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Summer Engineering Experience (SEE) Program - A Program to Prepare Freshmen Students for Engineering Studies

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Summer Engineering Experience (SEE) Program to prepare freshmen students for engineering studies

Abstract

This paper details the development process of the Summer Engineering Experience (SEE) program implemented at Vaughn College in order to prepare first-year students for engineering programs. Unlike the traditional pre-engineering programs held in other universities or colleges, which are devoted mainly to mathematics or physics courses, the objective of the Vaughn program is to enhance students' hands-on, computational, programming, communication, and problem solving skills.

The five-week SEE program was offered in the summer 2016, Monday through Thursday, from 8:00 am to 4:00 pm. Lectures and hands-on classes throughout the program covered topics such as engineering computation using MATLAB and C++, robotics, bridge truss design & analysis, technical writing and presentation. The Friday session of the SEE program was designated for technical seminars and workshops designed to enhance students' learning outcomes related to critical thinking, problem solving, and life-long learning. Guest speakers from the industry were invited to deliver lectures and host workshops current with today's technology. Given the rapid pace of technological change, the Friday seminar series and workshops were designed to foster in Vaughn's engineering students a mind-set receptive to changes in technology in order to prepare them for their future professional careers.

During the last two weeks of the program, students were arranged into two to three person groups to work with a SEE faculty mentor and develop a project with real-world engineering application. These projects were presented on the final day of the SEE program, and faculty evaluated the student performances according to specific learning outcomes. A rubric survey was also distributed to students in order to assess the program's effectiveness. The implementation and assessment process of Vaughn's SEE program based on both faculty and students' survey results will be discussed in the ASEE Annual Conference.

Keywords: Freshmen Students, MATLAB, C++, Robotics, Workshops.

1. Introduction

Many students today enter college lacking the foundation and preparation for academic level education. This lack of college level preparation can have an adverse effect upon student understanding and performance in engineering programs. The main objective of the Summer Engineering Experience (SEE) program is to help students to overcome those shortcomings and prepare them for core courses within engineering programs. The SEE program is therefore designed to enhance student understanding in engineering computation, programming, problems solving, design, project development and presentation.

In the computational engineering session of the SEE program, students were introduced to both analytical and finite difference numerical methods for investigating the solution of the governing equation of a physical body. Both MTHLAB and C++ programming are introduced to students as a computing tool to generate results and study behavior of an engineering system. This session not only introduced students to engineering problems and their solutions, but also, enhanced their ability to develop programs to facilitate the solution of a physical system [1]. In the Robotics session students were introduced to the hands-on application of robotics and autonomies programming. They learned about the fundamentals of robotics, program DC motors, motors drives, logic controllers and other VEX robotics components. In the Bridge design session, students were introduced to the hands-on design and application of the bridge truss structure. Basic concepts such as stress, strain, deformation and Hooke's law as used in mechanical engineering were presented to them. After studying the various types of bridges and the mechanisms involved in their load distribution, students applied these concepts to their examination of a basic Warren truss bridge. Finally, students participated in a Technical Writing seminar and workshop in which they learned how to revise their writing and how to make a successful oral presentation. Before the final program presentations, the students performed practice versions of these demonstrations for their classmates. A scoring rubric was employed in order for the students to benefit from peer evaluations of their classmates' work.

Each Friday, the speakers from the industrial seminar and workshop sessions introduced students to real-world engineering systems, and they provided them with the opportunity to work with engineering principles in a hands-on environment. Students were further exposed to programs which facilitate the design and advancement of more functional and smarter engineering systems.

2. Summer Engineering Experience (SEE) Program

The Summer Engineering Experiences, SEE Program is designed with the objective to enhance students' hands-on, computational, programming, communication, and problem solving skills. The SEE program was offered during the summer to the first year engineering students and covered topics related to engineering computation using MATLAB and C++, robotics, bridge truss design & analysis, and technical writing.

2.1 Computational Method with MATLAB and C++ Application

This topic in the SEE program provided students with some fundamental knowledge of engineering analysis and programming using both MATLAB and C++. Students were introduced to topics such as Taylor Series, finite difference, root determination, and numerical integration with application to engineering problems. Both MATLAB [3] and C++ were introduced to students as a computing tool to generate results and facilitate the process of investigating behavior in an engineering system. Through both computational and programming (MATLAB and C++) sessions, students were introduced to the following computational processes

- Mathematical governing equation of an engineering system
- Development process of an analytical and numerical formulation
- MATLAB and C++ Programming
    - How to work in MATLAB and C++ environment?
    - How to use logical control loops?
    - How to write a MATLAB and C++ program?
- Development process of closed-form and numerical solution of an engineering system

Figure 1 is a graphical representation of this computational project based learning.

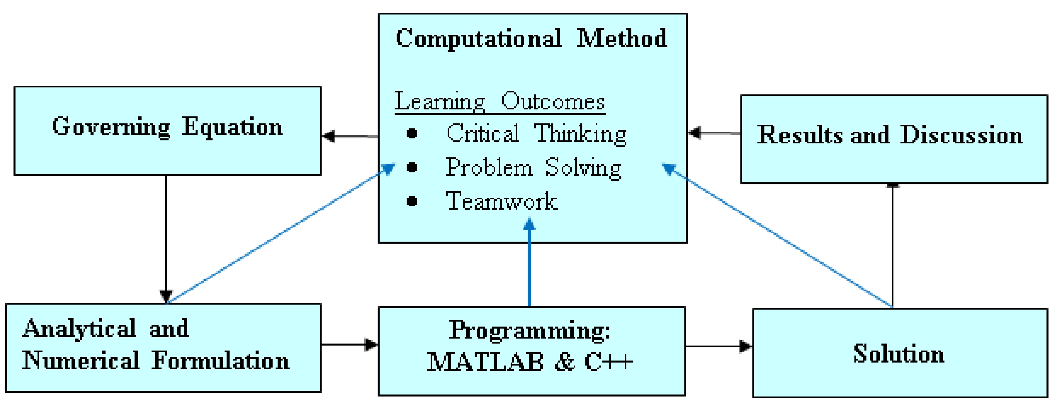

Figure 1: A graphical model of computational project-based learning

In the first two weeks (Two hours per day for four days per week) students were introduced to both MATLAB and C++ programming and how to use logical control loops such as for loop, while loop, conditional loop, switch, and function to develop programs for specific application. In the third and fourth weeks students learned how to write a program with application to engineering problems related to root determination, numerical integration, beam deformation analysis, impulsive vibration, and numerical analysis of a governing engineering equation. In the last week, students worked with faculty mentors and developed a project titled "Computational

Methods of Analysis Using C++ and MATLAB" and presented their work to faculty and the Vaughn community on the last day of the summer session. Their projects were assessed by faculty members according to the following learning outcomes

- Students will demonstrate an appropriate mastery of the knowledge, techniques, skills, and modern tools used in the engineering field – Both MATLAB and C++ are used as a programming and computational tool to solve analytical and numerical solution of an engineering system.
- Students will demonstrate an ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics – Both the analytical and the numerical form of an engineering governing equation require knowledge of mathematics and engineering principles.
- Students will demonstrate an ability to communicate effectively with a range of audiences – Projects require both report writing and presentation.

The process and learning outcomes assessment results based on faculty's evaluation will be discussed in the ASEE Conference. .

2.2 Robotics and autonomies programming

In order to enhance freshman students' engineering experience, the robot design and implementation were considered as an important part of the summer program. The course objectives were to help students understand engineering design, implementation and troubleshooting process using the practical platform -- VEX Educational Robots (EDR) [4].

Students for this session were involved with engineering design and development, understanding DC motors with the relationship between the speed, power and torque, and learning to use concurrently a variety of sensors in robot programming using RobotC [5] and VEX Cortex controller. Upon the completion of the class, students demonstrated knowledge of the engineering design process and had the ability to complete a project. They were, for example, able to build and to program a mobile robot using VEX robotic parts, different types of sensors as well as 3D printing parts. The activities of the course covered the following topics:

1. Introduction to engineering, team work, design process and design documents.
2. Discussion of DC motors as well as speed, power and torque limitations under the requirements of load and speed.
3. VEX Cortex controller as well as programming DC motors and sensors.
4. Program structure review and existing program analysis.
5. Robotic project design, implementation and trouble shooting.
6. Presentation of the robotic project.

During their five weeks of classes with four days per week and one hour per day, students learned step by step about the above subjects. In the first five weeks, their homework assignments included the development of engineering design concepts as well as robot programming to complete a sequence of tasks using a variety of sensors. In addition, three quizzes were given to examine students' learning outcomes.

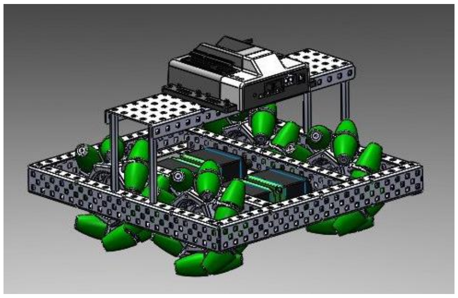

Figure 2: Robotic Chassis with Motor Mecanum Drive

By the end of the class, students selected a project titled Robotics and SEE Program. In the project, students built a robotic chassis with four motor mecanum drives as shown in Figure 2. On the chassis, six different sensors were installed. They are one encoder, one ultrasonic sensor, two line tracking sensors, one limit switch, five bump sensors and one potentiometer. A speaker module is also installed. The VEX Cortex controller was programmed to explore the possibility of developing sensor redundancy, i.e. when an object is captured, the correct result will be derived from the measured results from a number of sensors and the speaker will remind the designer which sensor(s) may have a problem.

2.3 Bridge Truss Design and Analysis

This session of SEE program introduced students to some basic concepts used in solid mechanics along with simple design and hands-on application.

During this session, students were given an introduction to basic concepts such as stress, strain, deformation, and Hooke's law. Applications of these concepts were then introduced to students in which they studied and analyzed a basic Warren truss bridge. Students were given an opportunity to design and build a simple Warren truss bridge which was required to support the load of a truck driving over it. During this design process, students used software such as excel and CATIA. As part of the class, students were also required to write a short report explaining their design process and build a small bridge based on their design. Figure 3 shows the bridge designed by students using CATIA.

Figure 3: CATIA design of a Warren truss bridge

In the last day of summer session, students presented their project titled "Bridge Design and Analysis – A hands-on project-based learning" to faculty. Their project was assessed according to specific student learning outcomes (Table 1).

2.4 Technical Writing and Presentation

This program addressed the technical writing needs of students in engineering, such as using plain language and clear word order and reducing ambiguous terminology. Students completed daily exercises covering many stylistic aspects of engineering writing, and they practiced the expression of technical knowledge in a concise and effective manner.

The program culminated with several group presentations, and in preparation for these public talks, students learned how to tell effectively the story of their work. After practicing their presentations in front of their classmates, they then made adjustments to their exhibitions based on the observations and comments they received.

2.5 Friday's Workshop Session

For Friday's industry and workshop session, guest speakers were invited to discuss and conduct workshops related to a real-world engineering system. The following is a list of the topics and workshops that were discussed in detail during Friday's session

On June 3, a Vaughn alumni and a Ph.D. student at City College (CUNY) addressed students in the SEE program about educational determination, willingness, and ethics as prerequisites for academic success.

On June 10, an outstanding senior student in the Mechatronic Engineering program and Co-Founder & VP of Union Crate talked about his start-up company.

On June 17, a Vaughn alumni and a Control Systems Engineer at Wunderlich-Malec, talked about efficient engineering in the workplace. In the afternoon session of the SEE program he conducted a hands-on workshop that was based on the Honeywell's Experion LX platform and Matrikon OPC Server. Experion is used in a distributed control system (DCS) for process control.

On June 24, an academic solutions advisor at Quanser, addressed students in the SEE program and talked about Quanser's engineering product and feedback control system designs [2].

3.1 Learning Outcomes Assessment

The following learning outcomes have been established to assess student performance in the Summer Engineering Experience program during their presentation on the last day of the program. These student outcomes are as follows:

(a) Students will demonstrate an ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics.
(b) Students will demonstrate an ability to design and conduct experiments, as well as to analyze and interpret data with the use of computer applications current to industry;
(c) Students will demonstrate an ability to design and apply creativity in the design of engineering systems, components and process;
(d) Students will demonstrate an ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty;
(e) Students will demonstrate an ability to communicate effectively with a range of audiences
(f) Students will demonstrate an appropriate mastery of the knowledge, techniques, skills, and modern tools used in the engineering field;

As it can be observed in table 1, each group project is used to measure specific student learning outcomes related to their research topic.

Project 1 - Computational Methods using C++ and MATLAB, is used to measure the following desire learning outcomes

a. An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics - This outcome is measured based on student ability to develop and solve the analytical and the numerical form of an engineering governing equation.
d. An ability to function effectively on teams that establish goals, plan tasks, meet deadlines – Each team member is responsible for an specific task and the attainment of this outcome can be measured through their report presentation.
e. An ability to communicate effectively – Their report and presentation is used to measure the attainment of this learning outcome.
f. An appropriate mastery of the knowledge, techniques, skills, and modern tools – This outcome is measured based on their ability to apply MATLAB and C++ skills to solve engineering problems.

Project 2 - Bridge Design and Analysis – A hands-on project-based learning, is used to measure the following student learning outcomes

a. An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics - This outcome is measured based on student ability to design and solve the Warren Truss problem.
b. An ability to design and analyze and interpret data with the use of computer applications –This outcome is measured based on student ability to use CATIA and excel to design, analyze, and build a simple Warren truss bridge.
d. An ability to function effectively on teams that establish goals, plan tasks, meet deadlines – Each team member is responsible for an specific task and the attainment of this outcome can be measured through their report presentation.
e. An ability to communicate effectively – The attainment of this learning outcome is measured based on their group report presentation.

Project 3 - Robotics and Autonomous Programming, is used to measure the following student learning outcomes

b. An ability to design and analyze and interpret data with the use of computer applications –This outcome is measured based on student ability to design, build a robot, and use VEX Cortex controller as well as programming DC motors and sensors to operate it.
c. An ability to design and apply creativity in the design – This outcome is measured based robot design and performance.
d. An ability to function effectively on teams that establish goals, plan tasks, meet deadlines – Each team member is responsible for an specific task and the attainment of this outcome can be measured through their report presentation.
e. An ability to communicate effectively – The attainment of this learning outcome is measured based on their group report presentation.
f. An appropriate mastery of the knowledge, techniques, skills, and modern tools – This outcome is measured based on their ability to use tools such as VEX Cortex controller, DC motors, and sensors to design program (RobotC) a robot.

The results for three groups of reports on the presentations, as demonstrated in the table below, are used to assess the effectiveness of the SEE program's learning outcomes (Rating: 1=worst and 5=best). Four faculty judges were selected to assess student attainment of these learning outcomes, and data in the table below shows the average values of those evaluations.

Table 1: Students' projects learning outcomes assessment

Title of Group Projects	student Learning Outcomes Rating: 1=worst, 5=best					
	a	**b**	**c**	**d**	**e**	**f**
1. Computational Methods of Analysis Using C++ and MATLAB	5			3.5	4	4.5
2. Bridge Design and Analysis – A hands-on project-based learning	4	4		4	3.5	
3. Robotics and Autonomous Programming		4	4	3.5	3.5	4
Average Outcomes Attainment	**4.5**	**4**	**4**	**3.7**	**3.7**	**4.25**

Rating: 1=Needs Significant Improvement, 2=Needs some improvement, 3=Average, 4=Good, 5=Excellent

Attainment of these outcomes prepares students in the SEE program for the core courses within engineering disciplines and provides them with the ability to be successful in their professional career path. The judges' surveys and these results will be discussed in the ASEE Conference. .

3.2 Students' Evaluation of SEE Program

As an indirect measure, a rubric survey based on contents of SEE programs has been given to students to assess the effectiveness of the SEE programs. Table 2 below provides the results of these evaluations.

Table 2: Survey's Result and Analysis

Questions	Response in percent of participants (Number of participants: 5)			
	Poor	Fair	Good	Excellent
1. Rate SEE program in preparing you with the applied computational, design, & programming.			40%	60%
2. Professor's ability in introducing you to MATLAB programing and application				100%
3. Professor's ability in introducing you to C++ programing and application				100%
4. Professor's ability in introducing you to robotics and autonomous programing		20%	20%	60%
5. Professor's ability in introducing you to bridge design and analysis			20%	80%
6. Professor's ability in introducing you to technical writing and presentation		20%	40%	40%
7. Rate SEE program in providing you with skills in problem solving, communication, and teamwork.			20%	80%
8. Rate SEE program in providing you with adequate knowledge and skills for your program of study.			40%	60%
Overall average Learning Outcome Attainment		**8%**	**36%**	**56%**

The survey results and student comments are an indication that the SEE program has been satisfactory and provided students with a profound appreciation for engineering education. Overall, 56 percent of the survey participants rated the SEE program as excellent and 36 percent rated their instruction as good. The survey and its results along with student comments regarding the SEE program will be available and discussed in detail during the ASEE Conference proceedings.

4. Conclusion

This was the first year of the Summer Engineering Experience (SEE) program and based on both faculty and students' evaluations and comments the program was a success and students recommended the SEE Program for all freshman students, because it prepares them for their program of study.

However, based on both faculty and student comments, more time should be directed towards technical writing and the student team project presentation. Also, some students expressed their preference to have more time dedicated to the group robotics project development and less on lectures. The department will take all necessary action plans to address these concerns in future SEE programs.

Overall, the program has been successfully implemented and students of this program had better performance through core courses within their discipline of study than those who did not participate in the SEE program. Currently, many first cohort students of the SEE program are involved in professional development and robotics club activities. The knowledge and skills they learned in the SEE program helped them to develop and design innovative robots for the 2016-2017 VEX U robotics competition. The innovative robotics designs with advanced autonomous programming, allowed Vaughn's Robotics team to be the 2016 tournament champion of the international congress of Technologies of Information and Communication (Queretaro City, Mexico), as well as tournament finalists and the recipients of the Excellence award of 2017 Vaughn College Regional Robotics Competition [2].

5. References

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