TABLE 3: Significance of Increase in Interest Values

much these topics are interwoven in the fabric of life. I further believe that their increased interest in taking additional science courses is indicative of improved confidence and realization that they are capable of doing science and engineering. Last, their interest in socializing with scientists and/or engineers may be an indication that the students now understand that scientists and engineers are not radically different.

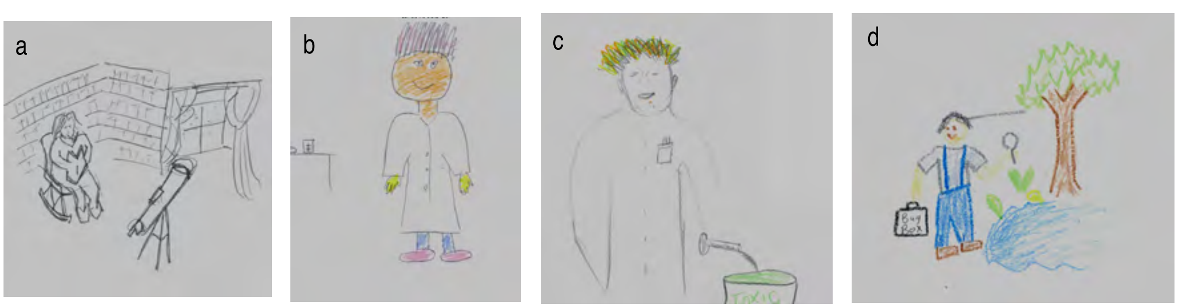
Student Drawings

We are all familiar with the phrase, "A picture is worth a thousand words." The developers of the "Draw A Scientist Test (DAST)" (Chambers, 1983) and the "Draw An Engineer Test (DAET)" (Knight & Cunningham, 2004) definitely know that phrase to be true and recognize that simple hand-drawn images can be useful for tapping into a student's understanding of and attitudes about science and engineering. Representative pre- and post-images of scientists and engineers generated in Experience Engineering are shown in Tables 4 and 5. Note that the images in a given row were generated by the same student.

Strikingly, 34 of the pre-course images of scientists and engineers created by 19 students were male. Of the three females in the class, one drew a female scientist and female engineer, one drew a female scientist and a male engineer, and one drew a male scientist and male engineer. The fact that the students were more likely to draw a male is consistent with the literature (Finson, 2002; Knight & Cunningham, 2004). One student commented, "An interesting observation was that all of the scientists and engineers drawn were men. That is evidence of one assumption made about engineers and scientists." One female student wrote, "As a female, I felt it necessary to represent a scientist as a woman because people rarely think of a scientist as a woman. The reason I drew a male engineer is because he represents a couple of specific people I know that are engineers." They were the only students to specifically comment on gender. Without additional information from each artist, this outcome may be interpreted as a clear understanding that these are male-dominated fields or as a perception that these careers are more suitable for men.

Looking more specifically at the pre-course images of the scientist, 17 (of 19) depicted a person in a laboratory setting (lab coat, safety glasses, beakers, and chemicals). Clearly, among the students in the class, scientists are largely perceived as working in a wet laboratory. The engineer was frequently drawn with a bridge and/or roadway (7 of 19), blueprints (3 of 19), and tools (2 of 19). Again, this is consistent with the literature (Knight & Cunningham, 2004) and supports the fact that engineers are perceived as civil engineers, designers, and people who fix things. However, there was some evidence of broader understanding in the subsequent writing comments about this exercise. One student commented, "You may think of the stereotypical scientist with his or her flask and Bunsen burner, but there are many other

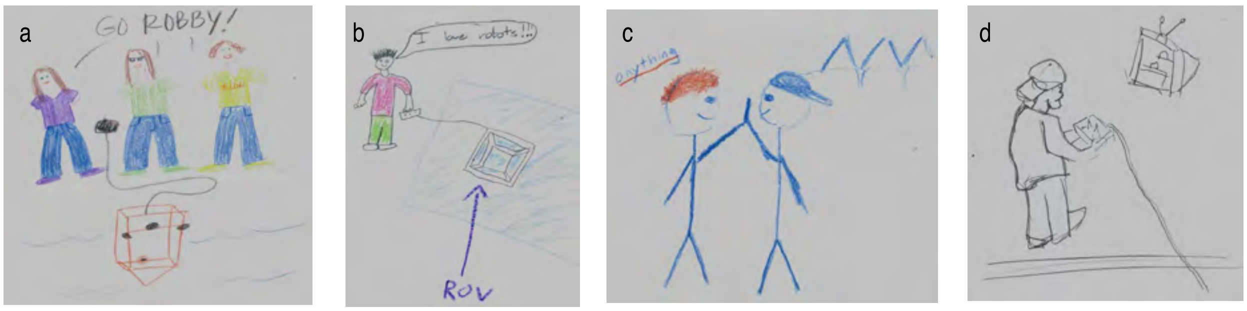
Pre-images of Scientists



Post-images of Scientists

TABLE 4: Representative Pre- and Post-Images of Scientists Drawn by Students in Experience Engineering

Pre-images of Engineers



Post-images of Engineers

TABLE 5: Representative Pre- and Post-Images of Engineers Drawn by Students in Experience Engineering

things they do." Another student said, "…I realized that it was very difficult for me to visually depict the difference between a scientist and an engineer."

There was little change in the post-course images in terms of gender. Both post-class images of scientists and engineers remained mostly male (25 of 38), but several were nondescript (10 of 38). Of the three females in the class, only one made a change in the gender of her depictions. She initially drew a female scientist and a male engineer, but her post-class images were of characteristics of a scientist and a team of female engineers. This is an indication that she was able to identify herself and her teammates with engineering.

Although the 19 post-class images of the scientist still included plenty of lab coats and beakers (8), they displayed a little more variety, including a person conducting research in the library (2), a person doing field work with a kite in a thunderstorm (1), an apple falling from a tree (3), or someone collecting insects (1). They also included representations of the general characteristics of scientists, such as the fact that scientists ask "why?", observe, and explore. Perhaps the class was instrumental in broadening their thoughts about scientists. The post-class images of the engineer still contained a number of bridges (7) and tools (2); however, several of the images were more reflective of themselves and their experiences in the class: more casually dressed (5), working with an ROV (8), and celebrating achievement with at least one other person (2). This suggests that students were able to identify with engineers and to realize that engineering is attainable on some level as a result of taking this course. This is an indicator of improved confidence in their ability to do science and engineering.

Student Journals

The student journals proved to be a useful way to delve into the students' perceptions of scientists and engineers and how they might apply what they learned and experienced in the course in other areas. Many of the quotes speak well for themselves; therefore, this section showcases some of the most representative ones.

As discussed earlier, several assessments were completed on the first day of class. The first journal prompt asked what they thought the assessments revealed about their thoughts and/or understanding of the nature of science, engineering, team work, and learning styles and what previous experiences might have influenced their thoughts and understanding. The following quotes from students represent the most common themes that emerged.

"The assessments we completed in class made me realize that science is a broad category."

"As far as engineering, I discovered that engineering is a major at Elon, which I did not know beforehand. I also discovered [that] engineering and science are different but share similar qualities as well."

"When we drew the scientists and engineers I noticed that neither I or anyone at my table drew people with significant differences."

"Since I have taken many science courses in high school, I am very familiar with the scientific process. However, I still feel I have much to learn about the processes involved in the engineering field."

"I have always liked group work, sometimes more so than individual work. I feel very prepared and excited to work with a team to build an ROV. I know this won't be an easy task, as all of the team members probably have little to no experience in this area, but with motivation, I'm sure we can get it done."

"These assessments also made me realize that science is much more than simply mixing chemicals and wearing lab coats."

"In a general sense they did make me think about how I am not a big fan of science (or the nature of it). It reminded me that I don't know a lot about engineering but as compared to other sciences, I am interested in learning about engineering."

"Because I am bad with science, I wasn't placed in an honors science class. The environment of non honors classes were not so good. There were many distractions from 'uncaring' students and my teachers tended to yell more than teach. This set a bad feeling for me in the sciences ever since."

"For me, I have sometimes viewed engineering in a negative light. I usually associate engineering with complicated math and physics without real world examples. That's part of the reason why I took this course. Most of my math and science education didn't teach me how the concepts related to the real world, and I felt like I was learning facts just to get a good grade."

Perhaps it is clear from these comments that the students began the course with limited or negative views of science and engineering, some level of comfort with teamwork, and poor memories of previous science-related experiences.

As mentioned in the introduction, an engineering course for non-majors can promote technological literacy. The National Academy of Engineering (NAE) has defined characteristics of a technologically literate person in terms of "knowledge," "ways of thinking and acting," and "capabilities" (Technically Speaking, n.d.). More specifically, NAE identifies seven knowledge characteristics, three ways of thinking and acting characteristics, and three capabilities characteristics.

The remaining selected student comments contain emergent themes reflective of the "knowledge" and "capabilities" characteristics. Of the seven "knowledge" characteristics, five are addressed in the following student comments: 1) recognizes the pervasiveness of technology in everyday life, 2) understands basic engineering concepts and terms, such as systems, constraints, and trade-offs, 3) is familiar with the nature and limitations of the engineering design process, 4) knows some of the ways technology shapes human history and people shape technology, and 5) understands that technology reflects the values and culture of society. Further, two of the three "capabilities" characteristics are addressed: 1) has a range of hands-on skills, such as using a computer for word processing and surfing the Internet and operating home and office appliances and 2) can identify and fix simple mechanical or technological problems at home or work.

Within the first week of the course, student teams were asked to research science and engineering professions with a focus on defining what they do, highlighting one famous professional, and explaining some major contributions of those fields to society as we know it. They then had to report their findings to the class and each student was asked to write about what they learned through this exercise. Nearly every student reported amazement at how broad these professions are, confirming the earlier thought that the class was instrumental in broadening their understanding of the work of scientists. Several also commented that the exercise helped them to develop a greater appreciation for the contributions scientists and engineers have made to humankind. Here are some representative comments:

"One of the groups actually had a list of many of the different fields of science and I was astounded to see how long the list went."

"I was reminded in my research of the amazing contributions each scientist has made in their field (Albert Einstein, Alois Alzheimer, Charles Darwin, etc.) and I have thought about how different my beliefs and the world might be if it wasn't for those people."

"I thought of [a] scientist being a chemist, but after our project I've learned most scientists are out in the field rather than in labs with chemicals."

As a part of their presentation, one team created an interesting video of impromptu interviews they conducted on campus where they simply asked "What is a scientist?" One member of that team said, "From all of the presentations I saw I became much more aware of the broadness of the word scientist. That same broadness I found almost no one talked about in any of our interviews, which shows how limited people's perception of scientists really are."

The words, "I'm learning a lot!" were repeated numerous times as I read the student journals every few days and talked to students in class. While that was great to hear, I wanted to know more; therefore, I asked for a detailed list in their journals. They then had to choose two from that list and discuss how that knowledge or skill might be used long after this class is over. Here are a few representative comments taken from those journal entries:

"Learning about the engineering [design] process will help me in all aspects of my life. It is a way of thinking, to look at a problem, and brainstorm until you can solve that problem. Whether I am building something at home or working on a project at school I can apply this method to help me get the tasks done."

"Before coming to college [I] used to spend the summers working on construction sites for an excavation company. Due to the fact that I did this for so long I considered myself to be a pretty handy guy but never had any experience in electrical wiring of any sorts. I think that the basic understanding of electricity will prove to help me in the future. Now that I have the basic understanding of how current and resistance and voltage works I will push myself to learn more because eventually I would like to completely build my own home."

"I have never spent so much time in a class working in teams and I think that it has taught me a lot. These experiences would come in handy as our business world today is becoming more and more dependent on team work. With these skills, I would know how to get along, participate, and help my team out the most possible."

"The differences between criteria and constraints can go into most parts of life helping decide between what you can't do, what you need to do, and what your priorities [are] and what you want to do."

"I value teamwork a lot more now after working with my group."

"I will need to work in groups in other classes and I will need to achieve a deadline. These 2 are crucial for success in and after college and this class emphasizes these aspects. This class is a good review [of] necessary skills to succeed."

"The second skill that will really help me after this class is my improved ability to think outside the box. This is an unconventional course, and by building an ROV I have come up with some pretty crazy ideas, but sometimes thinking outside the box can help make the final product even better."

"Learning to completely plan things through is a critical skill that will help me throughout my life."

"How to apply scientific knowledge to real life (circuit equations, finding the center of gravity, etc). How to complete a group project while relying on other team members rather than trying to do all the work myself."

The fact that more than half of the NAE-defined "characteristics of a technologically literate person" are identifiable in the student comments sufficiently indicates that the Experience Engineering course promotes technological literacy. It is also important to note one other student gain. Three females registered for the course, which created a unique opportunity to explore some gender-related issues using an all-female team. The young ladies quickly acknowledged their distinction and remained keenly aware of it throughout the course. They were first unsure and hesitant, but ended the course with certainty and confidence, which is best characterized by the following comment in one of their journals in response to the prompt about the lasting knowledge or skill gained from the course: "Girls can build robots too!"

Conclusions

Experience Engineering was successfully designed and implemented as an elective engineering course for non-majors at Elon University. Assessment outcomes indicate that students gained significant confidence in their ability to do science and engineering, acquired and/or sharpened skills that are useful in other areas of their lives, became more technologically literate, gained a better appreciation for the comprehensive nature and impact of science and engineering professions, and developed limited interest in science and engineering. It is known that these positives are beneficial for the future of science and engineering professions and addressing the so-called "quiet crisis" that exists in this nation. Therefore, it is hoped that others can implement a similar approach at other colleges and universities.

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References

ASEE Project Report: Engineering Education For A Changing World (1994). *ASEE Prism, 4*(4), 20–27. Retrieved from http://www.asee.org/resources/beyond/green.cfm.

Bohm, H. & Jensen, V. (1997). *How to Build Your Own Underwater Robot and Other Wet Projects*. Vancouver, BC: Westcoast Words.

Chambers, D. W. (1983). Stereotypic images of the scientist: The Draw-a-Scientist Test. *Science Education, 67*(2), 255–265.

Changing the Conversation: Messages for Improving Public Understanding of Engineering. (2008). Washington, D.C.: The National Academies Press. Available from http://www.nap.edu/catalog.php?record_id=12187.

Csernica, J., Hanyak, M., Hyde, D., Shooter, S., Toole, M. & Vigeant, M. (2002). Practical Guide to Teamwork. Retrieved from http://www.departments.bucknell.edu/ProjectCatalyst/Workshop%202004%20CD-Rom/bucknell_materials/TeamWork_Guide.pdf.

Ettouney, O. M. (1994). A New Model for Integrating Engineering into the Liberal Education of Non-Engineering Undergraduate Students. *Journal of Engineering Education, 83*(4), 1–7.

Finson, K. D. (2002) Drawing a Scientist: What We Do and Do Not Know After Fifty Years of Drawings. *School Science and Mathematics, 102*(7), 335–345.

Halford, B. (2004). Engineering for Everyone. *ASEE Prism, 14*(4), 22–27.

Jackson, S. A. (2002). The Quiet Crisis: Falling Short in Producing American Scientific and Technical Talent. Building Engineering and Science Talent (BEST). San Diego, CA. Retrieved from http://www.bestworkforce.org/PDFdocs/Quiet_Crisis.pdf.

Knight, M. & Cunningham, C. (2004). Draw an Engineer Test (DAET): Development of a Tool to Investigate Students' Ideas about Engineers and Engineering. *Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition*, Salt Lake City, UT.

Mahajan, A., McDonald, D. & Walworth, M. (1996). General Engineering Education for Non-Engineering Students. *Proceedings of Frontiers in Education Conference, 1996*, 3, 1264–1266.

Restructuring Engineering Education: A Focus on Change; Report of an NSF Workshop on Engineering Education. (1995, August 16). Retrieved from http://www.nsf.gov/pubs/stis1995/nsf9565/nsf9565.txt.

Science and Engineering Indicators, National Science Board. Washington, DC: 2004 (http://www.nsf.gov/statistics/seind04/); 2006(http://www.nsf.gov/statistics/seind06/).

Sorby, S. A., Oppliger, D. E., Boersma, N. (2006). Design and Assessment of an "Engineering" Course for Non-Majors. *Journal of STEM Education, 7*(1-2), 5–14.

Styer, D. F. (2002). Science as a Liberal Art. *Journal of College Science Teaching, 32*(2), 139–142.

The National Academies (2008, June 25). How To Attract Young People To Engineering: 'Make A Difference' Message Is Key. *ScienceDaily*. Retrieved from http://www.sciencedaily.com/releases/2008/06/080624145221.htm

Technically Speaking: What is tech lit?. Retrieved from http://www.nae.edu/nae/techlithome.nsf/weblinks/KGRG-55SQ37?OpenDocument.

Turbak, F., Berg, R. (2002). Robotic Design Studio: Exploring the Big Ideas of Engineering in a Liberal Arts Environment. *Journal of Science Education and Technology, 11*(3), 237–253.

Zande, J., Michel, D., Sullivan, D. (2005/2006, Winter). MATE ROV Competitions Bring Ocean Science and Technology to Students and Educators across the U.S. and Canada. *Marine Technology Society Journal, 39*(4), 111–115.

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