

**AC 2007-2409: PUSHING THE LIMIT: EXPOSURE OF HIGH SCHOOL SENIORS
TO ENGINEERING RESEARCH, DESIGN AND COMMUNICATION**

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Pushing the Limit: Exposure of High School Seniors to Engineering Research, Design and Communication

Abstract

There are many engineering summer programs in existence at various universities that have been designed to stimulate interest as well as inform K-12 students about the engineering field. Programs vary from one to ten weeks and may sometimes include a financial incentive. This paper describes and assesses a one-week summer program designed to push the academic and time management limits of students who are already interested in science and engineering. The primary objective is early exposure to research, design and communication with the expectation that all participants in the program will become undergraduates who are motivated to pursue research projects. Other objectives included the successful introduction of advanced concepts to 12th grade students through software; pushing the intellectual pace of these students, who are generally unaccustomed to academic pressure, and the development of the participants' leadership and teamwork skills. This program distinguishes itself among other summer programs in that it is an accelerated one and it introduces participating students to relatively advanced concepts in applied research, engineering design and communication. Additionally, the program seeks to develop the participants "soft skills" that will be necessary for future team oriented projects and/or leadership practices. The students selected are above average (regionally) and already have a strong interest in science and/or engineering. Assessment measures for the programs primary objectives are implemented in which the student's future academic activities are monitored. Assessment of the secondary objectives is performed based on immediate feedback from students and parents. Additionally, we describe and assess the methods adopted for the short summer program that introduce advanced concepts in planning, communication and design.

Introduction

Despite considerable effort from public and private entities dedicated to increasing the number and quality of students enrolled in engineering programs in the United States, the overall numbers continue to decline.¹ Additionally, the percentage of women and minorities enrolled and/or retained in engineering programs is still substantially disproportionate in comparison to the percentages within the general population.² While these numbers are declining, there is an increasing national need to integrate research into the undergraduate engineering curriculum^{3,4}. Students are recruited nationally and internationally at Armstrong Atlantic State University, Savannah, Georgia, USA; however the majority of students are from local and surrounding counties. The majority of public schools in these areas perform substantially below the regional and national averages in Science, Technology, Engineering and Mathematics (STEM) areas⁵. In many cases, local students who are mechanically inclined lack the fundamental mathematical skills necessary for success in an engineering curriculum. These students therefore often opt for the technical track in high school and inevitably choose to pursue post secondary programs that qualify them as technicians or mechanics. While the latter phenomenon is not necessarily a negative one, the lack of local engineering expertise has a strong potential to exacerbate cultural misunderstandings and negatively impact the relationship between local engineering industries have with the community. An increase in the numbers of local students who possess creative and mechanical talent, and are motivated to continue learning beyond the secondary phase, within the

local engineering industry will prevent these problems which will likely result in increased productivity. Additionally, the percentages of ethnic and gender minority students enrolled in accredited engineering programs and employed in the engineering industry continue to substantially lag their general population percentages⁶. Diversity remains a valuable asset for all corporations as customers, clients and competitors become increasingly diverse in all aspects. In order to tackle these deficiencies, a one-week summer engineering program for rising senior students was developed with the following objectives.

1. Increase the awareness of future students of mathematics and technology of the varied functions and roles for research engineers.
2. Encourage more local high school students to pursue careers in engineering research and development.
3. Push students beyond usual academic expectations to yield positive outcomes.
4. Provide participating students an awareness of the importance of “soft skills” in the engineering industry.
5. Increase the ethnic and gender diversity of students among the local student population who opt for engineering careers upon acceptance to college.

The emphasis in objective 1 is placed on research and development; this is done specifically to infuse local technological and engineering entrepreneurship in the community. If this objective is to be realized, it is necessary to provide a bridge that allows student engineering talent to be recognized by the local engineering firms. The bridge, in this case, was the attendance of local engineers or technical administrators along with the parents of the participants, some of who happened to be local engineers, at the final presentation by the students.

Course Structure

The one-week engineering workshop was called the Talented Researchers in Engineering (TRIE) program. There were eight student participants, all of whom were from local public or private schools. A special effort was made to encourage participants from public schools in which the majority of students are from minority ethnic or gender backgrounds. This was done through direct phone calls to counselors and teachers, face to face meetings as well as email. Administrators of other potential participating private schools received an email about the program only. Three faculty members and a graduate assistant supervised the eight participants. The curriculum design intent was to expose these students to engineering methods that demonstrate applications of mathematics and physics concepts taught in the current high school curriculum. The authors also endeavored to create a fast paced yet fun environment in order to eliminate any down time and maximize productivity.

The areas chosen had to be interesting to teens and provide visible results that lend themselves to dynamic presentations. With the above criteria in mind, the areas of emphasis chosen were Computer Aided Engineering and Design (CAE/CAD), Graphical Programming and Simulation, and Internet Communications. The objectives were designed with the intent to stimulate interest in research and development, therefore the engineering design problem was chosen such that

students could exercise their creativity within a structured environment. The design problem involved the development of realistic specifications for a lightweight robotic arm, restricted to three degrees of freedom, capable of lifting a 20 lb cylinder (size and geometry of a soda can) through a distance of 6 inches. The robotic arm size and geometrical constraints were consistent with those for the arm of an average human female within the US.

Students were divided into three groups of two or three; each group was then assigned to examine different aspects of the same design problem. The group designations and responsibilities are provided in Table 1. In order to arrive at realistic concepts, all teams were required to research the current state of robotic arm development using the Internet as well as university library resources (reports, journals, books).

Table 1. TRIE Program group designations and tasks

Computer Aided Design and Structural Integrity team	<ol style="list-style-type: none"> 1. Research current robotic arms, their uses, maintain daily log 2. Draw robotic arm and components in SolidWorks 3. Perform Basic Finite Element Analysis (Cosmos) 4. Provide structural characteristics and improvements 5. Develop presentation
Internet Programming and Communications team	<ol style="list-style-type: none"> 1. Research current robotic arms, their uses, maintain daily log 2. Develop website discussing project 3. Put daily design logs of all teams on website 4. Put Solidworks pictures and Labview VI on website (these will be available Thursday) 5. Develop interactive calculator for simple performance predictions (We will supply formulae) 6. Present and discuss website development
Dynamic Simulation team	<ol style="list-style-type: none"> 1. Research current robotic arms, their uses, maintain daily log 2. Develop a Labview VI to simulate 2-D robotic arm (be completed by Thursday afternoon) 3. Maintain daily log of VI design 4. Develop a power pt presentation about VI 5. Be able to explain all aspects of VI in presentation

Group projects were designed such that students would develop realistic expectations of desirable design project outcomes upon enrolling in a university engineering program. Therefore the project requirements were chosen such that several Accreditation Board of Engineering and Technology (ABET) criteria 3 outcomes could also be satisfied. The ABET criteria 3 outcomes satisfied were a, c, d and g⁷. The project focus was also geared towards tasks within the conceptual design and product development phases, as these phases often contain tasks unique to the “engineering” aspects of design. Figure 1 illustrates the stages within the conceptual design phase and shows their relationship with assigned student tasks. For example, the research tasks on day 1 include both the information and feasibility stages, while the discussion and final design decision at the end of day 1 would comprise the preliminary and final design selection stages.

Rationale for Tasks:

All students were required to learn the fundamental aspects of software packages used in Computer Aided Engineering and Design (SolidWorks), Simulation and Data acquisition (LabView) and Internet Website Design (HTML, DreamWeaver). One two-hour introductory “hands on” seminar was provided per day each morning for four consecutive days. The

non-interactive instruction time lasted for approximately a half an hour. The traditional one-way communication methodology was used to demonstrate the introductory physics behind each

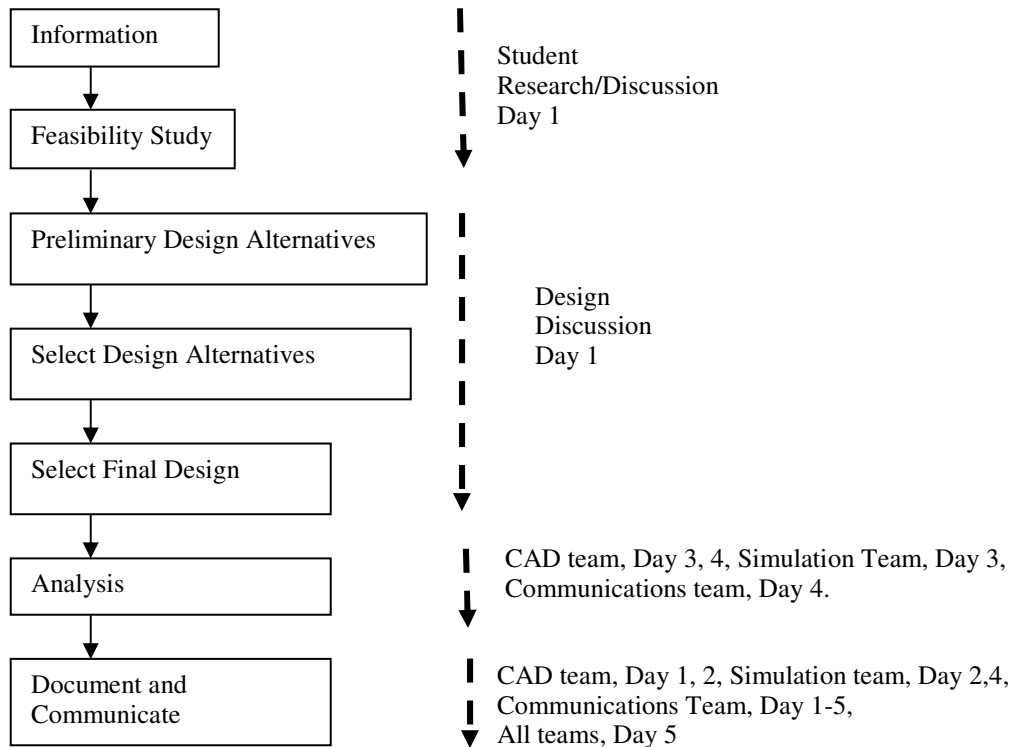


Figure 1. *Project Tasks Role in Overall Design Process*

computer tasks and received immediate feedback. Groups worked after the lunch hour for another three to four hours under the supervision of a faculty member or the graduate student. The program schedule is provided in Appendix A.

Computer Aided Engineering and Design Module

Students were required to use the basic features in Solid-Works to develop a parametric solid model of the robotic arm. Each student of the CAD/CAE group drew at least three components of the final assembly. The students were also introduced to the concepts of normal stress and strain, material properties, Young’s Modulus and the fundamental aspects of Finite Element Analysis (FEA) via lecture. They were then asked to research potential materials for the robotic arm and perform a preliminary analysis on the structural performance of the arm. The research of materials served to introduce students to design by selection. The constraints used were material strength, stiffness, cost and ease of manufacturing. The incorporation of more constraints would have been impractical as an understanding of optimization concepts would have been necessary. FEA was treated as a “black box” computational method after introduction of a basic linear spring system with two degrees of freedom example. In running the FEA programs, students learnt what questions should be asked in a true design scenario. For example, some of the questions students had to answer included, “Where will my part most likely fail?”

“How will my part deform?” and “What could be done structurally to minimize weight”. Figure 2 shows a CAD model of the robotic arm comprised of eight components, developed by the CAD/CAE group. In development of the assembled model, students were introduced to several CAD concepts such as geometric constraints, parametric modeling, tolerance requirements, acceptable dimensioning techniques, degrees of freedom and interference checks.

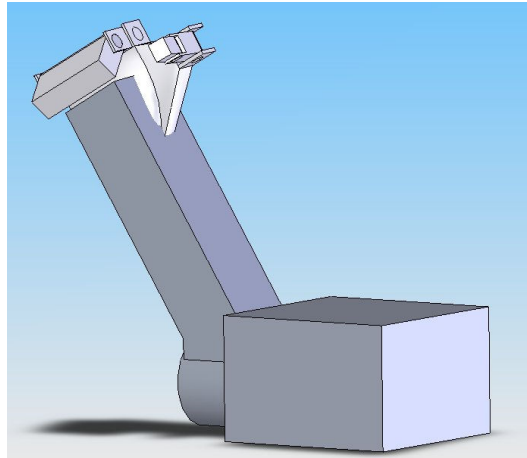


Figure 2. Robot arm CAD/CAE model developed by TRIE students

Graphical Programming and Simulation

The research team was charged with designing a control system using LabVIEW to handle varying loading conditions and operate the gripper claws to manipulate the canisters. The specific requirements of the LabVIEW based control system included the following:

1. Calculate the weight of a canister, given the load cell voltage and calibration information of the load cell. The load cell specifications are provided to determine how to calculate the weight based on the load cell voltage.
2. Based on the canister weight, calculate the required gripper force to safely lift the canister.
3. Display the required gripper motor voltage to lift the equipment canister if this force is less than or equal to the maximum possible gripper force. If the required gripper force is greater than the maximum possible gripper force, then the VI should display a message indicating as such and terminate the while loop of the VI (stop the VI). The required gripper motor voltage should be displayed only once the touch sensor (push button) is activated in the VI. At any other time, the voltage to the gripper motor should be zero.

The team was also given basic information on load cells and introduced to calibration factors. Using the calibration data, the team was able to calculate the calibration factor for the load cell and the force-voltage calibration factor for the gripper motor. It was left to the team to research how to perform a linear regression using the data with Excel. The required gripper force was another calculation for the design team. The team was briefed on free body diagrams, normal forces, and friction forces. They were also given the free body diagram shown in Figure 3 and

the coefficient of static friction between the canister and the gripper claws. With this information, they were then able to calculate the necessary gripper force.

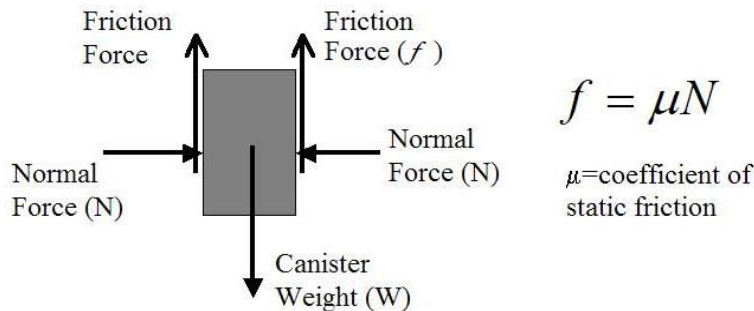


Figure 3. Free body diagram of the equipment canister

The remainder of the project consisted of creating a LabVIEW Virtual Instrument (VI) to execute the required control sequence. All TRIE participants were given brief tutorials on creating VIs using Boolean operations, case structures, formulae, and data manipulation. However, the team still had to establish an algorithm to meet the control specifications using the various attributes of LabVIEW. A block diagram of the team’s VI is provided in Appendix B. Their VI based control system met all the required design criteria.

Internet Programming and Communications

On the first day of the TRIE program, all students were given specifications for individual Web sites that they were to post online by the week’s end. Each student was to create a site featuring a home page, a research journal, and a page describing their projects in other classes. They followed three steps when building their sites: design, implement, and maintain. In the lecture series, students learned about Internet fundamentals such as uniform resource locators (URLs), browsers, and search engines. A portion of the lectures explained how the Internet is an effective tool for research. The students learned how various HTML tags are used to construct Web pages. In the labs and outside of the classroom, students used HTML tags to develop and upload their individual HTML pages. Each TRIE participant received ten megabytes of Web space and access to downloadable software that could be used anywhere for transferring Web files.

The Internet Programming team created a Web site about the research experience as their final group project. Before building the site, the project team was required to research and learn Camtasia, a video-editing software package that captures activity on computer screens as a video. The team was instructed to use the software’s editing features to create final videos of all participants’ projects from other classes. The Web development team also researched and used Dreamweaver, Macromedia’s web development software, to build the site. As required in the project, the group included a calculator applet written in Java, the Camtasia videos, and at least six pages to create the final Web site.

Assessment

Poole et.al⁸ demonstrated that a multi-pronged approach is required in order to develop a comprehensive and successful assessment plan for K-12 pre-engineering outreach programs. These authors proposed that assessment strategies have three key components: 1) assessment of workshop participant feedback (teachers and students), 2) assessment of long-term outcomes (teachers), and 3) assessment tools developed for the teachers' classroom use (i.e., embedded assessment). In this program, we adopted assessment methods 1) and 2), however teacher feedback was replaced with parent feedback for assessment method 1). The third assessment method was not adopted because our students were rising seniors, there were only eight of them and the program was in its first year. The latter factors would have negatively influenced the teachers' ability to develop embedded tools and meaningful comparisons.

The methods of assessment involved a course survey, direct feedback from parents as well as follow up surveys six months after the program. The students will also be tracked for three years after the program to determine if any of them participate in undergraduate research projects outside of the typical curriculum and whether this initial program had any effect on their choice.

Conclusion

Based on the initial and follow up survey, 90% of the students either agreed or strongly agreed that the program inspired them to pursue research at the undergraduate level. 85% of the respondents also agreed that the program improved their appreciation and knowledge of research and design processes in engineering. 100% of the respondents would recommend the program for high school students who are considering professional technical careers. Parent perceptions and expectations regarding future benefits of the program also correlated well with their children's responses. In the general commentary section, six of the eight students indicated that the program was too short given the research expectations. This was expected as the program was purposely designed to have an uncomfortably fast pace.

A fast paced one-week engineering workshop for RISING SENIORS was successfully developed and implemented using interactive learning modules with dynamic presentation ability. Students and parents perception of positive outcomes are consistent with each other. Future assessment based on follow up surveys will determine whether the long-term objectives of the program are met.

Acknowledgments

This authors wish to acknowledge the NASA Space Grant Consortium for providing funding for the TRIE program. The authors are also grateful to Ms. Iyatiti Mokube, graduate research assistant in the School of Computing at Armstrong Atlantic State University, for her assistance with student monitoring and classroom management.

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Appendix A

TRIE Program Schedule

Time	Day 1	Day 2	Day 3	Day 4	Day 5
0900-0930	Introduction to program and expectations	Website Design Introduction	Graphical Programming Introduction	CAD/CAE Introduction	Each Group Work on Final Aspects of Projects
0945-1045	Research and Design fundamentals:	HTML Lab 1hr	LABVIEW	SolidWorks	
1100-1200	Practice using internet and library resources	HTML Dreamweaver	LABVIEW	CosmosExpress	
LUNCH					
1315-1345	Meet with individual advisors 0.5 hr				Presentations
1400-1525	Research concepts for discussion	Groups work independently, Special instruction CAD/CAE group only	Groups work independently, Special instruction CAD/CAE group only	Indep. Group Work	
1535-1605	Group Discussion, make decision on final design, 1 hr	Group discussion: Exchange of ideas			Awards

Appendix B

Block Diagram of Robotic Gripper Control System designed by TRIE students

