Engineering Camp: a residential experience designed to build academic capital in pre-college students

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Abstract

Engineering Camp is a one-week on-campus residential program that exposes pre-college (post 7^{th} -11^{th} grade) students to engineering disciplines through introductory seminars, demonstrations, laboratory experiments, and design challenges. The program improves students' awareness of the breadth of engineering and emphasizes the benefit of developing skills in STEM. The camp is offered in grade-based parallel sessions geared to the audience, and campers can return in subsequent summers. Importantly, Camp provides a college-like experience that is integral to building academic capital and a sense of belonging for students.

During Camp students live in dormitories, eat in the university dining hall, go to class and laboratory sessions each morning and afternoon, enjoy an active "social life" (under close supervision), and get a full college experience. The main goal of the camp is to introduce students to engineering disciplines in a way that motivates and prepares them for undergraduate majors. Camp features highly active classroom and laboratory sessions that introduce technical topics not through lecture or 'cook-book' laboratory, but through active, collaborative, and problem-based learning approaches shown to be not only more effective at fostering student understanding than traditional approaches, but also superior for retaining the most diverse audience of learners[1-4]. Campers come from a variety of educational and economic backgrounds. We particularly reach out to students in urban and rural under-resourced schools who might not otherwise be exposed to topics in engineering and technology before graduation, and therefore may not have prepared themselves for or even considered an undergraduate major in a STEM field.

One of the many goals of Engineering Camp is to remove the mystique of going to college and majoring in a technical field. Many of the campers, particularly those from under-resourced urban and rural areas, would be first-generation college students without the family academic capital that could help them prepare for university processes[5]. Camp provides an opportunity to become comfortable with the residential living-learning environment. Both class and laboratory content are challenging but tailored to be interesting to students aged 13-16. By engaging campers in activities that closely mimic those of typical undergraduates in an engineering or technical major, their apprehension about college in general, and difficult curricula in particular, are significantly lessened.

Introduction

This paper is a collection of guiding principles, logistical information, and results compiled from six years of offering a one-week residential program that introduces pre-college students to a campus environment while providing them with a glimpse of the life of an undergraduate student pursuing a technical major.

Engineering Camp was first offered at Bucknell University in July 2008 with support from the NSF (as a "broader impact" part of a larger project)[6]. In this pilot year the program welcomed 26 8th–10th grade students aged 13-16 (10 girls, 16 boys); all but one were from local area schools, and many were from disadvantaged rural schools (schools in areas with a high percentage of low-income families and/or having limited course offerings in upper-level mathematics and science in the high school). Since its inception, camp has grown to incorporate three tracks (rising 8-10th grade "rookies", rising juniors, and rising seniors) and a significantly greater number of campers from an ever-expanding geographical area: 2009 – 51 students, 2010 – 52 students, 2011 – 83 students, 2012 – 97 students, 2013 – 124 students. The target enrollment for summer 2014 is 192 campers. The camp introduces students to numerous engineering disciplines and faculty members from each department in the College of Engineering at Bucknell are involved as instructors; 18 faculty members from across the university participated in the 2013 session. Since 2011 there have been more applicants for slots than there were resources to accommodate them. The program is now funded almost solely by tuition with financial aid being awarded based on need.

Engineering Camp has the lofty goal of fostering a broader interest in and awareness of engineering among the K-12 community, thereby hoping to increase the number and diversity of students pursuing undergraduate majors in STEM fields. In addition to classes in several engineering disciplines (chemical, biomedical, mechanical, electrical, civil, environmental), there are special topic discussions on everything from sustainability and green engineering to biomaterials and nanotechnology. Among the goals of the camp are for students to become familiar with a variety of engineering disciplines and to practice engineering design. Several of the assignments during the week include elements of design and innovation, including "Redesign Your Town Green", where students are asked to reduce the carbon footprint of residents of their towns by thinking about making communities more pedestrian-friendly or starting public programs that would encourage recycling or composting. Students are asked to propose new designs for common packaging as a way to reduce waste, to think about logical improvements to devices with which they are familiar, or to reverse-engineer processes or products. Throughout the camp, students have opportunities to make short presentations or report on results of their experiences; at the end of the camp, students often give presentations to their families, friends, and fellow campers. All together, these activities significantly boost students' confidence, interest, and identity in science, technology, and engineering.

There is a wealth of literature related to the need to draw diverse talent into STEM fields, and to inspire interest early in students' academic careers. If we are to build the capacity of pre-college students to be leaders and innovators in the global technological workforce of the future, as articulated in the *National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System*, and re-iterated in *Preparing the Next Generation of STEM Innovators: Identifying and Developing Our Nation's Human Capital*, "the Nation must enhance its 'ability to produce a numerate and scientifically and technologically literate society and to increase and improve the STEM education workforce.'" In order to both increase and improve this workforce, we must "expand the STEM pipeline from our own domestic talent pool".[7]

In their report, the President's Council of Advisors on Science and Technology outline "a two-pronged strategy for transforming K-12 education", by focusing "on both preparation and inspiration", and recommend that we must "create opportunities for inspiration through individual and group experiences outside the classroom" for all pre-college students.[8] Specifically, they call for creating "STEM-related experiences that excite and interest *students of all backgrounds.*"[8] [emphasis added]

The model of building academic capital and a sense of ownership and belonging among students directly addresses one of the primary issues with identifying and cultivating promising engineering students: "talented students from lower-income levels are underrepresented and lose ground at virtually every stage along the educational continuum".[9] This issue can only be ameliorated with concerted efforts across the board to support these students in their academic development. Under-representation has been attributed to "a systematic lack of opportunities and support for underrepresented minority students, inadequate teaching, and an absence of real-life, hands-on experiences with STEM materials".[9] We work with under-resourced schools to identify talented students and provide them with scholarships, transportation, mentoring, and support so that they gain the academic capital that is instrumental in their further pursuit of college preparation curricula.[10]

The need to work with schools that can identify talent in our most under-represented groups is very real. As emphasized by Levy & Murnane (2005), the challenge is to prepare the workforce of the future for "jobs involving extensive problem solving and interpersonal communication".[10] Without the benefit of hands-on design experiences during their pre-college development, students may not ever realize their own problem-solving talents, and may doubt their ability to succeed in design-based undergraduate coursework (engineering et al.). Without sufficient academic capital, even those students from under-resourced pre-college schools who do pursue technological undergraduate majors may lack the confidence and savvy to effectively interact with their college peers in project and study groups.[5] This can have negative consequences for their academic performance as undergraduates, thus resulting in attrition. It is imperative that we build the workforce of the future by building the pipeline to that workforce, and not dismissing the potential impact of ***immersive enrichment opportunities***.

Educational Objectives

Many pre-college students, particularly those from disadvantaged school districts, are not exposed to engineering or related technological topics prior to their undergraduate education. It is hoped that an experience like Engineering Camp cultivates the intent to pursue higher education in STEM, motivates obtaining the academic background and skills needed to succeed, and provides the academic capital to pursue this goal with confidence. Some strategies we use to have the greatest impact on the development of academic capital include identifying, recruiting, and financially supporting economically disadvantaged yet talented students from target urban and rural areas, thus improving students' awareness of and preparedness for technological undergraduate majors, regardless of prior academic capital. Engineering Camp introduces students to relevant technological topics, provides them with the confidence-building college campus experience, exposes them to myriad technical disciplines with the hope of keeping these students engaged and encouraged in their pursuit of college preparatory coursework.

The design and implementation of Engineering Camp is guided by the following desired outcomes for participants:

1) increased academic capital and sense of belonging
2) increased confidence in their abilities and potential in STEM fields
3) increased level of commitment to pursue studies and careers in STEM after participation

Program Organization and Implementation: a How-to Guide

The typical timeline for planning Engineering Camp starts in the previous summer with reserving on-campus housing and classroom space. In early fall the camp website is updated and the application webform is opened. For Engineering Camp 2014 we already have many applicants who have submitted an application and letters of recommendation from one teacher and a guidance counselor. A first pass for selection of applicants is typically done during spring break. At this time we also confirm participation of all of the faculty instructors and recruit the undergraduate engineering students who will serve as camp counselors and teaching assistants for the week of camp (these students are often on campus for a summer research project). Faculty instructors and undergraduate students are compensated for their time.

As a first recruiting tool, campers are identified through interfacing with our partner schools and programs. It is desirable to recruit several students from the same schools and programs so that they can support each other during the camp experience and to further maintain the sense of community and belonging. Recruiting students involves reaching out to the administration, guidance counselors, and teachers of partner schools and programs. The application process for the camp includes submitting recommendation letters from a teacher and a guidance counselor.

Students are accepted based on their academic merit as determined by demonstrated academic aptitude and positive recommendations. After the initial round of acceptance letters are sent out (by email) with an information packet that includes everything from permissions and medical forms to a campus map, preliminary schedule, and list of "what to pack", there is usually a flurry of email activity with parents asking about everything from financial aid to unique arrival and departure arrangements.

In a nutshell, to host a camp you need to provide a safe environment with a place for campers to sleep, eat, and take classes; you need sufficient staff to watch them 24/7 (we use 11:1 camper:counselor ratio), engaging instructors to lead classes, activities for every afternoon and evening, and a back-up plan for every scenario (from medical emergencies to homesickness).

On the first day of camp, students arrive to registration at the dormitory and are escorted to their rooms by their floor counselor. To facilitate participation from our partner schools that nominate students from under-resourced backgrounds, we send a shuttle to both Baltimore and New York City. The secondary function of the provided transportation is to allow students from out of the state to fly into either airport.

Getting the students to identify with their groups in a very short period of time is essential to a successful program that is inclusive and encouraging. Students arrive on a Sunday afternoon and within the first hours they are moved in to their rooms, meeting their room and hallmates, and interacting with their counselors. Similar to a first-year orientation experience, the students and parents are given a tour of campus, giving them time to observe where classes will be held and where the students will be eating, and then given an opportunity in an open forum to ask questions.

After the parents depart, the campers do some ice-breaker and teaming exercises, often including some kind of scavenger hunt, and then they are taken to the cafeteria at the slowest time and shown how to use their meal cards and get food. This may seem like a trivial thing, orienting campers with something as mundane as a cafeteria, but for those students who have never been to a campus before it might otherwise be intimidating just to get food. Because our goal is to best serve the students who have the least prior academic capital, we strive to make every experience accessible.

To keep students engaged and active we program a very full schedule. During the week (Monday through Friday) the students have breakfast starting at 7:30am. They are required to report to the common lecture hall at 8:30 for the day's announcements before heading to their first class. The counselors serve as the teaching assistants and there are two counselors assigned to each group of 24 students. Most sections are 90 minutes and one hour is given for lunch (8:45-10:15am, 10:30am-noon, lunch, 1-2:30pm, 2:45-4:15pm). After the last afternoon academic section the students have the option of swimming, playing soccer or volleyball, or doing something else recreational. We often have at least one counselor lead a group of students who prefer to run

around campus. After their recreational activity the students have time to shower and eat dinner before coming to the common lecture hall at 7pm to begin the evening academic program. The evening academic program typically ends at 9 or 9:30pm, after which time the students are free to return to the dormitories.

Figure 1: Model Camp Schedule; numbered blocks correspond to technical sessions. Sessions change every year, but a representative example of topics includes: [1]Bumps, Bruises, and Broken Bones: Biomedical Design for Safety; [2]Earthquake Analysis; [3]Food Engineering; [4]Electrical Engineering: Circuits; [5]CRODA Chemical Industries & Formulations (Industrial Presentation); [6]Playworld Systems: Design for Play (Industrial Presentation); [7]Atmospheric Particle Engineering; [8]Nanotechnology; [9]Mechanical Design; [10]Materials Engineering; [11]Sustainability; [12]Physics & Mechanics; [13]Design Competition (Juniors/Seniors); [14]Logic & Programming Competition, [15]Rookie Design Competition; [16]Biomechanics; [17]Biomaterials; [18]Power; [19]Polymers; [20]Biomimetics; [21]Engineering Entrepreneurship; [22]Design for Sustainability; [23]Statistics; [24]Air Products LiN Demonstration (Industrial Presentation); [25]Product Prototyping.

During the camp, students spend more than 35 hours in classes and laboratories; an additional 28 hours of extracurricular activities are also scheduled. Extracurricular hours include evening lectures and competitions, as well as afternoon recreation. The significant laboratory component of the camp provides an opportunity to participate in intellectually stimulating hands-on experiments. A sample weekly camp schedule is shown in Figure 1. Technical sessions indicated include faculty-lead sessions on structural engineering, biomechanics, food science, materials science, nanotechnology, and others as described above.

The types of courses offered during camp are meant to truly be multidisciplinary. In the past we have had sessions on everything from Biomaterials to Digital Circuits. Each year is slightly different so that a camper could return and because of the changes in sessions offered and the grade level of the student, they would experience a different academic program.

What we believe to be unique about Engineering Camp at Bucknell is the extent to which we try to make it feel like a first year college experience.

The engineering faculty at Bucknell has developed a strong program emphasizing effective teaching techniques such as active, cooperative, and problem-based learning with a considerable interest in hands-on experiences in the laboratories. A major focus of the engineering faculty is the improvement of engineering education through innovative pedagogical developments. For its topical sessions, Engineering Camp draws on the expertise of over 20 Bucknell faculty members from Engineering, the sciences, and across the university. This level of participation will continue moving forward, as the program is expected to grow to 8 sections of 24 campers (196 total).

Results

At the conclusion of their camp experience, campers are asked to complete a survey. In addition to some basic demographic information, campers provide feedback on their favorite aspects of camp, the topics and activities they liked or disliked, and comment about any changes they would like to see in a future camp experience. Survey results of previous years have all been overwhelmingly positive, and in 2013 we started using a standard assessment survey designed to reflect the most useful data gathered from previous versions. This instrument will continue to be used in the future. Students who attended Camp in 2013 (121 respondents) show a strong positive response to the following questions (related to camp attendance):

"I am (more likely, as likely, less likely) to pursue an undergraduate engineering major."

Over 80% reported that they were "more likely to pursue", with all but a few of the balance reporting they were "as likely".

"I (can, can sort of, can't really, can't at all) imagine myself as a practicing engineer."

Fully 97% of respondents responded they *can* imagine themselves as practicing engineers.

"I am (very confident; confident; not very confident; not at all confident) in my potential to solve engineering problems."

An encouraging 94% reported that they were confident or very confident in their potential to solve engineering problems.

And, importantly, 97% of respondents indicated that they would recommend Engineering Camp to a friend.

Summary

Engineering Camp is designed to be a high-impact opportunity for pre-college students to learn about engineering disciplines and better prepare for an undergraduate major in a technical field; engage traditionally under-represented groups in STEM-related activities through targeted recruitment efforts; and foster meaningful connections between the College of Engineering and the local K-12 community. Engineering Camp is institutionally supported and instructed primarily by faculty from the College of Engineering at Bucknell.

This program provides the opportunity to deliver more than an expanded and enhanced version of the typical one-day outreach program; it affords more time for student-instructor interaction and gives students time to reflect on their on-campus experiences and what they have learned. Currently, few high school programs are properly equipped to conduct educational laboratories that introduce students to topics in engineering and technology. Because Engineering Camp is a dynamic program with annual topical changes, students can (and are expected to) repeat the experience. Also, because the topical sessions are targeted to the audience, even similar topics provide a very different experience in each of the tracks (rookie, junior, and senior). This type of program can significantly impact students' attitudes toward science, technology, and engineering as well as introduce students to more general topics of engineering and science while giving them the extended on-campus experience to build academic capital. The longer duration also affords greater opportunity for student mentoring, allows students time to work on projects, and can provide encouragement for the students to seek more enrichment opportunities.

A limitation of many pre-college initiatives is that we are unable to reach all those students and schools that are most in need of this type of enrichment, and parents may not inquire about such programs if they presume they will be unable to afford to allow their children to participate. These are the students we need to be targeting to make the greatest impact. Students who feel there are barriers to their participation in programs of this type must be identified and encouraged, and financial support must be provided if real changes in undergraduate enrollments in STEM fields are to be impacted.

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