

Promoting Construction in K-12 STEM Education Through an Innovative University-based Summer Camp

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This project comprised a multi-faceted approach to increasing student interest in construction management and its subcomponents of science, technology, engineering, and mathematics fields. Sixty students in Contra Costa County participated in a five-day, residential camp at California State University, East Bay. The camp brought together teachers from the county, faculty and students from California State University, East Bay, partners from a participating local non-profit organization, and representatives from local industry leaders, culminating in a project-based student competition. After completing the program, students experienced different roles within construction management and engineering professions and understood the university application and financial aid processes. The project benefited the community by increasing student awareness of construction management and engineering as an attractive career option and facilitated their transition to a college program.

Key Words: construction management, STEM education, K-12, student camp.

Introduction

Unlike other careers that are glamorized in the media, traditional engineering fields and the construction management profession are rarely portrayed to teenagers as exciting fields; therefore, additional efforts are needed to present engineering and construction management in a positive light to students. This need is particularly relevant for students who belong to underrepresented groups, as they may not be in close contact with engineers, construction managers, or other Science, Technology, Engineering, and Mathematics (STEM) professionals who could act as role models or mentors. In addition, most students who are interested in STEM lean toward high-tech fields instead of traditional engineering career paths (i.e. civil, mechanical) or construction management.

Many sub-components of construction management are STEM oriented, although they are not historically associated with STEM. Projections show a continued trend of job growth in the STEM fields out-pacing other areas by a ratio of three to one (Langdon, *et al.*, 2011). However, this job growth has also been outpacing the number of new qualified workers.

Construction management, which focuses on “leading, controlling and planning construction activities” (Raiola & Kovel, 2014), is a career that is largely overlooked by many graduating high school students making career decisions. This phenomenon could be attributed to the construction management's being a relatively new field of study, and the negative impression that some students, parents and counselors may have of construction as a whole (Rosenthal, 1990).The lack of knowledge about the career paths as a construction management major among minority students further enables students to accept negative perceptions about working in construction (Bringham Jr.*et al.*, 2012), yet studies show that when students are exposed to construction classes, they enjoyed them, particularly the hands-on components. Students are attracted to the idea of leaving something permanent behind to be remembered by (Bringham Jr.*et al.*, 2012).

Real-world application of STEM concepts via experiential learning is essential to the engagement of both K-12 and university students. Studies show that hands-on activities and inside/outside work experiences are influencing factors in promoting construction as a career option and the STEM field as a whole (Kisi, Shields, & Shrestha, 2011). Also, experiential learning makes STEM disciplines more accessible to students when the concepts are presented in a more practical, hands-on manner (Kline, Hill, Birney, Sarris, & Gauthier, 2014). Through design and development of STEM principles, students’ soft skills such as critical thinking, decision-making, and teamwork improve, along with their technical knowledge and skills (Altuger-Genc & Issapour, 2014).

STEM education outreach efforts through pre-university programs have proven to be an effective tool in educating teachers and volunteers to promote problem solving based in both scientific and engineering principles (Sheikh & Arvaniti, 2014). This foundation then helps student develop the skills that are necessary for university-level capstone projects. Capstone projects provide students the crucial opportunity to apply their cumulative academic curriculum to real-world situations. Students assume the role of the party responsible for executing the project through its resolution (Holt, 2012).

Collaboration between industry and education is critical to the growth of STEM education in K-12. Currently, students focus on facts, tests, and grades, rather than concepts and processes. Implementation of STEM concepts prepares students to integrate knowledge, processes, techniques, and tools to solve the multidisciplinary problems that our world faces today (Craig & Jensen, 2010).

Starting in 2013, California State University, East Bay (CSUEB) and a Contra Costa-based nonprofit, the Contra Costa Economic Partnership (CCEP), have partnered with private industry to bridge the gap between education and industry. The joint project has been aimed at Project Lead the Way (PLTW) and Mathematics, Engineering, Science Achievement (MESA) students in Contra Costa County. Unlike most STEM education projects that focus almost exclusively on engineering, we proposed a hybrid approach combining engineering and construction.

Project Objectives

The objectives of this project were to:

- Raise awareness of construction management and the STEM fields as a whole and the intimate connections between them.
- Demystify the college experience for high school students from underserved communities by providing the experience of living and learning in the campus environment.
- Visit construction and STEM-related workplaces.
- Provide students the opportunity to work in small groups with undergraduate students, University faculty and staff, and industry professionals.
- Develop students' soft skills through teamwork, presentations, and writing.

Methods

Being an engineer means being a creative problem-solver who works as part of a team to use math and science to improve society through development of new infrastructure and technological advancement. These concepts of teamwork and applied technology experience, which are the hallmark of a good engineer, are introduced in the PLTW classroom during the school year and amplified in an extended summer program at the Hayward campus. The unique experience of working in an unfamiliar setting with new teammates to form a group tasked with developing devices or infrastructure based on customer specifications, complete with milestones and deadlines, provides a powerful life-changing experience for young people. Completing the experience was the opportunity to immerse themselves in the college environment for five nights and six days, including the group living situations of sleeping in the dorms and eating in the campus cafeteria.

Students participated in a five-day residential camp at the CSUEB campus, taking part in activities including lectures from industry leaders, field trips, and a competition. Working in smaller groups, students worked closely with industry professionals to experience first-hand what their professions entailed. Students' soft skills were further enhanced by composing project logs and delivering presentations on their projects. The schematics in Figure 1 shows the combination of activities and skills developed for the camp.

This research project is a descriptive case study (Yin, 2003), as it focused on a real-life intervention without manipulation of the behavior of the participants. To determine what facet of the summer camp was most effective in engaging students with the STEM fields, students were given a questionnaire at the end of the weeklong program. Sixty questionnaires were completed by the group of students who had little prior access to STEM fields in their traditional K-12 classrooms. The relevant aspects of the camp will be presented and the results analyzed based on the exit survey data.

Figure 1. Activities and skills developed for the summer camp.

Summer Camp Organization

Working in collaboration with PLTW, MESA, and CCEP, faculty at CSUEB created a summer camp to promote engineering and construction management among 10th- through 12th-grade high school students. Youth from four Contra Costa County high schools in the Bay Area participated in a weeklong residential program centered on a multidisciplinary student competition that combined construction management and other STEM fields. Transportation, boarding, and food were provided to 60 participants and their teachers. The faculty at CSUEB collaborated with CCEP to develop a plan and curriculum for the camp, booked dorms and other facilities, and coordinated various parties including the CCEP partners and teachers. Three volunteer teachers comprised the organizational staff, two of whom coordinated the competition and one of whom coordinated and was in charge of dorm accommodations. Six in-residence teachers acted as chaperones in the dorms and assisted the lead teachers during the day, staying the five nights with the students in the dorms. Two support teachers also aided the competing students during the day.

Each day began with sessions on construction and engineering theory in the morning, followed by work on their core camp project in the afternoon. This Linked Learning approach (i.e., featuring a project in the afternoon) was employed to enhance student learning by tying engineering concepts to industry-themed applications (such as civil engineering projects, manufacturing, or robotics).

Morning sessions combined relevant aspects of STEM, problem-solving, and teamwork, all skills that successful engineering or construction management college students must have. Examples of topics in morning sessions included introduction to the engineering design process, sustainability, the engineering and the construction management career paths, critical thinking, communication skills, learning math through engineering design, and how to combine math and science to accomplish engineering and construction projects. The concepts learned during the morning sessions were applied in the afternoon, as students developed their final projects.

Afternoon sessions prepared students for an end-of-camp competition in which student teams competed in executing a project that combined different construction and engineering fields, such as civil, computer, electrical, and mechanical engineering. Students formed teams and were advised by the high school teachers and aided by the construction management program faculty and students. The projects were designed to engage both construction management and traditional engineering students and also students with varying math backgrounds. Therefore, the project involved some activities that were more theoretical and others that were more hands-on, effectively engaging all team members.

The agenda for the camp was as follows:

- Sunday: Check-in and Welcome
- Monday AM: Keynote Address: Solar Energy Executive; Project Team Ice-breaker
- Monday PM: Project Design Brief & Introduction
- Tuesday AM: Field Trip – Local Utility Provider
- Tuesday PM: Career Exploration – Industry Roundtable Discussions
- Wednesday: Field Trip – CAD Company Headquarters
- Thursday: Competition – Robot and Bridge Testing
- Friday: Student Presentations
- Daily: Camp Exploration (Student Journals)

Student Competition

The best way to develop innovative practitioners is through context: placing actual multidisciplinary problems in front of students (Craig & Jensen, 2010). Therefore, a student team competition was designed that combined aspects from both the construction management and engineering fields. Each team was given a design brief that read: "Your team must design a bridge that will connect the existing abutments that span the chasm between the two roadways of the model track built for this prototype trial. Your bridge must hold the most added weight using the least amount of constituent material. Your team must also design a vehicle (rover) to autonomously navigate a specified portion of the track and that will cross your bridge. Your vehicle must also carry a loading platform onto it under remote control."
The project brief summarized the design and construction restrictions and conditions associated with the project, including (a) available supplies, (b) ramp abutment and span geometry, (c) bridge dimensions and clearance restrictions, (d) rover size limits, (e) rover self-driving capacity requirement, and (f) rover load-carrying capacity requirements.

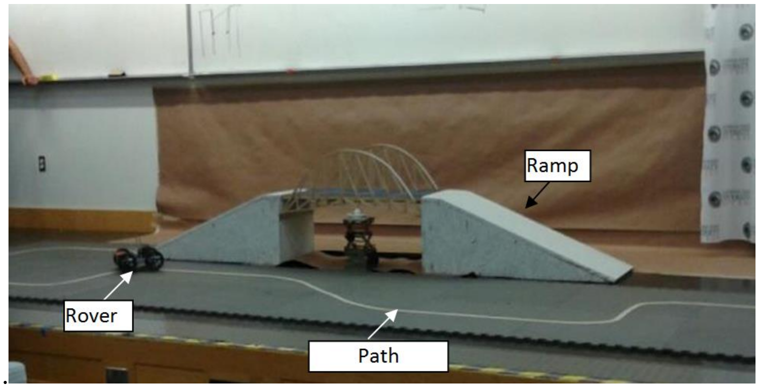

Figure 2. Full competition circuit including path, ramps, egg beneath the bridge, and students' designed bridge and rover.

The 60 students were separated into ten teams based on age, school, and previous extra-curricular coursework with PLTW and MESA in order to create equally qualified and diverse teams. Each team member was assigned an area of interest, which included: (a) two students for construction management and civil engineering in charge of the bridge design and construction, (b) two students for electrical, mechanical, and computer engineering in charge of designing, programming and building the rover, and (c) one student acting as a documentarian completing the design log and recording other relevant information throughout the project.

Each team received a design specification, a set of three robotic kits (i.e., structural, servo and automation, and mechanical/electrical), and equal quantities of balsa wood, card stock, and glue. The robotic car was to autonomously navigate its way along a colored strip of tape as shown in Figure 2, approaching a ramp of 43% slope. At the base of the ramp, the car navigation switched to manual piloting, and the students controlled the car with a joystick and parked it on the bridge. Students then began loading the car's platform with weights (in this case bearing plates used as structural hardware in construction) until the bridge deflected enough to break an egg situated underneath it or failed structurally. Figure 3 shows an example of a rover and bridge designed and built by one of the teams.

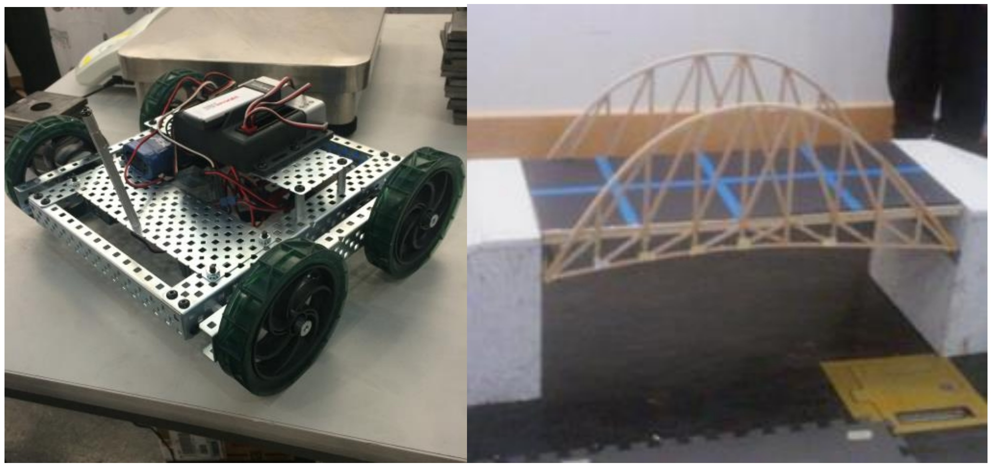

Figure 3. Rover and bridge sample.

This project helped students understand how various STEM fields can interact with construction management in a hands-on approach. The idea behind the design brief was to expose students to the construction management and engineering design world. The assembly and navigation of the robotic car incorporated computer engineering as well as electrical and mechanical engineering. The construction of the balsa wood bridge involved civil and construction engineering. Design and construction aspects of both the bridge and rover utilized core areas of construction management knowledge such as project management, estimating, and scheduling. The combination of these different fields helped students develop skills in analyzing situations by visualizing interrelationships among all elements involved in a project. Throughout the course of the project, students kept design and construction logs intended to aid in the preparation of their final reports and presentations, all of which were aimed at developing their soft skills.

Students tested their rovers and bridges on Thursday afternoon and spent that evening finishing their reports and PowerPoint presentations. On Friday, reports of no longer than five pages and 15-minute PowerPoint presentations were given to a panel of judges consisting of high school teachers, industry representatives, and university faculty. Student teams were evaluated using a rubric divided into three equal sections: robot, bridge engineering, and report and presentation. The rubric covered both technical (design, construction quality) and management aspects (use of materials, cost and schedule) of the project. These presentation exercises were considered to be essential to the development of students’ soft skills such as presenting, team-work, critical thinking, and decision-making in addition to the technical knowledge and skills gained completing the project itself (Altuger-Genc & Issapour, 2014). A final ceremony was held with presentations from the construction management program faculty and representatives and sponsor representatives. Awards and certificates were presented to students to validate their efforts.

Field Visits

Students visited a major wastewater treatment plant, as well as the headquarters of a leading CAD software company. These visits provided students the opportunity to observe where and how various STEM applications exist and gain first-hand experience to engage their interest. Engaging students' interest is key to making construction and other STEM fields appealing to students so that these areas can compete with other potential areas of employment (Piper & Liska, 2000). Visiting the major water treatment plant was an opportunity for students to understand how engineers, construction managers, and scientists work together and how STEM supports a crucial part of our lives. This was an excellent opportunity for students to gain first-hand knowledge of how collaboration is helping to solve the greatest water crisis in California's history and allowed students to see how they could make an impact.

At the CAD software company, students saw real-life applications of CAD in building and industrial design, giving them the opportunity to appreciate how engineering design, construction management, and software are interconnected. This helped the students and teachers understand the opportunities available in the construction management profession (Raiola & Kovel, 2014). Students saw first-hand how software and computer sciences as a whole can apply to construction, construction management, manufacturing facilities, and prototyping.

One-on-One Mentoring Sessions (Industry Roundtable)

The camp facilitated a series of small-group meetings for the students with professionals and representatives from industry, construction, and STEM fields. Students interested in pursuing a career in the trades met with construction trade representatives. Students interested in careers as engineers met with representatives from a telecom and energy companies, as well as representatives from two local energy companies. Construction management faculty and ambassadors advised students about the construction management career paths. University representatives advised all students in the application and financial aid processes. Facilitating these mentoring sessions was important as many high school students, guidance counselors, and parents are unaware of career options available in construction management and engineering (Raiola & Kovel, 2014).

Speakers

Among the keynote speakers was an executive from a prominent solar energy company. His perspective helped students understand the connections between construction management, electrical engineering, and sustainability. Hearing such perspectives first-hand helped students understand the many career paths available in the STEM fields, some of which are not as obvious as others (Holt, 2012).

Partnership with Industry

CSUEB along with CCEP solicited private funding from the oil and telecom industries, as well volunteer support from local industry leaders in facilitating this weeklong program. Meaningful, sustained interaction is a critical element in bridging the disconnect existing between the educational and professional worlds. Students and teachers benefit from direct contact with industry professionals to better understand the roles that engineers, scientists, and mathematicians play in solving society's problems in energy, environment, sustainability, health care, water shortage, and poverty. In addition, students and teachers alike can observe the concepts, processes, and tools used to solve those problems, helping students develop the personal and professional attributes essential to being a technological leader (Craig & Jensen, 2010). Sustained connections between local school districts and CSUEB also aid in innovative recruitment programs for graduating high school students from underrepresented populations by raising their awareness of career opportunities and providing them with proper role models (Raiola & Kovel, 2014).

Analysis of Data

At the end of the weeklong program, students were asked to complete a survey rating the individual activities on a scale of "very bad", "bad", "fair", "good", and "excellent". Being the camp's inaugural session, this was the first year of collected data; more data will be collected in summers to come.

Preliminary data shown in Figures 4 and 5 indicate that students were highly interested in the use of CAD/CAM techniques for designing buildings or prototyping products. 78% of students evaluated visiting the headquarters of a prominent CAD software company as an "excellent" activity. One could conclude that students seem very interested in the high-tech facets of the STEM fields, and one way to promote construction would be to emphasize areas such as Building Information Modeling (BIM) applications in construction management. In contrast, only 55% of students rated the visit to the wastewater plant as "excellent" or "good", suggesting that students viewed this industry as less appealing. Students expressed a positive appraisal of the Industry Roundtable, with 66% of students expressing an "excellent" or "good" opinion of it. A positive response to this activity is encouraging as close interaction between students and both faculty and professionals is considered to be an effective tool in recruitment and retention of students.

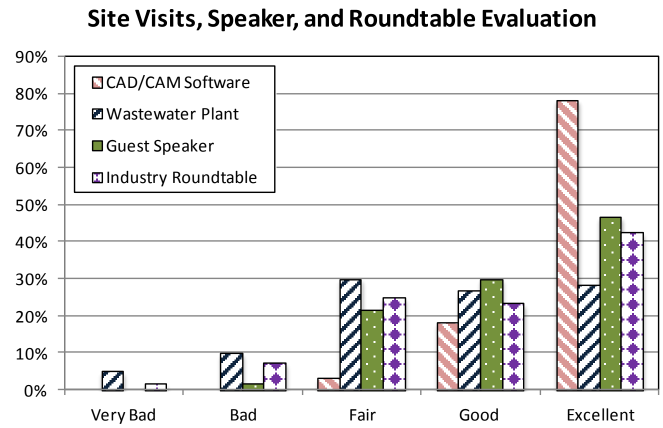

Figure 4. Analysis of camp activities.

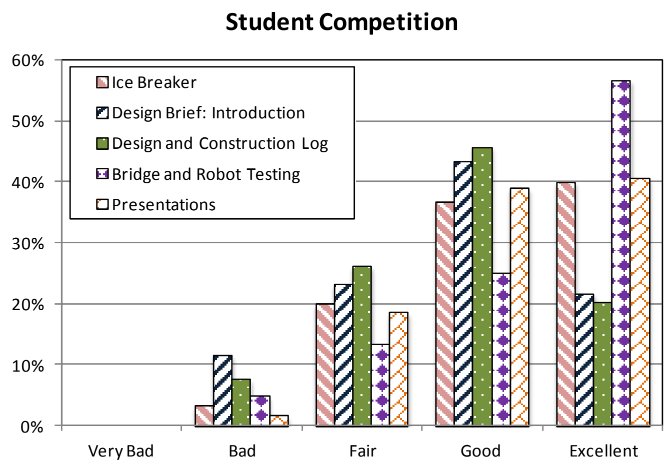

Figure 5. Analysis of competition components.

Figure 5 shows an evaluation and comparison of different components in the student competition. All elements of the competition were highly rated by students, with an average of 77% of students evaluating all activities as "good" or "excellent". Active, hands-on learning was clearly an effective tool in promoting STEM and construction management to students.
Students were particularly interested in the testing phase, as 82% of students evaluated this part of the competition as "excellent" or "good". This finding was expected, as all previous student work culminated at this juncture. In contrast, only 22% of students ranked the design brief introduction as "excellent". This finding was not surprising, as this was the most lecture-intensive portion of the competition. The ice-breaker activity was well received by students, with 77% rating it as "excellent" or "good". This activity was designed to be fun and generate team cohesion. The activity that was least interesting to students was the design and construction log, rated as "fair" by 30% of students. Again, this finding was not unexpected but it does show the need for further development of effective tools for improving students' communication in construction and STEM.

Conclusions

The intent of this program was to provide K-12 students from underrepresented groups with a means to become familiar with construction management and the STEM fields in general. Students participated in hands-on activities, site visits, and individual attention from professionals were effective tools in engaging students' interest. Lectures, notation, and presentations were intended to prepare students for the academic work necessary to pursue a career in these fields and were found to be the most challenging aspects of the program for students. Emphasizing high-tech aspects of the construction industry such as Building Information Modeling (BIM) may be a pathway to attract more high school students to the construction field. On the whole, given the resources currently available to these students, the program proved to be valuable based on the outcome measure of the student surveys. Anecdotally, the program was also successful based on the quality of the students' reports and presentations, and a secondary outcome measure of judges' appraisal of the reports and presentations will be added in future iterations of the program.

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