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Enhancing Students' Learning Outcomes Through Freshman Summer Engineering Experience (SEE) Programs

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Enhancing Student Learning Outcomes through the Freshmen Summer Engineering Experience (SEE-STEM) Program

Abstract

This paper details the development, implementation, and assessment process for the achievement of specific learning outcomes in the Summer Engineering Experience program implemented at a college in the Northeastern region of the United States. This five week summer program is designed to prepare first-year students for engineering curriculums. The development and implementation of this program is supported by the Department of Education federal fund as part of Title III, Part F, HSI-STEM and Articulation grant.

This program is designed with the objective to enhance students' hands-on, computational, programming, communication, and problem solving skills. Since 2016, the SEE-STEM program has been offered during the summer to engineering and engineering technology students as a bridge program from freshman to sophomore year. It is offered Monday through Thursday (8:00 am to 4:00 pm) with lectures and hands-on classes covering topics related to engineering computation using MATLAB and C++, aerodynamics, bridge truss design & analysis, technical writing and presentation. The Friday session of the SEE program is designated for educational seminars and technical workshops.

The development and implementation process of the SEE program was presented to the 2016 ASEE annual conference. In this paper a set of learning outcomes was introduced based on specific class topics and students' group reports and project presentations. A rubric score was used to assess the attainment of those learning outcomes in the preparation of freshman students for engineering programs. As part of this study, students in the SEE program are monitored through their core courses in sophomore and junior years, and their performance in those classes is to be compared with the performance of other students who did not participate in the SEE program.

Students' group projects are presented on the last day of the summer session, and their performance is evaluated by faculty members, based on their attainment of specific learning outcomes. Also, as an indirect measure, a rubric survey based on the contents of the SEE program is distributed to students to assess the effectiveness of this program.

Keywords: MATLAB, C++, Student Learning Outcomes

1. Introduction

The main objective of the Summer Engineering Experience (SEE) program is to provide students with the basic computational and hands-on project-based learning in numerical analysis with MATLAB and C++ programming, aerodynamics, bridge truss design & analysis, technical writing and presentation. This program not only introduces students to basic skills in developing solutions to engineering problems, but also enhances their ability to develop programs to facilitate the solution of a physical system [1], [2].

The SEE program is designed to enhance student learning outcomes related to analysis, programming, design, communication and teamwork, and to prepare freshmen engineering students for the core courses within their program.

To assess the effectiveness of the SEE program, both a student learning outcomes assessment process based on topics covered in the program, as well as a continuous improvement loop are used [3], [4], [5], [6]. This process includes the following direct and indirect assessment process:

- **Student's Evaluation Survey of the SEE Program**
  As an indirect measure, a rubric survey based on the contents of the SEE program is given to students to assess the effectiveness of this program.
- **Faculty Evaluation Survey**
  As a direct measure, a rubric faculty evaluation survey based on student learning outcomes provides assessment of those outcomes in students' projects and presentations.
- **Monitoring and assessment of SEE students' performances within their discipline of study**
  As a direct measure, the performance of two cohorts of students who participated in 2016 and 2017 SEE programs are monitored through core courses within their discipline of study and compared with those students who did not participate in the freshmen year of the Summer Engineering Experience program.

In assessing the summer STEM program, our overall goal is to ensure that at least 70 % of the students achieve a success rate of a score above satisfactory for each outcome, as indicated on the rubric. An outcome with a success rate below 70% requires an action plan for improvement. The details and implementation process of the SEE program, the assessment of the program, and the continuous improvements to the program are to be presented and discussed during the 2018 ASEE Annual Conference Proceedings.

2. SEE-STEM Selection Criteria

Students within engineering and engineering technology programs who completed their first year and satisfy the eligibility requirements as indicated below are eligible to participate in the summer SEE-STEM scholarship program.

- Student must be pursuing a Bachelor of Science (B.S.) degree in at least one of the following disciplines:
  - Mechatronics Engineering
  - Mechanical Engineering
  - Electrical Engineering
  - Mechanical Engineering Technology
  - Electronic Engineering Technology
- Engineering students must have completed MEE115 (Statics), ELE117 (DC/AC Circuits), and MAT225 (Calculus I for Engineers) with a grade of C+ or better.
- Engineering Technology students must have completed EGR115 (Statics), EET115 (DC Circuits) and MAT120 (Calculus I) with a grade of C+ or better.
- A short essay (500 words or less) discussing their reasons for joining the SEE-STEM program and expressing their academic and professional goals

3. 2017 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 2017 Summer Engineering Experience program covered topics related to engineering computation using MATLAB and C++, bridge truss design & analysis, applied fluid & aerodynamics, and computer aided design (CAD) & additive manufacturing, and technical writing. Friday's session of the SEE program, designated for technical seminars and workshops, was designed to enhance students' learning outcomes related to critical thinking, problem solving, and life-long learning. Given the rapid pace of technological change, the Friday industry seminar series and workshops helped students in the SEE program to be more receptive to these changes in technology and to better appreciate the concrete applications of their engineering education.

3.1 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 with application to engineering problems, such as Taylor Series, finite difference, root determination, complex number, and numerical integration. Both MATLAB and C++ were presented to students as a computing tool to generate results and investigate 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 numerical formulation based on finite difference methods
- 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 numerical solution of an engineering system with MATLAB and C++ to investigate behavior of an engineering system.

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 entitled “Computational Methods of Analysis Using C++ and MATLAB”, and on the last day of the summer session, students presented their work to faculty and to the Vaughn community. 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 programming and computational tools to provide analytical and numerical solutions in 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.

3.2 An Introduction to Aerodynamics and Wind Tunnel Testing

In this section of the SEE program, students were introduced to aerodynamics design as an example of applied engineering. They learned the basic formulation of fluid mechanics equations, which lead to application of continuity and Bernoulli’s equations. Students had an opportunity to verify these equations through hands-on projects and direct measurements in the thermos-fluid laboratory. Also, students were introduced to basic force analysis on aerodynamic vehicles, with an emphasis on lift generation airfoils. They were also given the opportunity to use simulation tools to better understand flow properties and their effect on the aerodynamic loads.

Through this session of the SEE program, students were introduced to both theoretical and experimental topics related to:

- Bernoulli’s and continuity equations.
- Aerodynamics of airfoil.
- Wind tunnel testing.
- Measurements techniques in wind tunnel testing.
- Aerodynamic simulation using COMSOL Multiphysics.

In the last week, students worked with a faculty mentor to develop a project entitled “Applied Fluid and Aerodynamics”. On the last day of the summer session, they presented their work to faculty and to the Vaughn community.

3.3 Bridge Truss Design and Analysis

The "Introduction to Engineering" course introduces students to some basic concepts used in solid mechanics along with simple design and hands-on application. During this course, 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, as 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 use 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 to build a small bridge based on their design. Figure 1 shows the bridge designed by students using CATIA.

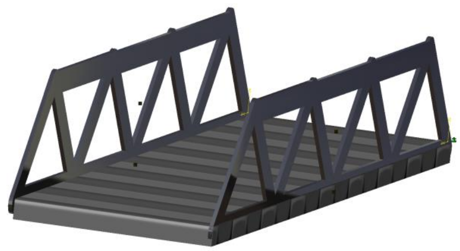

Figure 1: CATIA Design of a Warren Truss Bridge

The required specifications of the bridge to be designed are as follows:

- Material for Truss members: A36 structural steel (yield strength, 36ooo psi)
- Span of bridge : 63 ft. with 2 lanes (13 ft. each)
- The four bays, 15.75 ft. each
- Member assumed to have an initial cross-sectional area of 20 in2.
- Deal load: steel members (150lbs/cu.ft), an 8-in concrete deck(490lbs/cu.ft)
- Live load: Truck (dynamic amplification factor assumed to be 1.2)

The specifications of the truck required to be supported by the bridge are as follows:

- The truck has 3 axels, each one with different weight.
- The (1st) front axle of the truck exerts: 12,000 lb.
- The (2nd) central axel exerts: 48,000 lb.
- The (3rd) rear axle exerts: 50,000 lb.
- For this particular truck, the axels are separated by a distance of 15.75 ft., the same distance between each joint of the bays in the bridge.

Figure 2 shows a completed bridge made of Popsicle sticks.

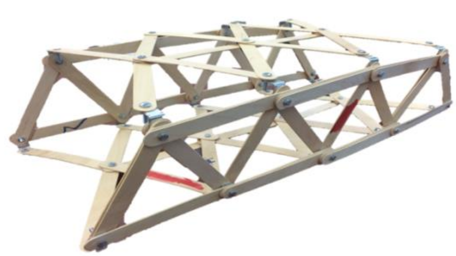

Figure 2: Popsicle Sticks Warren Truss bridge

3.4 Computer Additive Manufacturing

For this session of the SEE program, students worked on projects related to rapid prototyping, surface modeling, and 3D scanning. This part of the program encouraged a hands-on mindset in our students, in order to promote club participation at Vaughn College, which leads to the development of strong industry connections.

Projects were developed using SolidWorks and CATIA assembly design software as a tool for virtual prototyping and visual communication. Students designed assemblies such as a bridge, car, and computer case in SolidWorks. Part fits and tolerances were optimized before committing to the expense of 3D printing. Lectures related to MakerBot, Fortus 250 MC, and Form Labs 3D prints exposed students to new low cost accessible machines that can drastically accelerate part development. Reverse engineering was covered using the Catia Digitized Shape Editor, Quick Surface Reconstruction Workbench, and Artec Spider 3D scanner. At the end of the course, students presented a PowerPoint presentation where they showcased projects related to rapid prototyping, 3D scanning, surface modeling, and product assemblies. After participation in the SEE program, students have moved on to prominent roles in the UAV and Robotics clubs where they routinely employ the techniques learned in this program.

3.5 Technical Writing and Presentation

Students in engineering often need to eliminate ambiguous terminology and industry jargon from their writing, and they should learn how to write industry reports in a manner that is accessible to their targeted audience. Because most of these students have received traditional grammar instruction, in which instructors typically focus only on “rules” of grammar, they have often developed an antipathy to writing. Rather than having students focus on what is wrong with their writing, in this class students were redirected to focus their attention more towards the ideas they need to communicate. They were shown how grammar is best learned through the process of writing, rather than through the memorization of sets of rules. Students learned how to compose clear effective sentences through syntax imitation exercises. Through the imitation of these model sentences, students experienced, for example, how combining basic sentences and paying attention to word order can produce more effective writing.

Since science writing is often complex, the book *Writing Science in Plain English* by Anne E. Greene was used in this class, so students could learn how to use simple stories with characters and actions to express their complex ideas. Greene explains how students are used to thinking that stories are made-up and science is fact, but linguistic research supports the idea that when people read unfamiliar information they are actually looking for simple stories. In the SEE program, for example, students experimented with conceptualizing the bridges and trusses they were describing as characters in a simple story, a technique which produced clearer and more accessible reports. The students also studied other models of science writing in order to observe and imitate effective techniques in their own writing.

Collaboration also played a key role in the SEE Technical Writing program. Each student group contained a drafter, a reviewer and an editor, and the groups traded papers and asked questions of the other groups. Each group then presented its final report in an oral presentation. Reading their own reports aloud and hearing others present their reports are effective ways for students to learn how to improve their own writing.

4. Student Learning Outcomes Assessment

The following learning outcomes have been established to assess student performance in the Summer Engineering Experience 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 apply creativity in the design of engineering systems, components and process;
(c) Students will demonstrate an ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty;
(d) Students will demonstrate an ability to communicate effectively with a range of audiences
(e) Students will demonstrate an appropriate mastery of the knowledge, techniques, skills, and modern tools used in the engineering field;

Attainment of these outcomes prepares students in the SEE program for the core courses within engineering disciplines and provides them with the ability to succeed in their professional career paths.

4.1 Learning Outcomes Evaluation of SEE program by Faculty

As observed in table 1, each group project presented by students on the last day of the SEE program, June 30, 2017, is used to measure specific student learning outcomes related to their research topic. The results for four 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**
1. Computational Method Using MATLAB and C++	4.5		4.75	4.50	4.40
2. Fluid Mechanics and Aerodynamics	3.5	4	5		4.50
3. Bridge Truss Design and Analysis	4.00	4.60		3.50	4.75
4. CAD and CAM (Additive Manufacturing)		4.60	4.50	4.00	3.90
Average Outcomes Attainment	**4.00**	**4.40**	**4.75**	**4.00**	**4.39**

Success Rate (70% of students attaining a score greater than 3): An outcome above a rubric score of 4 out of 5 indicates students have a good grasp of important concepts of the materials in the Summer STEM Program, and our overall goal is to ensure that at least 70 % (success rate) of the students achieve a score of above 4 for each outcome. An outcome with a success rate below 70% requires an action plan for improvement.

Analysis: Overall, the attained student learning outcomes were satisfactory, and every team attained an average score of 4 or better out of 5 for each measured outcome. Attainment of these outcomes prepares students in the SEE program for the core courses within engineering disciplines. The faculty evaluation rubric surveys and these results will be discussed at the ASEE Conference.

4.2 Assessment of Students' Evaluation of SEE Program (2017 Summer STEM program)

As an indirect measure, a rubric survey based on contents of the SEE programs has been given to students to assess the effectiveness of these 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: 7)**				
	Poor 1	Fair 2	Good 3	Excellent 4	**Success Rate(SR); % of student with score ≥ 3**
1. Rate SEE program in preparing you with the applied computational, design, & programming.			2	5	Score=3.71 100%
2. Professor's ability in introducing you to MATLAB programing and application			1	6	Score=3.86 100%
3. Professor's ability in introducing you to C++ programing and application				7	Score=4.0 100%
4. Professor's ability in introducing you to Fluid Mechanics and its application			3	4	Score=4.0 100%
5. Professor's ability in introducing you to Aerodynamics and its application			1	6	Score=3.86 100%
6. Professor's ability in introducing you to bridge design analysis and its application			1	6	Score=3.86 100%
7. Professor's ability in introducing you to CAD and Additive manufacturing				7	Score=4.0 100%
8. Professor's ability in introducing you to technical writing and presentation			2	5	Score=3.71 100%
9. Rate SEE program in providing you with skills in problem solving, communication, and teamwork.			1	6	Score=3.86 100%
10. Rate SEE program in providing you with adequate knowledge and skills for your program of study.			1	6	Score=3.86 100%
10. Rate SEE program's industry and workshop sessions in providing you with adequate technical skills.			1	6	Score=3.86 100%
Overall average Learning Outcome Attainment			**17%**	**83%**	

Success Rate (70% of students attaining a score greater than 3): An outcome above a rubric score of 3 out of 4 indicates students have a good grasp of important concepts of the materials in the Summer STEM Program, and our overall goal is to ensure that at least 70 % (success rate) of the students achieve a score of above 3.0 for each outcome. An outcome with a success rate below 70% required action plans for improvement.

Analysis: Overall, 83 percent of the survey participants rated the SEE program as excellent and 17 percent rated it as good. The survey results and student comments are an indication that the SEE program has been satisfactory and has provided students with a heightened appreciation for engineering education.

Below are some students' comments regarding the SEE program

- I would recommend offering it to all freshman students because it helps prepare them for future courses. A good improvement to the program would be to provide a stipend for food for the students. Overall, the SEE program was a great experience.
- The SEE program helped me gain knowledge about my major and it helped me understand more topics that I will encounter in my upcoming classes. I would suggest creating two sessions of the SEE program, one for the freshmen and one for sophomores. I would also recommend one or two breaks between classes. I enjoyed the SEE program and I learned a lot from it.
- It was a great learning experience for the future classes in the program. I would recommend it to the new freshman students, because you learn a good deal of useful information from the program that will become handy in the next semester. As for changes, I would recommend just two things, more breaks between classes to rest the mind from all the acquired information, and adding more time to the most complex classes so the hard topics can be explained and understood by the students.
- This program was an excellent opportunity for me to get an introduction to core courses of the engineering curriculum. This program allowed me to get a glimpse of the topics and the work load required of the mechatronics program. Although this program was effective in introducing the engineering topics, the time schedule was tightly packed leading to student fatigue. Additionally, the time allotted for each sub sections was not adequate for covering the topics per session. For a better student experience, the sub sections should be timed in such a way as to cover an good portion of material but with less sub sections in a day, that is, having two or three subsections each day which last 1.5 to 2 hours. Overall, the See Program led to well spent one third of a summer.

Recommendations: After reviewing students' comments, we are adding more time to the Summer STEM program and extending it from 5 weeks to six weeks as of summer 2018. Also, we will add more hands-on classes related to aerodynamics and robotics.

4.3 Monitoring and assessing SEE's student performance within their discipline of study

As a measure to assess the effectiveness of the SEE program, the performance of two cohorts of students who participated in 2016 and 2017 SEE programs are monitored through core courses within their discipline of study and compared with those students who did not participate in the freshmen year of the Summer Engineering Experience program. As shown in table 3 (2016 cohort) and table 4 (2017 cohort) below, the results for both cohorts of the SEE program through various engineering courses are compared with total students within each course who received a grade of B or better.

Table 3: 2016 Cohort of SEE Program

Course	Total Number of Students	Number of 2016 SEE Students	% of total Students with B or better	% of SEE Students With B or better
MEE220, Mechanics of Materials	24	6	10/24=41%	5/6=83%
MEE235, Material Science	26	5	11/26=42%	3/5=60%
MEE345, Fluid Mechanics	15	5	8/15=53%	3/5=60%
MEE365, Machine Design	17	6	9/17=59%	5/6=83%
ELE220, Electronic Circuits	16	6	12/16=75%	5/6=83%
ELE220L, Electronic Circuits (Lab)	16	6	13/16=81%	6/6=100%
ELE230, Digital Systems Design	11	5	8/11=73%	4/5=80%

Table 4: 2017 Cohort of SEE Program

Course	Total Number of Students	Number of 2017 SEE Students	% of total Students with B or better	% of SEE Students With B or better
MEE210, Thermodynamics	28	8	52%	88%
EGR230, Mechanical Testing	7	6	85%	100%
MEE220, Mechanics of Materials	24	6	7/24=29%	4/6=67%
MEE235, Material Science and Failure Analysis	21	5	9/21=43%	4/5=80%
MEE340, Computational Method	15	7	9/15=60%	5/7=71%
MEE345, Fluid Mechanics	15	5	8/15=53%	3/5=60%
ELE220, Electronic Circuits	18	6	15/18=83%	6/6=100%
ELE230L, Electronic Circuits (Lab)	18	6	15/18=83%	6/6=100%
ELE230, Digital Systems Design	12	4	8/12=67%	3/4=75%

As shown in the table above, 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. Also, many of first and second cohort students of the SEE program are now active in professional development, robotics and UAV activities.

5. Conclusion

This was the second year of the Summer Engineering Experience (SEE-STEM) program and student learning outcomes results based on both faculty and students' evaluations indicate that the program was a success. However, based on student comments, more time should be devoted to the program to ensure students have a more enhanced understanding of each topic covered. The engineering and technology department will take all necessary actions to address these concerns in future SEE-STEM programs.

Students of the SEE program also demonstrated much better performance through core engineering courses in comparison to other students. Both the hands-on skills and the theoretical knowledge that students attained through the SEE program promoted their participation in extracurricular professional activities. Many first and second cohort students of this program are currently involved in robotics, UAV and other professional and clubs activities. The knowledge and skills they acquired in the SEE program assisted them in the development and design of innovative robots and UAV capable of achieving top ranking in both robotics and UAV competitions [7], [8], [9].

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