An Engineering College Credit for High School Students through a STEM Summer Camp

Dr. Pattabhi Sitaram, Prof. Ellis Love, Prof. Tom Spendlove, and Dr. Anca Sala
Baker College of Flint
Flint, Michigan 48507

Abstract
In order to meet the demand for workers with science, technology, engineering, and mathematics (STEM) skills, many colleges and universities are offering on-campus STEM summer camps to high school and middle school students. Our institution has been offering a two-week, full day, sessions, "Explore Engineering and Technology" summer camp for high school students since 2013. In the first week of the camp a total of nine instructional modules, each three-and-a-half-hour long, were taught by the engineering faculty of the college. The modules involved in-class and lab activities covering different engineering disciplines - civil, computer, electrical, mechanical, and optical engineering. Those students from the first week interested in earning college credit for an engineering course EGR105, "Introduction to Engineering and Design" of our college curriculum participated in the second week of the camp. In this week several topics of the course were taught, and student homework, presentation, and final exam were evaluated. Additionally, during the second week of last year's summer camp, students were given the option to select one hands-on project from two areas- the balsa wood bridge from the structural mechanics area or the microcontroller board from the electrical engineering area. They were then given a month's time to complete the project working from home. The project involved the design, construction, testing, project report, and presentation. This paper discusses the course content, projects, assessments, rubric, and the results of the camp, as evidenced by student presentations and student surveys. The camp stimulated students' interest in pursuing careers in engineering and technology.

Introduction

In the last decade, on-campus STEM summer camps offered by colleges and universities for high school and even middle school students have been gaining an increasing popularity. This is due to a growing demand for STEM related jobs[1] coupled with low enrolments[2] in STEM programs in colleges and universities. While the main objective of summer camps is to stimulate and increase interest in pursuing a STEM career among young people, including under-represented minorities, its other objective is to attract students to join the institutions offering these camps.

Robert Fletcher[3] has discussed about four types of summer camp programs. The camp described in the present paper belongs to the one of those four types- introduction to engineering programs that expose students to the broad and many aspects of engineering. Many schools have also offered summer camps belonging to this type.

Our institution has been offering Robotics summer camps for high school and middle school students since 2009 and 2010 respectively. The robotics high school camps better prepare students to participate in the FIRST Robotics competition. To attract students to STEM, our school started the "Explore Engineering and Technology Camp" in summer 2013. The activities, and assessment results through student pre-camp and post-camp surveys of the first week of this

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camp are described in detail in a paper presented at the ASEE Annual Conference and Exposition in 2014[4]. The week 1 of the camp is prelude and mandatory to week 2. The present paper discusses in detail both first and second weeks of the summer camps of 2013 and 2014 that was participated by students interested in earning college credit for an engineering course "Introduction to Engineering and Design" of our college curriculum.

"Explore Engineering and Technology" Summer Camp: Week 1

The first week of the summer camp for high school students was offered, free of cost, during the week of July 7- 11, 2014. The camp had 17 participants represented by boys and girls from several schools. The schedule is shown in table 1. Students were taught 9 modules that covered engineering topics from mechanical, civil, computer, electrical, and electronics areas. Three faculty members with assistance from three undergraduate students taught the modules. Two modules (each three hour long) were taught every day-one in the morning and another in the afternoon, except the last day of the camp where only one camp was taught in the morning with the afternoon session dedicated for students to prepare and deliver their final presentation. The daily schedule started with a thirty-minute lecture of important points for students to consider in their teamwork and presentation. Students were then divided into two groups and rotated through the main teaching modules each day. Each module was taught with 50 minutes of lecturing which was followed by a 10 minute break, and an hour lunch time between the morning and afternoon modules.

Table 1. Schedule of sessions 1-9 (week 1)

Day	**Time**	**Topic**	**Faculty**
Monday, 7/7	8:30-9am	Introductions	All
	9am-12pm	1. CAD & Design	Spendlove
	12-1pm	Lunch	All
	1-4pm	2. Electronics	Love
Tuesday, 7/8	8:30-9am	Teamwork in Engineering	Spendlove
	9am-12pm	3. Advanced Manufacturing	Spendlove
	12-1pm	Lunch	All
	1-4pm	4. Photonics & Lasers	Love
Wednesday, 7/9	8:30-9am	Power Point Presentations	Spendlove
	9am-12pm	5. Simulation	Spendlove
	12-1pm	Lunch	All
	1-4pm	6. Microcontrollers	Love
Thursday, 7/10	8:30-9am	Rubric for Power Point	Sitaram
	9am-12pm	7. Materials Science	Sitaram
	12-1pm	Lunch	All
	1-4pm	8. Mechanics of Materials	Sitaram
Friday, 7/11	8:30am-12pm	9. Engineering Computation	Sitaram
	12-12:30pm	Lunch	All
	12:30-4pm	Prepare and Deliver Final Presentation	All

The last day of the week involved presentation from each group of two students on a topic from the modules of their choice. The whole learning process was carried out in an informal environment to better engage students and as well make the camp enjoyable.

The topics presented in each of the nine modules are shown in table 2. The modules had a good blend of theoretical concepts and hands-on activities, and were identical to the ones delivered in year 2013, except that the Thermal Science module (not well appreciated by students) was replaced with Microcontrollers. Additionally, a new experiment on the identification of plastic materials was included in the material science module.

Table 2. Topics presented in each of the nine modules (week 1)

Module	**Topics and lab experiments**
CAD & Design	Basic rules of sketching, drafting, and projection. Creating 3-D objects using ProEngineer software.
Electronics	Basic quantities (voltage, current, resistance, power), calculations (Ohm's Laws, Watt's Laws), and measurements, then breadboarding a simple circuit and measuring power transfer with a multimeter.
Advanced Manufacturing	Precision measurements, area, volume and weight calculations, making simple objects using 3D printers.
Photonics and Lasers	Basic properties of light, measuring the speed of light, fluorescence, basic quantities (frequency, wavelength, amplitude), reflection, refraction, and a lab experiment with laser pointers and acrylic prisms.
Simulation	Modeling and analysis of a L-shaped block using Solidworks.
Microcontrollers	Microcontrollers: basic logic operations, relays and gates, binary arithmetic, overview of programming languages to learn, then working through an online tutorial on the PLT/Racket programming language.
Materials Science	Sample preparation for microstructural analysis, microstructural analysis using a microscope, Rockwell hardness testing
Mechanics of Materials	Tensile test of steel and aluminum specimens, Charpy impact test, deflection of beams.
Engineering Computation Using Excel and MATLAB	Using Excel and MATLAB to solve linear simultaneous equations, single nonlinear equation, matrices, eigenvalue problems, graphing.

Figure 1: (a) Tension test; (b) Students getting ready for microstructural analysis of metals

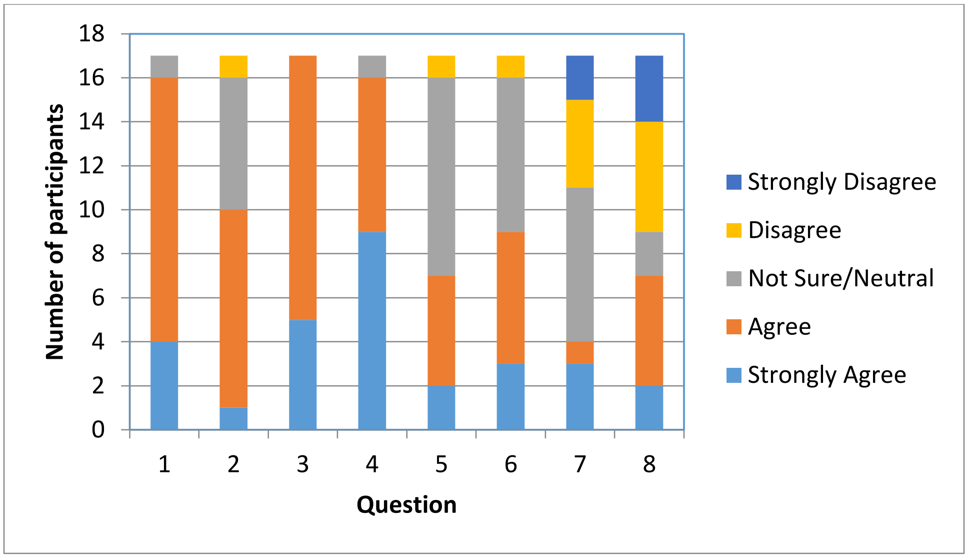
a) <u>Assessment Results:</u>
Students participating in week 1 were required to give group presentations (two students per group) on the final day of the week on a module they selected. Details about teamwork, powerpoint presentations, and rubric for evaluating their presentations were discussed with them during the half hour sessions each morning. The evaluation rubric had three categories- communication skills, technical content, and delivery. Each of them had five to six subcategories with points assigned to five classes- excellent, very good, acceptable, poor, and unacceptable. The judging panel comprised of faculty members and undergraduates students involved in the camp as well as the Dean of Engineering. Prizes were given to the top three presentations, and certificates to all participants.

Students were handed pre-camp and post-camp surveys to assess whether the desired objectives of the summer camp were met. The assessment was based on their answers (Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree) to survey questions. Based on feedback from the camp held in year 2013, additional survey questions were added to the 2014 camp. The following were the pre-camp survey questions:

1) I enjoy taking math and science courses.
2) I know what engineers do.
3) Engineering involves problem solving, lab work, design, and hands-on activities.
4) Teamwork is important in the work engineers do.
5) Engineering is a profession that appeals to girls.
6) I am interested in a career in Science/Technology/Engineering/Math (STEM).
7) I am interested in going to college to study engineering after finishing high school.
8) I am confident in pursuing a career in engineering.

Student responses to this survey are shown above in figure 2. Based on answers to questions 1, 3, and 4 it is evident that most students (94%) agreed or strongly agreed in enjoying taking math and science courses. The answers to questions 2, 6, and 7 also indicate that about 94% of the students did not disagree in not knowing what engineers do nor in their interest in a STEM career. About 64% of the students did not disagree in pursuing a career in engineering. The responses clearly reflected the motivation of students in attending the camp and their awareness about engineering.

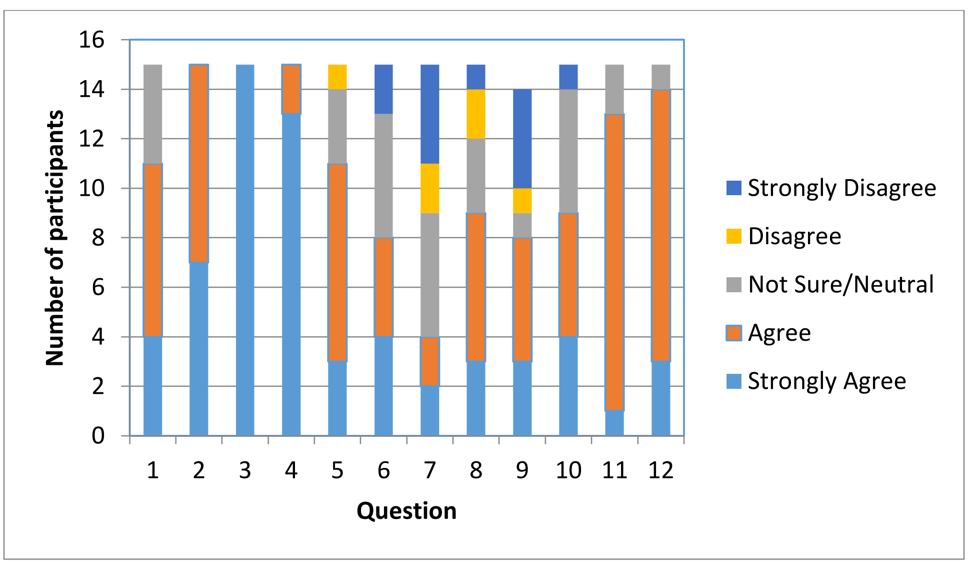
Figure 2: Responses to pre-camp student survey questions



The following were the post-camp survey questions:
Questions 1-8 were the same as pre-camp survey. There were four additional questions-

9) The summer camp stimulated/enhanced my interest in engineering.
10) Did you think that the amount of material covered was appropriate?
11) The camp helped improve my presentation skills.
12) Did you think that the number of activities was appropriate?

Figure 3: Responses to post-camp student survey questions



Student responses to this survey are shown in figure 3. Fifteen of the seventeen students participated in the survey, and responses to questions 2, 3, 4, and 8 showed an increase in the overall rating between 9-25% over the pre-camp survey which indicated an enhanced student understanding of the engineering discipline and thus the benefit of attending the camp. Based on the response to question 8, the camp benefitted the students as there was a 23% increase in the overall rating, reflecting an improved confidence in students in pursuing a career in engineering. Results of question 1, 6, and 7 showed a marginal decrease in the rating between 3-7% and therefore was not considered significant. More than 50% of the students agreed/strongly agreed that the camp stimulated/enhanced their interest in engineering. Student feedback indicated the need for more hands-on activities. This will be incorporated in the 2015 summer camp, and it is hoped that this would stimulate an interest in STEM in greater number of students. Responses to questions 11 and 12 show that 87% of the students felt that the camp helped them improve their presentation skills and 93% agreed/strongly agreed that the number of activities were appropriate.

As part of the post-camp survey, students were asked to rank top three modules and also what they enjoyed the most throughout the camp. The module on CAD & Design was the most popular (11/15) followed by Photonics and Lasers (10/15). This was surprising because in the 2013 camp the module Advanced Manufacturing had the most number of votes, which in 2014 had only two votes. The other favored modules were Material Science (7/15) and Microcontrollers (5/15). The other modules received few votes: Electronics (4/15), Simulation (3/15), Mechanics of Materials (3/15), and Engineering Computation (1/15). Modules which received few votes will be fine-tuned and made more stimulating for the 2015 camp.

The following are student comments to the question asked about what they enjoyed the most throughout the camp:

1) I enjoyed all of the learnings
2) I liked the CAD & Design module
3) I enjoyed the interesting activities and facts
4) The amazing teachers
5) Awesome teachers and having fun
6) The Racket programming language and meeting new friends
7) About the people here
8) Being with friends and learning new things
9) Learning new things about engineering, especially how math is involved
10) I enjoyed hands-on learning activities

All students answered the above question and some comments were similar. The usefulness of the camp was evidenced by the above comments and with no negative response.

"Explore Engineering and Technology" Summer Camp: Week 2

The second week of the camp was offered during the week of July 14- 18, 2014 for articulated college credit of the course EGR105 "Introduction to Engineering and Design" and was participated by ten students. The course surveys the profession of engineering through analysis and design problem-solving examples, and is a required course in the engineering curricula at our institution. The course contents were captured in a syllabus developed for the camp as shown in table 3.

Table 3. Topics of EGR105 “Introduction to Engineering Design”

Day	**Date and Time**	**Topic**	**Faculty**
Monday	7/14 a.m.	Introduction and Units	Spendlove
Monday	7/14 p.m.	Energy and Circuits	Sala
Tuesday	7/15 a.m.	Design Process	Spendlove
Tuesday	7/15 p.m.	Materials	Sitaram
Wednesday	7/16 a.m.	Manufacturing	Sitaram
Wednesday	7/16 p.m.	Electrical Engineering	Sala
Thursday	7/17 a.m. & p.m.	Project: Microcontroller or Truss Bridge	Sitaram/Love
Friday	7/18 a.m.	Exam	All
Friday	7/18 p.m.	Admissions Presentation, Student Presentations	All

The syllabus covered chapters from the textbook "Exploring Engineering[5]”. The learnings from week 1 of camp provided the necessary foundation for students for this course. The following chapters and topics of the book were discussed.

Chapter 1: Functions of an engineer, engineering disciplines, professionalism and ethics.
Chapter 2: System of units Newton’s second law of motion, and significant figures.
Chapter 4: Energy, kinds of energy, conversion, and conservation.
Chapters 8 and 9: Circuits, computers, and control systems.
Chapter 11: Strength of materials, defining materials requirements, materials selection, and properties of modern materials.
Chapters 15-17: The Nature of engineering design, qualities of a good designer, engineering design process, list of specifications, design milestone.
Chapter 22: Manufacturing
The topic on solving problems using spreadsheets, chapter 3 of text, was discussed in the module on Engineering Computations of week 1.

Table 4. Course requirements and grading scale

	Date	Weight
Homework	7/15, 16, 17	10%
Final Exam	7/18	20%
Engineering Topics Content	7/18	20%
Engineering Topics Presentation	7/18	10%
Microcontroller / Balsa Truss Bridge Project Content	8/19	30%
Microcontroller / Balsa Truss Bridge Project Presentation	8/19	10%
TOTAL		100%

Homework was assigned each day and was due the following morning. A comprehensive final exam was conducted on the last day of week 2 of the camp. Like in week 1, students were given the option to select an engineering topic of their choice and present it on the last day. The presentations were evaluated for technical content and delivery using a rubric. The grading scheme is shown in table 4.

Most students turned in their homework and did reasonably well. This helped them in doing well on the final exam. Their presentation on engineering topics benefitted them in a good understanding of the course content, and were able to get a good feel of the complexity and nature of an engineering course through its content and assessment. The experience gained by students from their presentations in week 1 helped them better prepare for their individual presentations in week 2. This was reflected in their scores which was based on the same rubric used earlier. One of the important aspects of this course is student work on an involved project. The project content, demonstration, and presentation therefore carried a significant weightage (40%) of their total grade.

a) <u>Student Projects</u>

After the exposure to various engineering disciplines during the two weeks of the camp, near the end of the second week the EGR 105 students of 2014 were offered two options to select and work on a project as an extended assignment. They were given a month's time to complete the project at home and return to campus for two more days in mid-August to finalize, demonstrate, and present their work. The project was evaluated for content, demonstration, and oral presentation that comprised 40% of the final grade. The oral presentation was evaluated by all faculty for content and delivery using the same rubric as in week 1 of the camp.

One of the projects was microcontroller-based and the other the construction of a bridge using balsa wood. In contrast to the 2014 summer camp, students of the 2013 summer camp were only given the balsa wood bridge project. Four of the five groups of students selected to work on the bridge project and the remaining group chose the microcontroller project. All incidental materials not borrowed from our school were procured by students during the following month. Students planned, purchased, assembled, tested, and programmed the projects themselves, working in teams of two or three.

1) Microcontroller Project

The Microcontroller project appealed to students who were especially interested in the 'Electronics' and 'Microcontrollers' modules of the first week, and the 'Energy and Circuits' and 'Electrical Engineering' modules of the second. These students could then deepen their interest in electronics, and strengthen their confidence, by building and programming a device of their own choosing. This assignment was planned to take advantage of the current popularity of robotics clubs, the 'maker' community, and the Internet of Things (IoT) movement.

Students were given wide latitude to choose a specific microcontroller project. They were not expected to think of an entirely new idea, or even write much original software, but rather explore the selection of books and websites available and choose a project to adapt. Our institution has plenty of resources, including Arduino, Galileo, and PIC-Explorer boards, as well as a selection of hobbyist books containing many appropriate projects. However, students were not limited to using just these materials, and thus could explore the various hobbyist sites and tutorials on the web.

The chosen project was required to include three broad elements: sensing, processing, and affecting. The project had to sense some aspect of its environment, and react to that aspect by affecting something else in its environment. Environmental sensing possibilities include sound, light, contact, and temperature. Environmental affecting possibilities include motors, speakers, visual displays, or the control of relays, solenoids, or valves. Wiring up sensors and actuators was the priority. While allowed, wireless control and network connections were de-emphasized.

2) Balsa Wood Truss Bridge Project
This project involved the construction of a Pratt truss bridge from balsa wood sticks. A single Pratt truss is shown in figure 4. The bridge consisted of two Pratt trusses that were connected by cross members both at top and bottom. The span of the bridge was fixed at 18 inches. However, for the other dimensions of the bridge-width and height, students were given ranges (3 to 5 inches) to work with. The minimum longitudinal dimension of the bridge at the top was set to 3 inches. The bridge was constructed using pieces cut from 36 inches long, 1/4" x 1", 1/4" x 1/2", and 1/4" x 1/4" balsa wood sticks. A loading plate was placed at the top of the bridge and the structure was tested for maximum load capacity by applying a compressive load using the MTS testing machine. Since the weight of the bridge in real life contributes to the overall cost of the bridge, the largest ratio of the maximum load capacity and the weight of the bridge was considered as the best design.

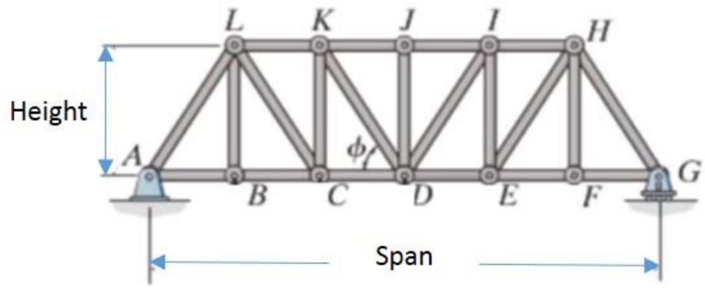
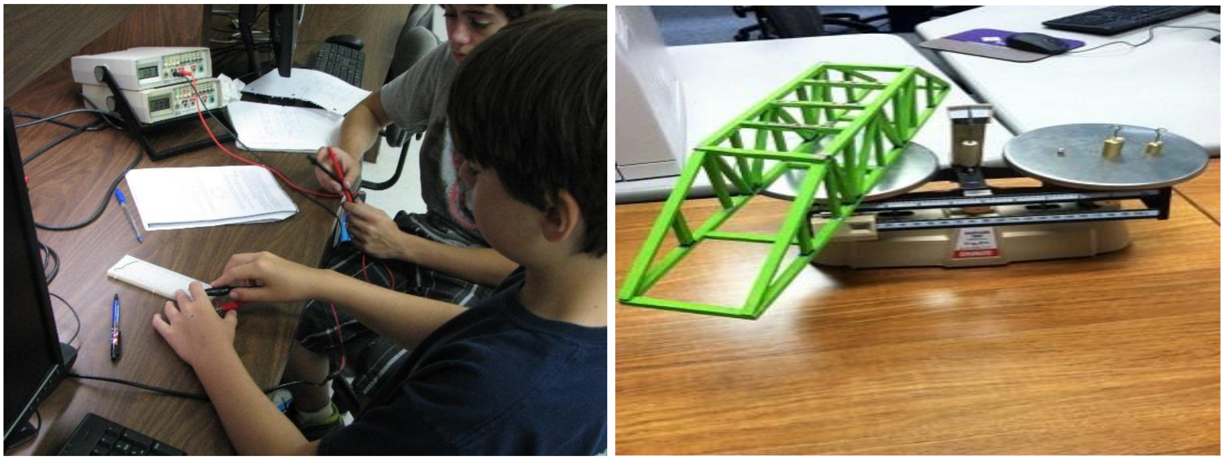


Figure 4: Pratt truss

Many high schools participate in the balsa wood bridge competition. However, the schools of the students of this camp hand not participated in any such event. The American Society of Civil Engineers (ASCE) through their local chapters conducts a balsa wood bridge competition each year to teach K-12 students about engineering. ASCE also conducts a steel bridge competition for the undergraduate students. Therefore, the project better prepares students from these schools to participate in balsa wood bridge competitions besides helping them develop hands-on skills and good understanding of the structural behavior. Students going into an undergraduate program can build on their learning and confidence gained from the balsa wood bridge project or competition to participate in the ASCE steel bridge competition.

Figure 5: a) Students working on the microcontroller project; b) The balsa wood truss bridge being weighed



Students were taught truss analysis using the method of joints in week 1 of the mechanics of materials module. They learned the determination of forces in each member of the truss as well as identifying members that are in compression and tension. Truss analysis is usually taught in the sophomore year of the engineering curriculum. However, the high school students of the camp were able understand the advanced topic and analyze the truss, and the learnings helped them in better designing the truss bridge.

Overall students enjoyed building the bridge and demonstrated excellent hands-on skills in meticulously cutting the balsa wood sticks and gluing them together to create the joints of the truss bridge. They exhibited a high level of confidence and euphoric feeling of achievement having built the bridge from scratch. Creativity was demonstrated as no two bridges were alike in design. All bridges that were tested showed good load carrying capacity as well ratio of strength to weight, thus reflecting good design and construction.

Conclusion

The summer camp “Explore Engineering and Technology” conducted in July 2014 at Baker College of Flint, Michigan attracted seventeen students in week 1. Nine modules were taught during this week, similar to 2013 camp, with the exception that the module on thermal science was replaced with microcontrollers. A new experiment on the identification of plastic materials was included in the material science module. Students thoroughly enjoyed this experiment, and we plan to continue with it for the next year’s summer camp. The modules exposed students to various disciplines of engineering as well as to theoretical aspects and hands-on activities. Responses to student survey resulted in in an increase in the overall rating for most questions of the survey from pre-camp to post-camp reflecting a positive impact of the summer camp. A feeling of marked improvement in their presentation skills was felt by the students. More than 50% of the students agreed/strongly agreed that the camp stimulated or enhanced their interest in engineering.

Students enrolled in the second week of the camp were interested in receiving a college credit for the course EGR105 "Introduction to Engineering and Design". The learnings from week 1 of camp provided the necessary foundation for students for this course. Like in a typical course, homework was assigned each day and a comprehensive final exam was conducted on the last day. Some of the features of the course included individual presentations by students and their work on an involved project that required good understanding of the engineering principles and hands-on construction skills. The summer camp was taught by multiple instructors which enabled students to get exposure to different teaching styles. By the end of the course, students had demonstrated significant improvement in teamwork, presentation, maturity, and confidence to design and build. They were exposed to the different disciplines of engineering very early on and this will better position them to choose their career path. The experience gained by students from their project work will help them in participating and competing in high school competitions that are available for those projects. We have successfully demonstrated that an engineering college credit for high school students is possible through a STEM summer camp of two weeks and an additional month for student project work. We plan to continue this format for next year with some enhancements to improve student learning and engagement.

Future Plans

Many students recommended more hands-on activities in week 1 of the camp and we are considering having them in the next year's camp. To help students organize their work as well have a workbook, a lab manual containing worksheets for all modules of week 1 is under development for deployment. Lecture notes in the form of powerpoint slides will also be made available to students. For students returning to the camp alternate activities that are more challenging are planned to be incorporated within the modules. Modules which received few student votes will be fine-tuned and made more stimulating for the 2015 camp.

The 2014 camp had only two projects for week 2 participants to select from. More options of projects will be provided moving forward. In the summer camps conducted thus far, students were given only one type of truss bridge- Pratt truss to design and construct. More bridge types will be introduced in the future. To better assist students in analyzing trusses an excel file that directly computes forces in truss members for any change in truss dimensions will be provided to the students. This will help students in improving their design to achieve a higher ratio of maximum load capacity to weight.

To improve active student participation in the "Introduction to Engineering Design" course, online discussion board forums will be set up in blackboard (a Web-based learning management system). The questions on the forum will pertain to the course topics, and student answers will be graded. Because answers to these questions can be seen by all students and instructors, it greatly enhances student learning. In an effort to help students better manage their time, the project will be divided into phases that require weekly project updates from them.

Acknowledgements

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Biography

Dr. Patabhi Sitaram is an Associate Professor and Chair of the Department of Engineering at Baker College in Flint, Michigan. He worked in the automotive industry, primarily at GM, for fifteen years as a crashworthiness simulation and methods development engineer. He hast taught extensively at both undergraduate and graduate levels in Civil and Mechanical Engineering disciplines. His research interests include Finite Element Analysis & Design, Crashworthiness, Vibration, Stability, and Plates & Shells.

Mr. Tom Spendlove is an Assistant Professor in the Department of Engineering at Baker College in Flint, Michigan. He teaches Engineering, CAD, and machining courses. He moved to academia from industry after working for ten years in product design in the automotive field. His areas of interest and study are 3d printing, the design process, and engineering education.

Mr. Ellis Love is an Instructor in the Department of Engineering & Technology at Baker College in Flint, Michigan. He teaches courses in Electrical Engineering and Electronics Technology. Prior to joining Baker College, he worked in the industry, mainly at Motorola. His areas of interest and study are microprocessors, photonics, and lasers

Dr. Anca L. Sala is Professor and Dean of Engineering and Computer Technology at Baker College of Flint. In addition to her administrative role she continues to be involved with development of new engineering curriculum, improving teaching and assessment of student learning, assessment of program outcomes and objectives, and ABET accreditation. She is a founding member of Mi-Light Michigan Photonics Cluster, and is active in the ASEE, ASME, and OSA professional societies serving in various capacities.