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

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Abstract – Recent literature attests to the fact that the number and quality of students enrolled in engineering programs in the United States is declining rapidly. In view of this, various undergraduate research projects, summer programs and other academic programs are being implemented at universities and high-schools. In an effort to effectively address this at the high-school level, a ten-day rigorous Talented Researcher in Engineering (TRIE) summer program was developed and implemented at Armstrong Atlantic State University. While most high-school programs do not contain a research component, this program is intentionally designed with an emphasis on engineering research using computer aided design, robotics, technical computing and internet programming. The relatively small size of the program (12 – 16 students and four faculty) is geared toward developing a mentor – student relationship between faculty and students. This paper presents an overview of the TRIE program as implemented in 2007 and 2008.

Keywords: High School Seniors, Engineering Research for K-12, Summer Research Program

INTRODUCTION

The number and quality of students in science, technology, engineering and mathematics (STEM) disciplines at the university levels in the United States is declining rapidly [1]. In addition, there is a need to incorporate research in undergraduate STEM programs, especially in the engineering curriculum [2], [3]. Various undergraduate research projects, summer programs and other academic programs have been implemented at universities and high-schools in response to these challenges [4-7].

The Engineering Studies Program at Armstrong Atlantic State University (AASU) is a part of the regional engineering program in which students complete their first two years of the engineering curriculum at AASU and then transfer to the Georgia Institute of Technology to complete their engineering degrees. Over the past four years, the program has had an average enrollment of 192 students with approximately 20% of them successfully transferring to the Georgia Institute of Technology to complete their degrees. Like many other engineering programs throughout the country, retention is clearly a challenge for our program. Majority of the students enrolled in the program are from local public and private high schools. The majority of public schools in these areas perform substantially below the regional and national averages in the STEM disciplines [8], and most students lack the fundamental science and mathematical skills necessary for success in an engineering curriculum [9]. In view of this,

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a ten-day rigorous summer program – the Talented Researcher in Engineering (TRIE) program, was developed at AASU 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 the usual academic expectations to yield positive outcomes.
4. Provide students with 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.

While most high-school programs do not contain a research component, this program was intentionally designed with an emphasis on engineering research using computer aided design, robotics, computing techniques and internet programming. The relatively small size of the program (12 – 16 students and four faculty) was geared toward developing a mentor – student relationship between faculty and students. The program was first successfully implemented in the summer of 2006 [10]. This paper presents an overview of the program as implemented in the summers of 2007 and 2008.

The following sections present an overview of the program structure, a brief description of the various projects, a summary of assessment, and conclusions of the authors' experiences.

PROGRAM STRUCTURE

The TRIE program was implemented as a 5-day program in the summers of 2006 and 2007 and as a 10-day program in the summer of 2008, based on feedback received from the participants regarding the time constraints of the 5-day programs. There were about 8-12 participants, all of whom were from local public or private schools. The program director made a special effort to encourage participation from students from minority groups and female students. The program had four faculty members who served as advisors and others who gave lectures and conducted workshops on various topics. The program structure was designed with the objective to push the limit of high school seniors beyond their usual academic expectations and to expose them to engineering research, design and communication. A sample program schedule from 2008 is shown in Table 1.

Days 1-3	Wed	Thurs	Fri
0900-0930	Introduction to program (0.5) Dr. Coates	Lab/lecture	Lab/lecture
0940-1145	Lab/lecture Internet Programming HTML (2.5) Mr. Mcarthy	Lab/lecture Internet Programming HTML (2.5) Mr. McCathy	Graphical Programming/Robotics LABVIEW/ PBASIC (2.5) Dr. Johnson
1200-1250	LUNCH	LUNCH	LUNCH
1300-1630	Group research and meet with advisor (3.5)	Group research and meet with advisor (3.5)	Group research and meet with advisor (3.5)

Days 4-10	Mon	Tues	Wed	Thurs	Fri
0900-1145	Graphical Programming/Robotics LABVIEW/ PBASIC (2.5) Dr. Johnson Movie (0.25)	Lab/Lecture Computational Modeling with MATLAB (3) Dr. Goeser	Lab/lecture Computational Modeling with MATLAB (2.5) Dr. Goeser Movie (0.5)	Lab/lecture Computer aided design (2.5) SOLIDWORKS Dr. Coates Movie (0.5)	Communication seminar (1) Dr. Desnoyers-Colas Special Guest Lecturer Lab/demo Biodynamics (2) Dr. Riemann
1200-1250	LUNCH	LUNCH	LUNCH	LUNCH	LUNCH
01300-1630	Group research and meet with advisor (3.5)	Group research and meet with advisor (3.5)	Group research and meet with advisor (3.5)	Final project preparations Mock presentation with faculty (3.5)	Meet and greet parents 1345-1530 Presentations, Judging, Awards

Table 1: TRIE 2008 Program Schedule

OVERVIEW OF PROJECTS

The program as introduced in 2006 had three projects in the areas of computer aided design and analysis, robotics, and internet programming and communication [10]. In addition to these three areas, the area of computational techniques was introduced in the program in 2007. The students worked in teams of four on these projects under the guidance of one faculty advisor each. Each project consisted of the research phase, the problem-solving phase and the final oral presentation. The students worked on their projects for a minimum of 3.5 hours every day during the program. A panel comprising of faculty other than the advisors, and engineers from industry served as the judges for the final oral presentation and competition. Monetary awards were presented to the students based on the results of this competition. Further details on the projects are presented in the following sections.

Computer Aided Design and Analysis

This project introduced students to engineering research and design practices using SolidWorks – a 3-D Mechanical Design and 3-D Computer Aided Design (CAD) software. In the TRIE 2007 program, students were introduced to these concepts via the design of a hovercraft. In the following year, the students designed an aircraft landing gear oleo strut system based on a given preliminary design and other criteria. The following paragraph presents further details on this project.

Students were given an overview of how the strut system works and then provided a set of design criteria. Students were also given two thirty minute tutorials on CAD where 2-D sketches of lines, circles, arcs were introduced and the powerful 3-D extrude feature. They were then required to research various struts and develop a conceptual model of a strut that satisfies the design criteria. Students were exposed to the concepts of geometrical and mass properties, material properties, environment effects through their research. Research was lightly guided by the following suggested questions: What type of airplane (size, geometry, shape, speed, weight) will this gear be used on? What is its primary purpose? What type of environment will the airplane be used in and how often? What type of landing gear has been used in the past on aircrafts with similar missions and physical constraints? Students were then encouraged to relate the answers to the above questions to their decision on landing gear shape, size, geometry, configuration (number of components and how connected), material choice and weight. The students were then provided the dimensions of the predesigned Oleo Strut and Piston and asked to replicate each component in CAD. Additionally, they were asked to develop an exploded view of the assembly and a dynamic simulation. The pre-designed package was used so that students had a clear benchmark for each step as they progressed in their CAD skills. The component views developed by the students are shown in Figure 1.

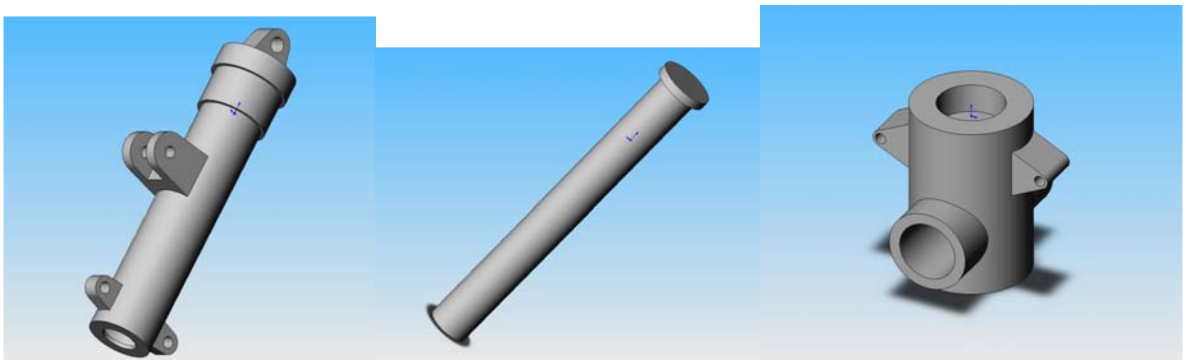

Figure 1: Component Views of the Oleo Strut, Piston and Wheel hub

Robotics

In the 2007 TRIE program, the robotics group was given a simulated Mars mission to design and program a robotic rover to explore a cavern and detect the number of dried-up underground water streams. A scaled mock-up of the cavern was provided to assist the team in designing the robot and testing their program. The dried water streams were to be detected based on the presence of a black marking on the cavern floor. The robot was required to use sensors to navigate through the cavern and count the number of streams autonomously. Upon exiting the cavern, the robot had to display the number of streams detected in the cavern on its display screen. The Lego Mindstorms NXT robotic kit was used as the platform for the team's rover. The Lego Mindstorms NXT kit consists of a programmable brick, sensors (e.g., ultrasonic, sound level, light sensors), and servomotors. The team was given three basic tutorials on how to program simple movements, decision based actions using sensor input, and the use of custom programming blocks (subroutines or functions). However, the team had to investigate the creation and use of variables and variable operations on their own. Figure 2 shows the robot designed by the students; it uses the ultrasonic sensor to detect the cavern walls and the light sensor to detect the dried water streams.

The 2008 TRIE robotics group was charged with the design of a sonar navigation robot using the Boe-Bot robotic platform. The specific tasks were: 1) Design of a mounting system for an ultrasonic sensor and a servo motor to rotate the sensor 180 degrees (attached to the front of the Boe-Bot); 2) Development of programming code to allow the sonar equipped Boe-Bot robot to scan a forward radial of 1.2 meters over 180 degrees, and travel to within 3 cm of any obstacle that is the closest to the robot within the field. The robot was also required to count the number of objects detected in the field and emit a 2 kHz tone for each obstacle detected. The obstacles consisted of cylinders 8 cm in diameter and 21.6 cm tall (a sheet of paper folded along its length); 3) Characterize the relationship between speed (rpm) and voltage pulse width of a servomotor and approximate the beam width of the ultrasonic sensor. Figure 3 shows the robot designed by the team with the mounted sensor.

Figure 2. NXT Robot Rover

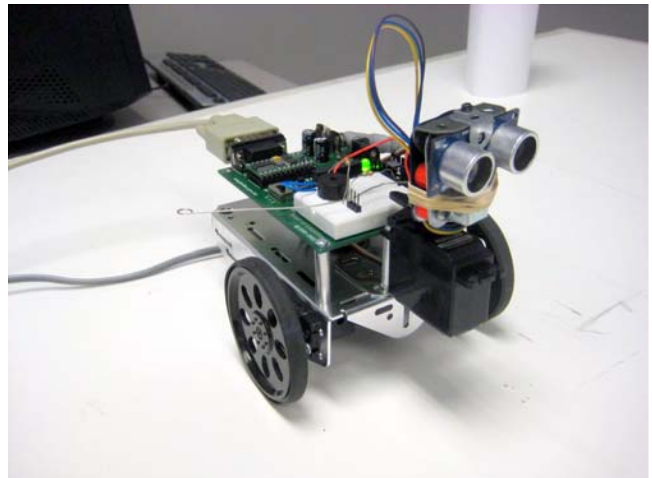

Figure 3. Final mounting system for the ultrasonic sensor.

Internet Communication and Programming

On the first day of the TRIE program, all students were given specifications for individual web sites that they were to create and post online. Each student was to create a site featuring a home page, a research journal, and a page describing their projects in other classes. The Internet Programming team created a web site about the TRIE program. The team studied and incorporated advanced web-techniques such as cascading style sheets, embedding multimedia using Camtasia (a video – editing software package) and creating html scripts. The team also documented the progress of all projects, posting such documentation online so as to provide an avenue for all teams to learn about projects in addition to the one assigned to them. Figure 4 shows the basic structure developed and used by the team to build the web-site for the program.

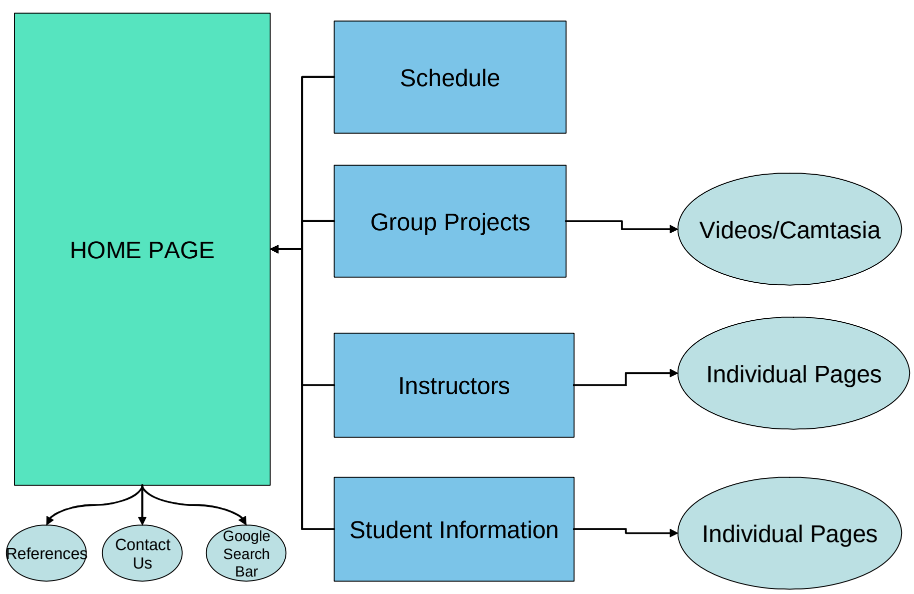

Figure 4: Basic Structure of the TRIE program Web-Site

Computational Techniques

The projects in this section address computational techniques commonly used in image processing applications. The students were first taught the fundamentals of algorithm development and computer programming and given tutorials on using MATLAB – a technical computing software. They were then asked to study and do research on the basic concepts of images and image processing and the various applications of image processing. The students then developed algorithms and programs based on templates of given programs to perform image processing techniques such as converting from color to grayscale, converting from color to black and white, creating a blurred image, reversing an image from left to right and creating a collage. These exercises introduced them to the basics of image processing using MATLAB. It is noted here that the students were asked to develop these programs without access to the image processing toolbox in MATLAB. The following paragraph presents further details on two common image processing techniques – image enhancement and edge detection which were the main problems addressed by the students in 2007 and 2008 respectively.

Digital images taken in poor visibility conditions such as in rain, fog, smoke, haze, etc. are typically of limited use. Common image processing methods such as changing brightness, contrast, color enhancements, etc. are limited in their effectiveness on such images. In the 2007 TRIE program, the image processing team worked on developing an image enhancement algorithm using MATLAB for use in poor visibility conditions. This project was based on the Retinex Image Processing Technique, developed by the Retinex team at NASA Langley Research Center. Another operation commonly performed to reduce the complexity of an image is edge detection, in which the complete image is replaced by a very small number of points that mark the edges of interesting artifacts. In the 2008 TRIE program, the team developed an edge detection program using MATLAB for use in aerospace and other applications. Figure 5 shows the algorithm developed and used by the team for the edge detection program.

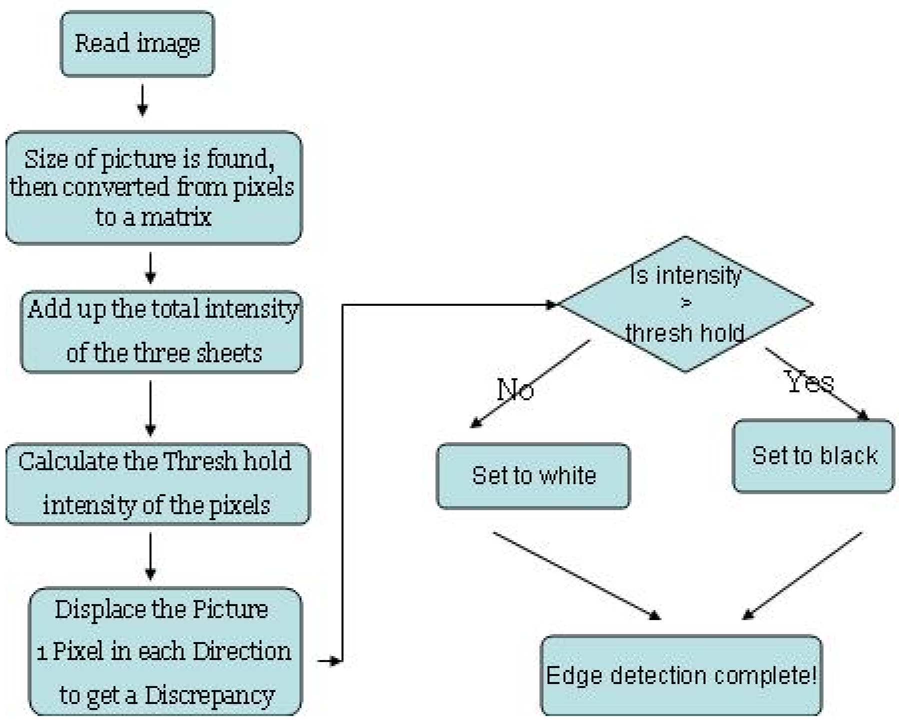

Figure 5. Algorithm for the edge detection program (TRIE 2008)

ASSESSMENTS

In order to assess the effectiveness of the TRIE program, surveys were provided to the students to complete and return anonymously. A summary of results based on the students who completed the survey for the program as implemented in the summers of 2007 and 2008 are provided in Table 2. It is observed that 66.67% of the respondents in 2007 and 100% in 2008 strongly agreed or agreed that the program increased their motivation to pursue a career in engineering; 100% of the respondents in both years strongly agreed or agreed that the program challenged them beyond the usual academic expectations and an average of 81.67% of the respondents strongly agreed or agreed that the program helped them develop their communication and presentation skills.

Questions	**Options**	**Summer 2007 (N=12)**	**Summer 2008 (N=5)**
The TRIE program increased my motivation to pursue a career in engineering.	Strongly agree Agree Impartial Disagree Strongly disagree	50.00% 16.67% 25.00% 8.33% 0%	60.00% 40.00% 0% 0% 0%
The TRIE program has made me more aware of the various functions and roles that engineers have within the engineering research and development field.	Strongly agree Agree Impartial Disagree Strongly disagree	75.00% 25.00% 0% 0% 0%	40.00% 60.00% 0% 0% 0%
The TRIE program challenged me beyond the usual academic expectations.	Strongly agree Agree Impartial Disagree Strongly disagree	58.33% 41.67% 0% 0% 0%	80.00% 20.00% 0% 0% 0%
I have better communication and presentation skills having participated in the TRIE program.	Strongly agree Agree Impartial Disagree Strongly disagree	16.67% 66.67% 8.33% 8.33% 0%	20.00% 60.00% 20.00% 0% 0%
I think that the TRIE program was of appropriate length.	Strongly agree Agree Impartial Disagree Strongly disagree	41.67% 41.67% 0% 0% 16.67%	40.00% 40.00% 20.00% 0% 0%
The difficulty level of the Robotics module was appropriate.	Strongly agree Agree Impartial Disagree Strongly disagree	58.33% 25.00% 16.67% 0% 0%	0% 100.00% 0% 0% 0%
The difficulty level of the Computer Aided Design module was appropriate.	Strongly agree Agree Impartial Disagree Strongly disagree	33.33% 33.33% 16.67% 16.67% 0%	40.00% 60.00% 0% 0% 0%

The difficulty level of the Image Processing module was appropriate.	Strongly agree Agree Impartial Disagree Strongly disagree	50.00% 16.67% 25.00% 0% 8.33%	40.00% 60.00% 0% 0% 0%
The lectures were of appropriate length.	Strongly agree Agree Impartial Disagree Strongly disagree	58.33% 41.67% 0% 0% 0%	40.00% 60.00% 0% 0% 0%
The labs were of appropriate length.	Strongly agree Agree Impartial Disagree Strongly disagree	58.33% 33.33% 0% 8.33% 0%	40.00% 40.00% 20.00% 0% 0%

Table 2: Summary of results from the survey for Summer 2007 and Summer 2008.

Student general comments are shown in Table 3. The majority of student comments were positive. The students seem to have enjoyed getting an in-depth understanding of the topics covered and develop their communication and team working skills. It is also noted that some of the students perceived the program in 2007 (5-day program) to be too short for the material covered and the outcomes expected. This issue was addressed in 2008 by extending the program to a 10-day program.

What did you like about the program?	**Number of similar responses**
"Even though we were in the classroom all day I wasn't ever boring."	
"Helped me with my public speaking skills and learning how to work well with a group"	3
"It went beyond the tip of the iceberg to a deeper level of comprehension."	
"I enjoyed using the robotics, CAD and MATLAB programs; experiencing what engineering have to do."	4
"I liked the team concept and the opportunity to meeting new peers from other schools."	
What did you dislike about the program? If you circled 1,2 or 3 (strongly disagree, disagree, impartial) in questions 5-10, please explain. Do you have any suggestions for improving the program?	**Number of similar responses**
"The program labs should be lengthened so the students have more time to improve their project." (Summer 2007)	4
"I disliked not having the opportunity to pick which project I was able to work on."	2

Table 3: Summary of other comments from students in Summer 2007 and Summer 2008

The results of the surveys and student comments show that the TRIE program was well received by the student participants. In addition to benefits such as increasing awareness and motivation among local high school seniors about engineering, the students also learned the fundamentals needed for scientific, productive and systematic research and improved their ability to perform independent study. The faculty advisors were available only for guidance, encouraging the students to read and study articles and book chapters relevant to the topic of the project.

Conclusions

This paper presents an overview of the Talented Researcher in Engineering (TRIE) program - a summer program for high school seniors, first introduced in 2006 and implemented again in 2007 and 2008 with a few changes. The primary objectives of this program were to increase awareness of future STEM majors about the various roles and functions of engineers and to encourage such high school seniors to pursue careers in engineering research and development. In addition to meeting these objectives, students learned the art of in-depth research and developed soft skills such as professional communication and team working abilities.

Although the sample sizes for the surveys were small, the results indicate that the program was well received by the participants and increased the awareness of the engineering studies program at Armstrong Atlantic State University. The student participants also appreciated that the program challenged them beyond the usual academic expectations. Based on these responses, the authors are encouraged and plan to continue to offer similar programs whenever possible.

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