AC 2007-1704: ENGINEERING DESIGN VIA TEAM-BASED SERVICE-LEARNING PROJECTS: CASE SURVEY OF FIVE UNIQUE PROJECT GENRES

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Engineering Design via Team-based Service-Learning Projects: Case Survey of Five Unique Project Genres

Abstract:

We examine the introduction of engineering design to first-year college students via real community service-learning projects (CSLP) of five genres: (1) assistive devices, (2) civil/architectural designs, (3) educational tools, (4) information technology, and (5) urban development. Projects in each genre require different skills and approaches by students and instructors. We provide an in-depth analysis of successes and shortcomings for projects in these genres, completed as part of a first-year engineering design curriculum.

We developed a multifaceted engineering design course, whose goals are to introduce students to basic engineering design principles and professional skill methodologies, such as client interaction, teamwork, and presentation skills. Projects with community partners fulfill the need for real client interaction and robust design problems. Students gain hands-on experience from directly applying concepts taught in the course, while community partners benefit from the projects' research and proposed solution.

Over 1000 first-year engineering students have participated in CSLP since its inception in Spring 2004. We have worked with over 50 community partners yielding more than 200 semester-length projects, some of which embark on a continuation over several semesters. Our experience complemented with extended evaluations after each semester shape the project selection task throughout the duration of the course. Decisions are based on student and client responses to evaluations and successful project utilization. The distribution of projects in the five major genres has shifted focus as a result.

Results of the program have been encouraging, as student and client satisfaction and quality of projects have increased significantly. Student evaluations show great enthusiasm for the course curriculum with most students showing interest in their intended fields of study yielding a lower transfer/drop out rate from the engineering school. The wide range of our designated project genres has enabled students with a limited technical background to better work in teams. Task distribution within teams is more balanced, resulting in a larger coverage and more thorough analysis of the project's scope. The implicit pedagogic success is demonstrated in a more concrete understanding of basic engineering design principles and professional skills by students.

Improvements to ensure continuing success of the program largely depend on new methods to find robust projects that meet the needs of our design course. Considerations for selecting projects of a fitting genre include, among other factors, fulfilling the community partner's need and appropriately dimensioning time of project. Further investigations regarding continuity plans are necessary for multi-semester projects.

Introduction:

Engineering design is defined broadly to include all activities related to the acts of conception and description of engineered products, systems, processes and services, including analysis and selection of alternatives. The process of design is imperative to advance understanding of the fundamentals of product creation.

Dr. William Wulf, President of the National Academy of Engineering notes that "engineering design is what sets engineering apart from the sciences." It is the cornerstone of engineering education and practice and thus a necessary concept for students to understand on their journey to becoming effective “engineers.” This makes the first year of an undergraduate engineering curriculum an ideal time for introducing students to the principles of engineering design.

The basic principles of engineering design include creating a framework for comprehensive models starting with a clear, concise, and full statement of purpose. Coupled with decision-making analysis of the feasibility of proposed solutions is the need to interface between computational capacity and human needs and experiences. The role of information technology, automation, visualization, learning technologies and systems will be an increasingly important aspect of effective design practice. The key is to design an effective course that allows for students to learn and experience this process.

One of the key challenges in designing the course is to create the necessary connections between the principles of design theory and the practice of design across the broad spectrum of engineering disciplines through the creation of new tools and methods. The focus of the program is to not only provide students with a holistic view of design but also to teach each student the basic tools needed in engineering. Two software packages have been implemented into the course curriculum to assist with this specific course goal: MathWorks Matlab for computational purposes and Alias Maya for 3D image renderings.

Service learning projects with community partners serve as such a media. These projects allow for the need for advanced understanding of the identification and definition of preferences, analysis of alternatives, effective accommodation of uncertainty in decision-making, and the relationship between data and knowledge in a digitally supported process.

Service learning projects also assist in meeting the goals of a multidimensional course. The course is taught with many goals, each meeting the needs of the different entities involved: students, instructors, and community partners. Students are given the opportunity to experience the application of design principles discussed in class and to develop professional when meeting with clients and interpersonal skills when meeting amongst their own team members. Instructors demonstrate the real-world application of the principles while the community clients benefit from the students’ work and ideas.

The application of course material on real-world design problems serves as one of the program’s greatest caveats. To further enhance each student’s experience in the course, we propose five main genres for the types of community projects: assistive devices, civil/architectural designs, educational tools, information technology, and urban development. Each genre caters to student interests in a particular engineering major because first-year students enter the program with very diverse interests for their proposed major as shown in Table 1.

Table 1: Distribution of Intended Student Majors.			
	Academic Year		
Major	2003 - 2004	2004 - 2005	2005 – 2006
Applied Math/Applied Physics	35	42	38
Biomedical/Chemical Engineering	112	79	73
Civil Engineering	29	38	17
Computer Science/Engineering	64	46	39
Earth and Environmental Engineering	4	6	5
Electrical Engineering	37	36	19
Industrial Engineering/Operations Research	26	41	95
Mechanical Engineering	32	33	38
TOTAL	339	321	324

Course Structure:

A typical class session is approximately three hours and is divided into two equal parts. An instructional lecture about professional development and project management skills is administered during the first half of the class session, with built-in enhancement activities. This opportunity affords students to brainstorm in their groups in front of the instructional staff for any additional guidance that may be needed. The second part of class time is dedicated to instructional workshop-type lectures regarding the software packages in the renowned Botwinick Gateway Laboratory. Students can follow along as instructors lecture. We introduce two different software packages, and thus we have learnt that the best method to do so is to divide the academic term of typically fourteen weeks into two parts. The first part being dedicated to computational analysis using MathWorks Matlab and the latter for 3D modeling and rendering using Alias Maya. This arrangement is successful since computational tools are useful for analysis of data gathered by students during their research phase for their project at the beginning of the term. The use of Maya for 3D modeling and renders is useful towards the end of the academic term when students have reached some type of solution to their project. Additionally, students are not only required to use these tools for their course final project but they are also given individual assignments to complete during the academic term.

Teams are assigned for the each community project to assure that students are given the complete team development experience. Students are selected for the projects based on an assessment survey. The assessment survey provides the instructors with information about each student's aptitude and interests in various subject areas[1].

Assistive Devices:

Assistive devices are becoming more prevalent in communities. This project type is especially interesting to those considering biomedical/chemical engineering, electrical engineering, and mechanical engineering. Projects focus on developing and redesigning equipment to comply with American Disabilities Act (ADA) standards. Teams are required to understand ADA standards and rules of compliance as part of their preliminary project research.

An example of such a project was our collaboration with New York City Department of Parks and Recreation beginning in Summer 2004 to design a novel "Playground for All Children" in Marcus Garvey Park. Even though there are many playgrounds around New York City, very few of them are designed to accommodate children with disabilities. The final goal for the summer was for students to produce initial design ideas and renderings for one piece of playground equipment that would meet the needs of the assigned type of disability.

The project continued in the following semesters focusing on creating a prototype for one of the pieces of playground equipment, the wheelchair swing. The wheelchair swing allows children confined to wheelchairs to make use of a swing without the discomforts and complications of reseating themselves. Its ease of use for both the child and guardian make the swing an invaluable asset to any playground accommodating those with disabilities. The proposed design went through several iterations before the final design was completed in Spring 2006. Figure 1 shows the evolution of the wheelchair swing over the academic terms.

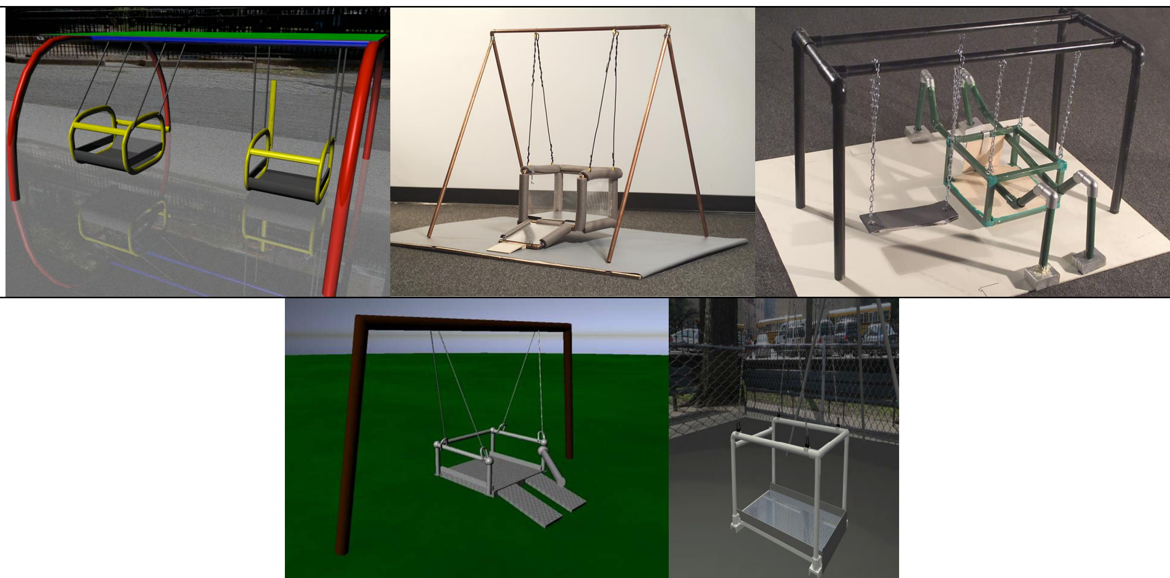

Figure 1: Evolution of the wheelchair swing project for the assistive devices genre. (first-row) Design proposal by student teams in Fall 2004 and Spring 2005. (second-row) Picture on left is modified design proposed in Fall 2005. Image on right is final design.

In Spring 2006, the full-sized prototype was tested in Marcus Garvey Park with students from PS 79M, a school for children with disabilities across the street from the proposed location of the swing. The results of this project were extremely positive for all involved and the children who were selected to test the prototype all showed favorable reactions to the swing as shown in Figure 2.

Figure 2: Wheelchair swing design project. Usage of designed prototype by PS 79M student.

One of the main challenges in this particular genre is the lack of specific technical skills that first-years possess. In many instances, students have developed novel design concepts, which cannot be implemented in the prototype phase of the design process by successive teams due to the lack of mechanical feasibility. A possible solution to solve this problem is to have team advisors who are knowledgeable in these particular areas to provide students with adequate direction and information for successful completion of their assigned project. In most instances, this role is fulfilled by one of the members of the instructional team for this course. Other times, this is accomplished by pairing students with senior-year design teams working on their design capstone projects.

One such example exists when a group of freshman students teamed with a group of senior students in the Biomedical Engineering program to create an improved form of protective headgear for a non-motorized sport. The team was required to design and, if possible, produce a prototype model of a new protective headgear that decreased injuries by providing increased protection to vulnerable areas of the head, face and neck. In response to this design challenge, the team chose to prototype a helmet that could be used for playing ice hockey. By the end of the term, the team of students had successfully prototyped and modeled an effective design for such a device as shown in Figure 3.

Figure 3: 3D rendering of proposed design from front view (left) and side view (right).

In instances where the first-year team does not seek additional help; the prototyped projects are usually unattractive and unusable, deeming the project a failure.

Civil/Architectural Designs:

Civil/architectural design projects are ideal for those students interested in civil engineering or mechanical engineering. These projects typically focus on design challenges in enclosed places.

Primary concerns for such projects include interior lighting, storage, shelving, and effective space utilization. Typical projects usually involve the redesign of space for a given area.

An example of this project genre involved the task of redesigning the physical layout of a food pantry for a local organization, Community Impact. For this project, the team focused on Ford Hall Food Pantry. The pantry serves low-income and homeless individuals, families, seniors, and people with AIDS/HIV. Clients are generally on public assistance or are receiving Medicaid. Community Impact oversees the program by providing funds for the pantry and staffing it with volunteers. The main design challenge presented to the students entailed ineffective usage of space to store, prepare, and distribute food along with inefficient lighting. The main objective was to propose a solution for effective space utilization and storage in order to reorganize the supplies in order to create a reception/intake room. After a trip to the food pantry, a few brainstorming sessions, and some meetings with the staff at Ford Hall, the team composed a list of recommendations to propose to the director of Community Impact. In order to get a visual sense of the final design, a 3D representation of the food pantry was modeled and rendered. Table 2 shows the comparison between the team's recommendations and the current situation, while Figure 4 shows the complete overall proposed design solution. The team also successfully implemented their proposed design plans in Ford Hall even after the completion of the project term.

Table 2: Ford Hall Food Pantry project in the civil/architectural designs genre. Comparison of current situation versus proposed design solution for the three rooms in Ford Hall Food Pantry.

	Current Situation	**Proposed Design**
Front Room		
Middle Room		
Back Room		

In most instances, projects in this genre usually terminate with a design plan for feasible implementation. Lack of available resources results in the failure of completion of projects for this genre along with time constraints for students during the academic term. Community partners are aware of this issue and thus expected final deliverables are typically a complete design package with 3D renderings of layout, budgets, and materials lists.

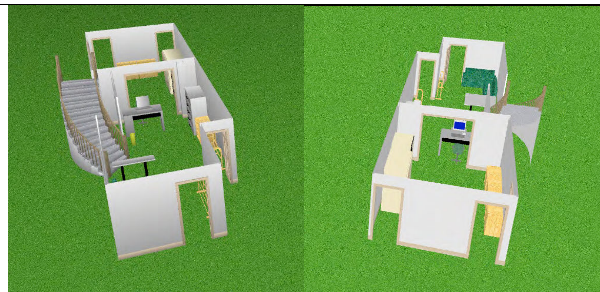

Figure 4: Redesign of Ford Hall Food Pantry project in civil/architectural designs genre. (left) Proposed layout view from front. (right) Proposed layout view from rear.

Educational Tools:

The educational tools genre is interesting to those students in the engineering school who are curious to learn about the process of teaching students. However, this genre is also beneficial to those students maybe uncertain about their prospective major as well, since many of the projects explore different fields of academics. The projects are geared to students also considering the fields of computer science and computer engineering. They primarily focus on enhancing current educational products on the market to meet the needs of academically challenged students from underprivileged areas.

The Comprehensive Math and Science Project involved creating a series of different mathematical software tools for students to use in learning fundamental principles in mathematics. Aligned with Marta Valle High School, these tools were needed by academically challenged students in preparation for passing the Regent's Exam and successfully completing high school in the state of New York.

One particular design problem given to the students involved in improving an existing mathematical program that generates equations to be more user-friendly and less time consuming from the teacher's perspective by keeping a record for each students progress. This would allow teachers to focus their attention on struggling students. A key design challenge was to ascertain that the software would motivate students not only to do well on their Regents Exam but also to perhaps consider continuing their education.

This success of this genre depends greatly on the team's technical ability. In many cases, we are able to identify at least one student per team who is extremely apt in a programming language. Thus, most projects completed are successful. However, each project could always benefit from a refining step to make designed software more user-friendly. Many times the students build excellent functioning programs for their community partners, but these unfortunately lack the computer architecture needed for the software program to be truly implemented on a mass scale.

Information Technology:

Information technology based projects require students with some technical background and aptitude for programming computer-based tools. Students involved in such projects are typically interested in pursuing majors in computer science/engineering.

Two student teams developed an intranet for the Apollo Theater in Harlem (Spring 2003 and Fall 2004). The first team conceived and created the intranet; while the following semester, the second team improved the site by adding a frequently asked questions page with information on the theater's history for box office employees and converting the theater's check request form to an online format.

The same semester in Spring 2003, a group of students worked on a project for Harlem LIVE. a non-profit teen-staffed Web magazine. The students developed a system that would more easily organize Harlem LIVE, then developed and implemented a Web-based "clickable" map of Harlem, providing information on landmarks, cultural resources, and other places of interest.

Information technology projects make it arduous to fulfill the instructional goals of the course, in terms of teaching students to use the design software tools. Thus, the need arises to circumvent this issue by interweaving it with projects from other genres to ascertain that students are given the opportunity to experience the full breadth of the course. This is also beneficial since identifying students whose only interest lies in these two areas can be difficult.

A partnership with the Wildlife Conservation Society (WCS) exemplifies the partnership of the information technology genre with the disabilities genre. Teams worked on developing interactive accessibility maps for all five WCS facilities — the Bronx Zoo, the Central Park Zoo, the Prospect Park Zoo (Brooklyn), the Queens Zoo, and the New York Aquarium at Coney Island. The project expanded and the following teams developed PDA software to make maps mobile as shown in Figure 5.

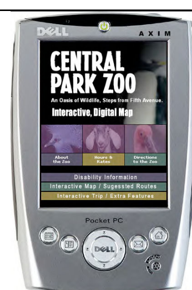

Figure 5: Accessible PDA project for the Wildlife Conservation Society (WCS) in the information technology genre. Prototype of PDA with accessibility map created for Central Park Zoo.

Similar concerns like those for the educational tools genre exist for this genre as well. Technical expertise is crucial for this genre. The use of project advisors has greatly helped students produce better solutions to the engineering design tasks proposed by their community partners. Even so, we attempt to pick elementary type projects in this genre so that our students can complete the projects with little assistance from the advisor.

Urban Development:

Urban development projects typically pertain to those students interested in earth and environmental engineering, civil engineering, and mechanical engineering. These projects are primarily concerned with new innovative technologies for environmentally friendly designs.

In Fall 2004, a team of students partnered with the Metropolitan Transit Authority (MTA) worked to develop a new design for all New York City bus shelters. The design problem stated that the new shelters needed to be energy-efficient, sustainable, and economically self-sufficient. They also needed to provide information to bring about environmental awareness. The team proposed that the new bus stations be constructed of aluminum with tempered glass for paneling and include features that allowed water runoff and developed a new floor plan as shown in Figure 6.

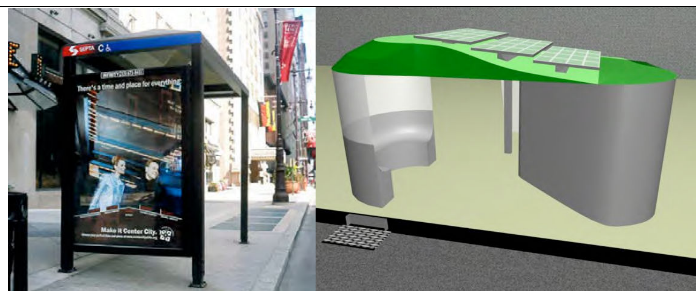

Figure 6: Design of New York City bus shelters project for the Metropolitan Transit Authority (MTA) in the urban development project genre. (left) Current design of bus shelters in New York City. (right) Proposed render of newly designed environmentally friendly bus shelter.

The typical concerns that arise in this genre are similar to those from the civil/architectural designs genre. Project implementation is usually the goal strived for by most of our community partners. With urban development projects, this goal is a little too over-realistic, since our students do not have experience with large-scale manufacturing. Often times, 3D dioramas are created alongside 3D renderings to help the community organization in pursuing the actual development of the concept.

Discussion:

While teaching engineering design principles is the primary goal of the course, professional skill methodologies are also emphasized. Students are expected to take part in client interaction, teamwork, and presentations. Thus, each student is given a specific role on the team as means of facilitating this experience.

Two majors that were un-addressed specifically offered – industrial engineering/operations research and applied physics/mathematics – are key to any of the five genres discussed. Industrial engineering/operations research students are useful for project management and for successful overseeing of team progress throughout the project. These students usually partake in the more non-technical parts of the process and in ensuring effective communication between the student team, client, and instructors. Applied physics/mathematics students are beneficial to each team, as they possess the interest in helping with the technical computations required by the course for each project assigned.

Existing programs at other institutions differ greatly from the one we offer to our students. While similar in goal, Purdue's Engineering Projects in Community Service (EPICS) program is designed for undergraduate engineering students. This requires for integration of students from varying engineering disciplines and from different educational levels of their undergraduate tenure. Our program is focused to serve as an introduction to engineering design for first year students with limited technical backgrounds in any specific realm of engineering. Furthermore, EPICS is not a mandatory component for students at Purdue. However, since our CSLP program is integrated into our mandatory first-year curriculum, we can ensure that each student is given the opportunity to participate.

Our program is part of the National EPICS program. While we share the same vision as our partner institutions, our approaches vary significantly. We believe in the importance of having first-year students have real-world engineering design experience and thus soliciting projects that are manageable for students with this skill set. Therefore, the creation of the genres to help identify potential projects for students is imperative.

An institutional goal is to meet the Accreditation Board for Engineering and Technology (ABET) requirements. The engineering school strives to ensure that each course addresses as many of the ABET criterion as possible. Table 3 shows the general course objectives as required by ABET. The multidimensional and multi-modal aspect of our engineering design course assures that we meet all the requirements listed. Students complete course surveys at the end of each academic term which ask about their opinions on how well the ABET objectives were met. We have unanimous agreement in all surveys conducted by students agreeing that they feel the ABET objectives were fully met.

Table 3: General course objectives for accreditation by the Accreditation Board for Engineering and Technology (ABET)
• An ability to apply knowledge of mathematics, science, and engineering.
• An ability to design and conduct experiments, as well as to analyze and interpret data an ability to design a system, component, or process to meet desired needs.
• An ability to function on multidisciplinary teams.
• An ability to identify, formulate, and solve engineering problems.
• A recognition of the need for, and an ability to engage in lifelong learning.
• A knowledge of contemporary issues.
• An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
• An understanding of professional and ethical responsibility.
• An ability to communicate effectively.
• The broad education necessary to understand the impact of engineering solutions in a global and societal context.
• This course provides students with the necessary tools (mathematics, chemistry, physics, Earth sciences, and engineering science) to understand and implement the underlying principles used in the engineering of processes and systems.

- This course prepares students for engineering careers in industry, government agencies and other organizations concerned with the environment and the provision of primary materials and secondary materials and energy, as well as graduate studies in related disciplines.
- This course teaches the basic concepts and skills needed for the practice of Earth and Environmental Engineering, including measurement and control of material and contaminant flows through the environment, assessment of environmental impact of past, present and future industrial activities, and analysis and design of processes for remediation, recycling, and disposal of used materials.
- This course ensures that the technical training of our students is based on a strong liberal arts core, professional ethics and responsibilities are well understood, and written and oral communication skills honed.

Sustainability:

Sustainability of such an intricate course surprisingly does not require too many additional sources than that of a normal lecture-driven course would entail. Since the projects are all from community partners, there is no monetary investment in attaining projects for students. The cost arises when a projects reaches the prototyping phase. However, since the service-learning program is supported by a grant from the National Science Foundation, these costs do not burden the academic institution. Our course models instructional staff is varied from undergraduate students who serve as course teaching assistants to academic professors who serve as the main lecturers. Table 4 shows the resource requirements breakdown for running this program for a given academic semester. Thus for an academic semester with 14 weeks, approximately 2408 hours of commitment are required.

Table 4: Resource Requirements Breakdown

Resource	**Requirement**
Teaching Assistants	4 individuals – 120 hours/week
Community Partner Outreach and Solicitation	1 individual – 40 hours/week
Lecturers	3 individuals – 12 hours/week
TOTAL	172 hours/week

Teaching assistants are responsible for holding office hours, assisting with team projects, and grading papers. Additional hours are scheduled as need for teams involved in the prototyping phase of a project. All students are given access to the machine shop on campus for their prototyping needs. Large-scale working prototypes are typically created in the machine shop on campus while smaller prototypes may be constructed in students' own premises. On occasion, our community partners have facilities available for students to use when working on a prototype for the organization. Lecturers are responsible for developing curricular content for their lectures and hosting additional office hours as needed by the students.

Conclusions:

Since its implementation into the engineering design course curriculum, CSLP projects have been extremely successful and well-received amongst all involved: community organizations and partners, students, and instructional staff. The symbiotic relationship between the community and the students in the CSLP program help to make these projects not only fun for students but also worthwhile for community partners. We conduct frequent surveys to determine the success of the program amongst students and community partners. Survey results indicate that students are excited to gain practical experience in their fields of interest while community partners appreciate the work completed in helping the organizations. Survey results also indicate that students are typically disillusioned about their choice of major. For instance, a student once with a proposed major of chemical engineering noted “[she] had no idea of the amount of physics that was needed in this field and the lack of basic general chemistry in the concentration.” Most students share some aspect of surprise in understanding their fields of study and the true meaning of a project relating to the field. Since our goal was to introduce students to their intended fields of study, we feel that these results show success in our attempts.

We have also noticed a much lower transfer rate out of the engineering school since the institutionalization of the service-learning projects. (Unfortunately, we cannot provide exact figures on the rate, as this is confidential information for the institution.) This shows that the practical experience gained by students during their first year in the program through these projects helps to spark their interest in their intended fields. We also find that fewer students are changing between majors after their experience with CSLP. The introduction to engineering they are given allows for students to make more educated decisions in choosing a major during their second year in the engineering program.

Acknowledgments:

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