AC 2012-3982: INTRODUCING FACULTY RESEARCH TO UNDERGRADUATE ENGINEERING STUDENTS: ENHANCING ACTIVE COOPERATIVE LEARNING

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Introducing Faculty Research to Undergraduate Engineering Students: Enhancing Active Cooperative Learning

Abstract

Involving students in research projects can be seen as a form of inductive teaching. However, the few studies the authors could find regarding the benefits of incorporating research in undergraduate classes show mixed results and opinions. This paper discusses preliminary results of introducing faculty on-going research to undergraduate students, in a form of multidisciplinary projects and team environments, focusing on student-centered approaches, such as active cooperative learning.

In the summer of 2011, a small informal team of students was assembled and presented them with an open-ended multidisciplinary problem. The students were from the Electronics and Telecommunications and Manufacturing and Mechanical Engineering Technology program within the Engineering Technology and Industrial Distribution Department at Texas A&M University. The challenge was to develop a low-cost "standardized" vehicle, capable of supporting customization and adaptation to meet a number of divergent needs. The students were required to come up with a collective solution. The instructors from both programs provided weekly discussions in response to the students' efforts while offering little direction. Students' involvement in the faculty on-going research, the minimum guidance provided by the instructors and the trial and error consequently required by the students, were used as tools in the learning process.

The current paper is based on our preliminary experience and aims to address the need for combining multidisciplinary theoretical knowledge with practical hands-on experience, with a particular focus on integration of research and education. The main goal was to try to assess how well students work under that model and share our experiences. The strategy further strengthened faculty beliefs in the future of the research-teaching nexus.

Introduction

An instructional strategy that comes close to emulating research is inductive teaching [1]. In this approach, the students are first presented with a challenge and they attempt to solve it. Learning takes place while students are trying to understand what they need to know to address that challenge. Students tackling these challenges quickly recognize the need for facts, skills, and a conceptual understanding of the task at hand. At that point, the faculty provides minimal instruction to help students learn on their own. Bransford, Brown, and Cocking [2] survey extensive neurological and psychological research that provides strong support for inductive teaching methods. Ramsden [3], Norman and Schmidt [4] and Coles [5] also demonstrate that inductive methods encourage students to adopt a deep approach to learning. Felder and Brent [6] show that the challenges provided by inductive methods serve as precursors to intellectual development. Prince and Felder [7] review applications of inductive methods in engineering education, and state the roles of other student-centered approaches, such as active and cooperative learning, in inductive teaching.

Engaging students in research projects can be seen as a form of inductive teaching and is frequently cited as an effective way to link faculty research to undergraduate teaching. Sabatini [8] discusses several examples of how undergraduates and high school students can be involved in engineering research. The NSF Research Experience for Undergraduates (REU) program [9] promotes and supports research involvement and this activity clearly has the potential to benefit students. Pascarella and Terenzini [10] note several positive outcomes for students who participate in undergraduate research programs, among them greater retention in the curriculum and greater likelihood of enrolling in graduate school. On the other hand, Seymour et al. [11] argue that most studies of undergraduate research did not include proper control groups, used biased samples or failed to provide sufficient details of their evaluation methods.

The sections that follow provide an overview of our efforts to improve the learning environment for undergraduate engineers by incorporating research in a multidisciplinary team environment and discuss the early accomplishments that our working group has achieved.

Motivation

The faculty main goal was to let each student experience being an engineer by introducing an open-ended research problem, and thereby forcing the student to link engineering theory to real-world applications. Preparing students to actively participate in the learning process, by exercising original thinking, evaluating alternative solutions, making decisions and defending them, was our motivation. Since students who are capable of self-learning are better prepared to become lifelong learners, the teams were provided with limited guidance and, to guarantee success, their work was assessed using weekly meetings throughout the class duration.

Scope of the Project

Within academia, and other research development environments, there is a need for a low cost, "standardized" vehicle capable of supporting customization and adaptation to meet many divergent needs. Researchers at Texas A&M University are interested in identifying a physical system (common platform) and hardware/software architecture (control system infrastructure) to address these needs. During the Summer 2011, a small informal working group composed of faculty members and students from the Electronics and Telecommunications and the Manufacturing and Mechanical Engineering Technology Programs at Texas A&M University came together to develop resources and capabilities to support both education and research in the area of ground-based robotics. The overall goal of the open-ended challenge was to develop a reproducible, low-cost wheeled robot suited for operation on rough terrain in remote environments, to support current and future education and research activities. The beauty of the open-ended problem is that the students become emotionally involved, as the available information is insufficient to solve the problem and the student must generate the missing information, which makes the answer unique to the student. The answer that the student gets to the open-ended problem is not as important as the student's logic and rationale for his/her design.

Course specific material was identified and included in the curriculum and then mapped to desired course development and outcomes. The students had to be able to develop selection criteria considering all relevant issues, develop and evaluate alternative solutions and chose a possible solution.

Project Specific Goals and Outcomes

The challenge, presented to the students, aims to take the study of engineering design to the next level by incorporating faculty on-going research into the educational process and to motivate the undergraduates with real-world problems. The students work in multidisciplinary environments, take the theoretical ideas and implement them with limited guidance.

The goal of the modified class curriculum was to give the engineering undergraduates the ability to understand and apply design tools and skills such as:

(1) sketching and drawing, in order to communicate design ideas in the team environment (see Figure 1, representing students' work);

(2) kinematics, in order to understand what will work and what not and evaluate alternative solutions (see Figure 2, Figure 3 and Figure 4, representing students' work);

(3) statistics, to be able to work with data (see Figure 2, representing students' work);

(4) materials and manufacturing, to understand materials and processes;

(5) economics to understand that cost is extremely important and usually determines whether a product will sell or not;

(6) communication skills to learn how to work in a multidisciplinary environment and understand relationships between mechanical and electronic concepts;

(7) make decisions and defend them.

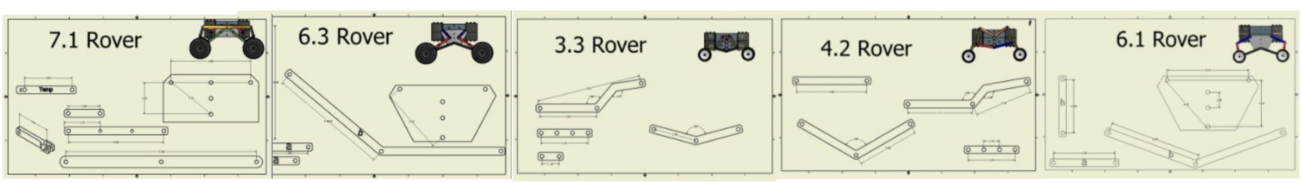

Figure 1. Samples of Student's Work: Linkage Type and Link Lengths for Different Platform Designs.

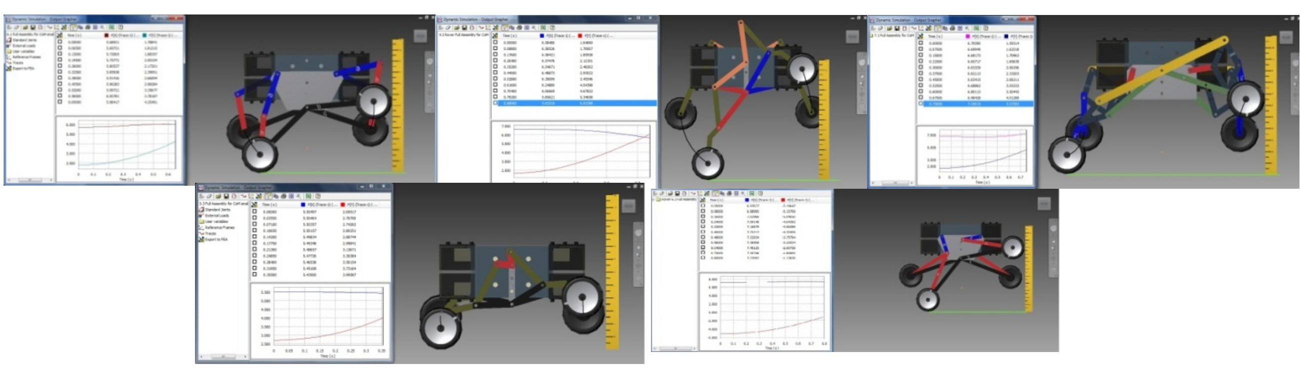

Figure 2. Samples of Student's Work: The Five Design Concepts and their Suspension Climbing Ability.

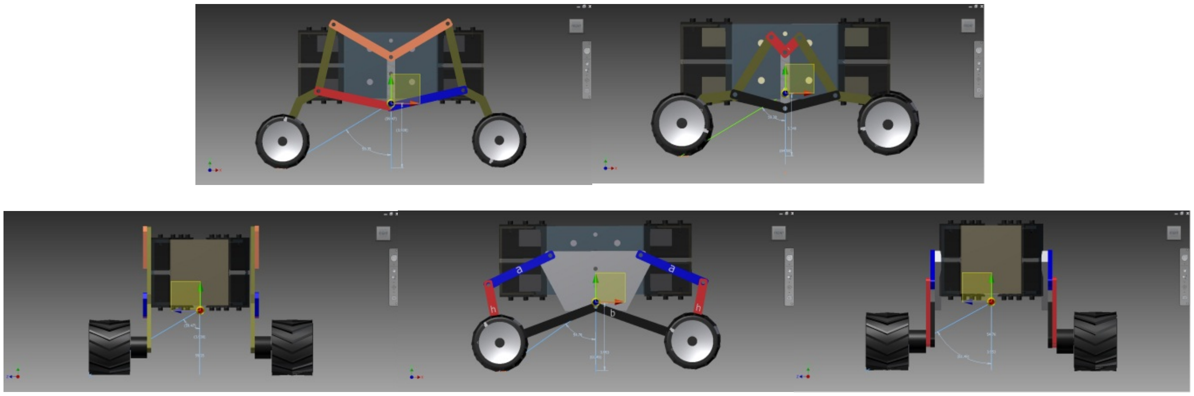

Figure 3. Samples of Student's Work: Center of Gravity Location for the Five Design Concepts.

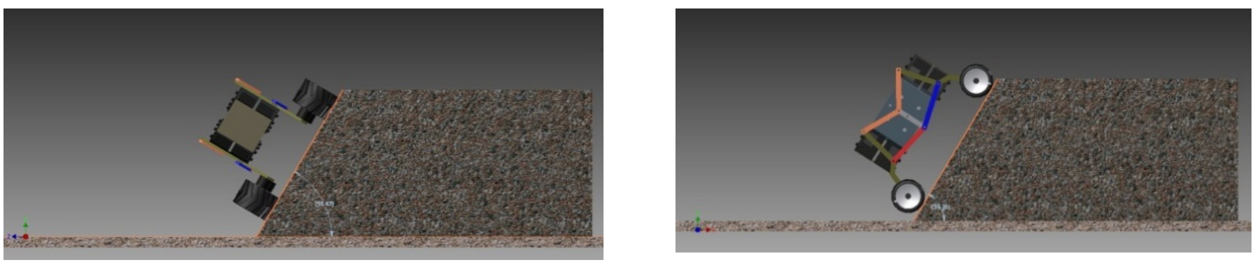

Figure 4. Samples of Student's Work: Visual Representation of Gradeabilty of Design 4.2

To increase the quality of writing [12] the students were asked to submit design overview reports at the end of the class. To let the students experience some of the challenges related to performing research, they were asked to co-author a conference paper, describing the problem and the solutions. Finally, in order to be able to share the results with others, the students were asked to be prepared with ideas regarding the dissemination of their research project outcomes.

Effectiveness of the Approach

The effectiveness of the approach was assessed through a collaborative effort with all those involved via evaluations, weekly meetings and surveys. The main goal was to assess how well the students work and learn under the model. The project was evaluated at the end of the Summer, 2011 by a survey. The students were asked to provide feedback regarding the extent of knowledge and confidence they were able to gain in the class. A summary of the student's answers and the average score for each of the ten survey questions is given in Appendix 1. Below are some of the student comments:

- During our summer research, we not only learned crucial skills and picked up valuable information, but we were also able to appreciate the scope of the field in which we were working;
- By making direct comparisons between designs, we were able to logically narrow our selection;

- There were a lot of problems that had to be solved through critical thinking and independent research and therefore the summer research project proved to be an excellent learning environment that necessitated the ability to solve problems;
- While the majority of the projects could be understood in terms of general concepts and ideas, further developments required higher-level knowledge of multiple subjects;
- Although such material sometimes posed challenges, this was rarely a problem due to the guidance and support offered by the faculty and the project advisors;
- The summer project proved to be an excellent learning environment that necessitated the ability to solve problems;
- Although a great amount of guidance and support was offered, there were a lot of problems that had to be solved through critical thought and independent research.

The student comments without a doubt give credence to the faculty efforts in emphasizing research in education, confidence in working out real world complex engineering problems, quality work, critical thinking and design innovation. The survey also revealed an area where students did not feel very comfortable, such as understanding the relationship between concepts. This issue is understandable and in some ways expected given the fact that most of the students have not had a previous opportunity to work in a multidisciplinary set up. Questions, regarding student's ability to understand the relevance of the project to real world issues, to appreciate the field, to think through a problem or challenge, as well as gaining confidence in working problems in this field were scored the highest.

The understanding and learning outcomes for the students were also assessed by the faculty, via two main objectives: (1) student's ability to prepare and publish a research paper, describing their work; and (2) student's ability to disseminate their results. From the results of this project, the students were able to put together a research paper outlaying the achievements and future goals. With regard to disseminating the results, the students came up with a prospective business model for designing and marketing the developed robotic device. As a result, the faculty is now seeing an interest, generated by external groups. One of the leading supplier of open source educational robotics programs and hands-on engineering GearsEds is interested in using the ASEP robot as an on-line "real" game that users could request mission times and then log in and control the ASEP over different missions. In lieu of the high-cost command robot vehicle NASA JSC has also shown interest in order for the platform to be used as an "expendable" data collector that would explore areas that may not be easily mapped. The platform was also a great success at the Aggie Land Saturday, where the team did demos and interacted with high school students. Finally, and most importantly, a group of the students working on the project have become so involved in the design and development of their research that they are continuing to work together and are seeking out additional projects to tackle as a team.

Impacts and Future Directions

There has not been a great deal of research done on the effectiveness of research in undergraduate engineering classes. The challenges provided by inductive methods and, particularly, incorporating faculty on-going research in education are a great way to motivate students, encourage them to adopt a deep approach to learning and serve as precursors to intellectual development. A significant advantage of introducing faculty research is its capacity to motivate students, providing them with the opportunity to explore and seek information that satisfy their natural curiosity and consequently creates a more engaging learning environment. The mathematical tools in the engineering analysis and design that the students must understand are at times overwhelming, but when students are given a chance to develop devises that have immediate real-world applications, they are motivated to progress in unimaginable ways. Despite the high resistance from both students and educators, the ideas behind inductive teaching and incorporating research with education are getting more and more accepted, as industry begins to seek employees who are better problem-solvers and independent workers. Ultimately, isn't producing graduates capable of designing high-quality products the ultimate goal of engineering education?

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Appendix A: Survey Results

Use a scale from 1 to 5 (not at all, a little, somewhat, a lot, great deal). Please add comments after each of your responses.

As a result of what you did in this class to what extent did you make gains in:

1. Solving problems: 4.5
   Starting from the ground up was an opportunity to solve an iterative problem that required generating multiple conceptual designs. Upon building the unit, there were opportunities to solve practical problems as well. The summer project proved to be an excellent learning environment that necessitated the ability to solve problems. Although a great amount of guidance and support was offered, there were a lot of problems that had to be solved through critical thought and independent research.

2. Working efficiently with others: 4.5
   There were aspects of the design process that allowed the mechanical side to work independently from the electrical, but overall the two had to come together in the end. Since all the summer projects were group projects, teamwork was almost a non-issue. Despite the fact the team members usually worked on different aspects of the same project, collaboration and the sharing of thoughts and ideas became crucial to the overall success of the project.

3. Understanding the main concepts: 4.5
   A great chance to pick up concepts in a new field at an accelerated pace. Although the summer projects explored many new and previously unlearned concepts, they placed a great emphasis on the material that had been taught throughout the past year. Furthermore, in order to successfully develop the summer projects, a solid understanding of the fundamental concepts, whether electronic or mechanical, was crucial.

4. Understanding the relationship between concepts: 4.0
   There were multiple opportunities that we as a team took to determine the critical path for each end of our projects so that we could be ready to test at approximately the same time.

5. Understanding how ideas in this class relate to those in other science classes: 4.5
   A great chance to apply classroom knowledge about material properties, strength of materials, kinematics, programming, and hardware design.

6. Understanding the relevance of this field to real world issues: 5.0
   The base process that we walked through could be applicable to a variety of engineering problems. One of the main purposes of the summer projects was to give students a feel for what would be experienced in the coming years. The projects placed a large emphasis on development that might have possible external applications, including solving real-world problems, research, or commercial applications.

7. Appreciating this field: 5.0

I enjoyed having to opportunity to learn more about the electronics side, while being responsible for the mechanical. During our summer research, we not only learned crucial skills and picked up valuable information, but we were also to appreciate the scope of the field in which we were working; different projects ranging from a rover, to a Bluetooth-controlled robot, to a cuff that measures the vital statistics of a horse all have their origins in the field of electronics.

8. Ability to think through a problem or argument: 5.0
   When choosing between designs, there were aspects of each that had to be weighed in. By making direct comparisons between designs, we were able to logically narrow our selection. There were a lot of problems that had to be solved through critical thinking and independent research and therefore the summer research project proved to be an excellent learning environment that necessitated the ability to solve problems.

9. Confidence in your ability to work problems in this field: 5.0
   Practice builds confidence. Although development and a working prototype were one of the goals of the summer projects, other goals were to test and develop the critical thinking skills, creative problem solving, and collaborative skills of the students. These goals were accomplished by posing relevant problems that related to the field of electronics and requiring the students to solve the problems and successfully develop the projects.

10. Feeling comfortable with complex ideas: 4.5
    Working under some level of supervision, while also being offered some autonomy generates a creative atmosphere, which opens communication of complex ideas. While the majority of the projects could be understood in terms of general concepts and ideas, further developments required higher-level knowledge of multiple subjects. Although such material sometimes posed challenges, this was rarely a problem due to the guidance and support offered by the faculty and the project advisors.