Novel Approach to Developing and Implementing Curriculum in a 2-Week High School Summer Engineering Experience (Work in Progress)

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Abstract

A shortage of graduates in the science, technology, engineering, and mathematics (STEM) fields has become a priority in the United States (Chen, 2013; Moore et al., 2014). Informal learning settings, such as summer experiences, provide a unique environment in which to capitalize on K12 engineering exposures. This paper examines the efficacy of a 2-week summer camp experience as an ongoing work-in progress. The presented model engages high school students in current engineering practices and research in a higher education environment while exposing them to life on a college campus. The structure and content of this summer experience is designed for students to meet the following goals: define and apply the engineering design process; explore various fields of biosciences and engineering through novel, applicable, and engaging activities that are linked directly to current research at Duke University; discover current research at Duke University by visiting research labs and engaging in real time data collection and analysis; define and analyze engineering ethics; improve technical communication skills; learn about college and career opportunities in engineering; and apply acquired content knowledge in math and science to define, analyze, and solve a problem that will help society in a capstone project. Additionally, this experience is designed to provide students with mentorship and exposure to novel engineering curriculum developed and delivered by current undergraduate and graduate students. This model focuses on a coordinated effort between Duke University researchers and students to promote the "engineering habits of mind" and provide students with opportunities to practice engineering problem solving in a college engineering laboratory as they build their STEM identity.

Introduction

Duke University's High School Bioscience and Engineering camps have employed our model during four 2-week sessions over the summers of 2013 and 2014. Each session had between 26 and 40 high school-aged students that were either over-night or day campers. Currently, enrollment is open to all applicants with no conditions, though the activities and model design may be adapted towards experiences with targeted enrollments (i.e. gender, ethnicity, etc). The current cost of this particular camp is around $200/day for residential campers, and $120/day for day campers with need-based scholarships available, and the proposed camp experience structure may be adapted to fit other financial settings. We incorporate engaging field trips, immersive activities, hands-on lessons, emphasized involvement in research and technology, and grounded each activity in current research at Duke University. Throughout the camp sessions, there is mentoring from current undergraduate and graduate students and exposure to a college lifestyle. The experience culminates in a team capstone project that demonstrates the students' ability to define a novel problem and pose a novel solution based on what they have learned through the camp experience. This summer camp model suggests moving away from the traditional "egg drop" and "marshmallow tower" activities, and moving toward integrating current fields of study anchored in current research topics and cutting-edge technology. This model is unique in the fact that it incorporates design activities directly related to current research, while providing mentoring and skills needed for the transition to college. Here, we explore best practices in implementing programs like this summer experience and includes suggestions for sustaining and replicating this model in other institutions and settings. Preliminary survey data suggest that this summer experience meets the goals of the model and needs of the students. Though initial efforts have been successful, it is still a work in progress. We propose the future downstream effects will be improved recruitment and retention of students in engineering.

Proposed Model

The current schedule is based on 9 days of instruction, it can be easily adapted to fit shorter or longer experiences, as well as less or more expensive experiences, or camps with target audiences. Five primary components enhance campers experience in this program: 1) utilizing research lab space and equipment to provide exposure to current research topics, methods, and practices in order to promote familiarity and a certain confidence level with these tools; 2) interactive mentorship opportunities with current undergraduate and graduate students in engineering to provide instruction and guidance through the transition from high school to college and potential paths through the field of engineering; 3) interactive tours of various research facilities; 4) unique curriculum rooted in research; and 5) a final engineering design capstone project.

Component 1: Utilizing lab space and tools

The students work in research labs to provide exposure to current research topics, methods, and practices in order to promote familiarity and a certain confidence level with these tools. Additional materials for activities were purchased based on meeting the needs of the project as well as introducing students to technology undergraduate engineering students encounter. For example, we have had an electrical engineering challenge where students design a circuit to respond to sound and light, which required specific equipment: LED lights, breadboards, capacitors and resistors, metal wires, and piezoelectric and light sensors. In another lesson involving computer programming and digital logic, campers worked in a university computer lab with biomedical researchers to write a code in MATLAB that models how a soccer ball is kicked around a field. All activities were taught by and related to current research labs helping students became familiar and confident in college level engineering labs. Since these activities are centered on current research and researchers, they are dynamic and can be adapted to new research projects, or different universities and colleges.

Component 2: Interactive mentorship opportunities

By design, there is a benefit to all parties involved in the summer experiences: both with the campers and with mentors that create and facilitate the activities. By serving as leaders and mentors, the undergraduate and graduate students involved in the running the camps gain a connection to outreach, communicating their research, and advising. One tangible example is a graduate student mentor that developed an activity for camp to communicate their research in a K-12 setting that has since been published through TeachEngineering as an activity and lesson. Another example is a former high school BSE camper that has gone on to study engineering at her undergraduate university and returned to the camps as a mentor, and continued her K-12 outreach as a result of her summer experiences. Further, we have modified some camp lessons to bring into local public schools for Science Days. These experiences encourage K-12 activity development and use, which indirectly helps in increasing early engineering exposures.

Additionally, the mentors build a rapport with the high school students and share their engineering experiences with the participants of the program. Through formal and informal interactions, campers gain a better understanding of how to decide on, apply to and survive in an undergraduate engineering program. Further, by creating a specific time to address the transition to college, students and mentors were encouraged to have more informal discussions over lunch or before and after camp activities.

Component 3: Interactive tours of various research facilities

During the camp, students explore relevant fields of biosciences and engineering through the current research at Duke University. Students visit research labs, where they learn and practice safe research practices by adorning lab coats, goggles and gloves (Image 1). The students conduct an experiment and participate in real time data collection and analysis. An example of a research lab our camps interacted with is a machine learning and brain-machine interface lab where they worked with electrical engineering and biomedical engineering students to create truth tables and learn digital logical applications to brain-machine interface devices (see Table 1). In combination with a bioscience and animal-research lesson, students visit the Lemur Center, which houses the most lemurs located outside of Madagascar. Students learn about the current diabetic and cancer research being conducted with the lemurs, the math and engineering behind building the center, and the ecological niches and environmental impacts of lemurs. Accompanying a computer science lesson, students visit the Digital Immersion Virtual Environment (DiVE), where they are immersed in various computer simulated environments. They learn how this type of technology can be used in training airplane pilots, exploring building designs and more. During an environmental engineering lesson, students visit the Home Depot Smart Home (Image 1), which uses the newest environmentally friendly engineering designs: solar panels, passive heating, rainwater collection, rooftop gardens, recycled materials and more. Students tour the home and offer other ideas they would like to see added to the home to increase its efficiency or decrease the environmental impact, and a follow-up activity is designing a passive water filter from sustainable and economical materials. Though some of these activities are directly affiliated with Duke University, these tours and field trips can be adapted to fit other cities and universities.

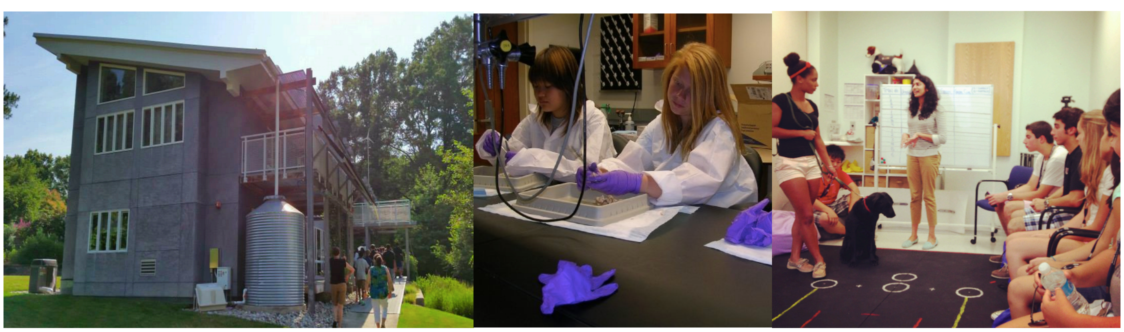

Image1: Students and mentors visiting the Home Depot Smart Home (left), students adorning appropriate lab attire in a research lab (middle), and designing an experiment at the Canine Cognition Center (right). Photo credit: Duke Youth Programs

Component 4: Unique curriculum rooted in research

This curriculum is unique in that it focuses on hands-on activities and active research projects. For example, the students wrote a code for a game in MATLAB, then toured the digital immersion virtual environment (DiVE) to see and play games written by graduate students and play the coding game for brain machine-interface game “brain pong”. Another example is the impact design challenge, which is deeply rooted in the research being conducted at the Duke University’s Injury Biomechanics Laboratory. During this activity students were tasked with designing, and testing, a cost-effective energy dissipation "matrix" that could be implemented in helmet designs for the third world, using cheap and readily available materials, such as cardboard, straws, and sponges. Their designs were tested using state-of-the-art accelerometers and "drop rigs", designed by the Duke University Injury Biomechanics Lab. Furthermore, students were encouraged to consider the material and structural design, but also the repeatability and reproducibility of their products. Not only did they attain a great understanding of the engineering behind such a product, but also what truly goes into the product design process. The students use a “lab notebook” to document all research activities, results and ideas. The notebooks will help emphasis communication and writing skills, and give students a tangible take-away from the camp.

Component 5: Engineering Practices and Capstone Project

In the introductory portion of the camp, we begin by defining the engineering design process and the experimental approach; these are over-arching themes carried through the duration of the camp. We examine the different types of engineering and the relationship engineering has with science. During these first sessions, we have engineering challenges to encourage creativity and team building as well as function as icebreakers. We target introductory activities based on applicable concepts. We either have graduate student instructors develop activities or find an activity from one of the online resources (TeachEngineering or TryEngineering) that provide updated and focused activities. In order for an activity to be chosen as an introductory activity, it must define and apply the engineering design process, require creative thinking with multiple possible solutions, demand that students work in teams to accomplish the goal. During these challenges, we review and further emphasis the engineering design process. The final part of the camp culminates in a team capstone project requiring students to work together to make a poster and prototype presentation. They are asked to apply acquired content knowledge in math and science to define, analyze, and solve a problem that will help society in a capstone project. They then build a prototype and present a technical PowerPoint to present to the teachers and their parents. The aim is to improve technical communication and presentation skills, as well as offer another connection to research practices.

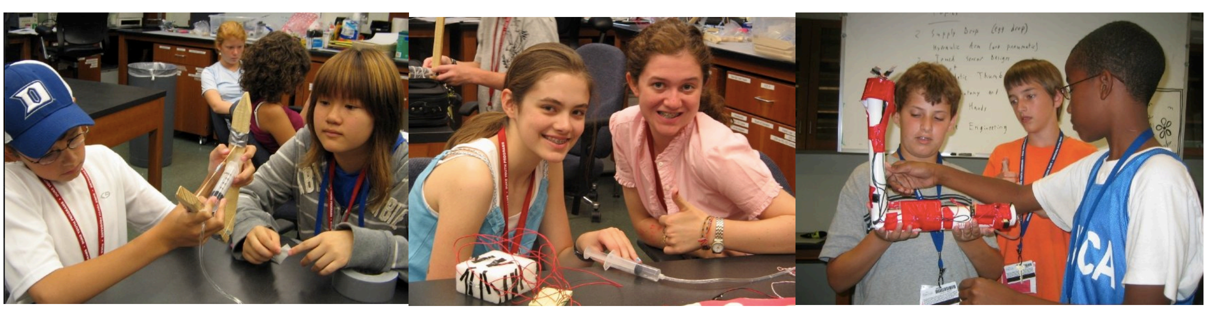

Image 2: Capstone prototype construction and presentation. Photo credit: Duke Youth Programs

Initial results and proposed future work

The final presentations, survey data and student performances suggest that skills and engineering concepts were improved as a result of the camp. From post-camp survey data, we currently enroll around 50% female students and around 15-20% of the students are returning campers. Eighty-two percent of the students indicated their experience was "great" (the highest rating) and, when asked to elaborate, comments looked something like this one: "I will remember this camp for the rest of my life and keep in contact with the new friends I have made." After reviewing the camp surveys, we have proposed a new off-target application of the camps; the students are strengthening a support network of other students interested and involved in engineering. Having a group to support and encourage one another during education may be an added aspect of these experiences.

This model has only been in practice for two years, so we do not yet have data suggesting any effects in college enrollment and retention in engineering of the students, but we hope to get this data in the future. Additionally, we hope to provide pre- and post-experience evaluations to assess effects on learning and engineering problem approaches. We believe that our structure encourages self-assurance and confidence in students. To emphasis this, we are already seeing some downstream benefits; several have decided to continue their capstone projects for their science fair or competitions, students who have decided to join robotics or computer coding teams at their schools, and graduate students who have continued to work in engineering outreach. For future camps, we hope to further examine and quantify the downstream benefits of the camp.

Conclusions and discussion

Overall, the unique experience is designed to provide students with mentorship and exposure to innovative engineering curriculum. Our camp experience structure addresses key skills for success in engineering; collaboration and communication, exposure modern techniques, introduction to research practices and early introduction to the engineering design process. This early connection with engineering activities, engineering mentors and a potential engineering student network will increase interest and comfort level, helping to transition efficiently in the high stake settings at university.

We propose that most universities could introduce these types of experiences, and high schools could even add aspects into their curriculum. Our model includes areas to individualize and adapt to meet the academic level and interest of the students and accommodate the available lab space and equipment. For instance, if a college has a strong robotics or automotive program, the camp model can be adapted to include engine development or a robotic-car race, with a tour of an automotive lab. Additionally, as current research changes and develops, the model will change to adapt. By being dynamic, the experiences can remain current and relevant.

For future directions, we hope to continue improving the camp experience structure: adding new lessons and research practices, publishing additional lessons and activities to K-12 engineering sites, and responding to survey feedback on areas to improve. We also hope to receive follow-up data involving undergraduate engineering enrollment and retention, and monitor down-steam effects of the camp experience.

References

Chen, X. (2013). STEM Attrition: College Students' Paths Into and Out of STEM Fields. *National Center for Education Statistics.*

Moore, T.J., Glancy, A.W., Tank, K.M., Kersten, J.A., Smith, K.A. & Stohlmann, M.S. (2014). A framework for quality K-12 engineering education: Research and development. *Journal of Precollege Engineering Education Research,* 4(1), 1-13.

Additional materials
Table 1: Sample two-week BSE camp schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
Check in	all check in	all check in	all check in	all check in	all check in
Morning (9:00 – 12:00)	Intro to engineering, campus and lab tours, icebreakers	Earthquake activity: building construction challenge and shake-table testing	Brain Machine Interface Project: Brain pong using your mind based on graduate student research	Biomechanics Overview and Activity: design an inexpensive helmet	Intro to "Green Building/LEED" and SmartHome Tour (10:00 - 11:00); activity: how much energy is in your home?
Lunch (12:00 - 1:00)	lunch	lunch	lunch	lunch	lunch
Afternoon (1:00 - 3:30)	Targeted introductory engineering and design activities	Canine Cognition Center Tour- "how to design an experiment and collect data"	Lemur center tour and research information session: diabetes, Alzheimer's, and torpor research introduction	Engineering Colleges and Careers, Types of engineering	Water filter challenge, tour environmental engineering lab, intro to water-borne diseases

	Monday	Tuesday	Wednesday	Thursday	Friday
Check in	all check in	all check in	all check in	all check in	Campers home
Morning (8:30 - 12:00)	Computer Programming overview and activity (MATLAB): modeling a soccer ball being kicked around a field	3D printing introduction and activity—designing a McDonalds children's toy	Technical Communication (Guest Speaker Vanessa Woods)	Capstone Group Work; poster and prototype build	N/A
Lunch (12:00 - 1:00)	lunch	lunch	lunch	lunch	N/A
Afternoon (1:00 - 3:30)	DiVE field frip (1:00 - 3:00) Computer programming challenges and games	Capstone research and literature review	Capstone Group Work, poster and prototype design	5:00 pm reception and poster and prototype presentations	N/A