2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering
Education for 130 Years
ASEE
Paper ID #37660

Energizing High School Students Toward Building Design: A Summer Camp Experience

Prof. Moses Ling P.E., Pennsylvania State University
Maureen Kelliher
Jonathan Michael Broyles, Pennsylvania State University
Dr. Ryan L. Solnosky P.E., Pennsylvania State University

Ryan Solnosky is an Associate Teaching Professor in the Department of Architectural Engineering at The Pennsylvania State University at University Park. Dr. Solnosky has taught courses for Architectural Engineering, Civil Engineering, and Pre-Major Freshman.

Heui Young Park
Lily X. Li, Pennsylvania State University

Lily Li is a PhD student in Architectural Engineering at Penn State. Their work focuses on grid-interactive building controls. They are passionate about undergraduate engineering education and research.

Baraa J. Alkhatatbeh
Lorine Awuor Ouma

Energizing High School Students Towards Building Design: A Summer Camp Experience

Architectural Engineering (AE) is a critical engineering major for the future of building design given how important buildings impact our everyday lives as well as our environment. However, the major of AE is comparatively small and relatively unknown as compared to other majors like civil engineering and mechanical engineering. It has been shown in the pre-college literature that the most impactful time to energize students about careers in STEM is in K-12 settings. To emphasize and spotlight the importance of buildings on humans, along with providing an interactive learning experience for potential future STEM students, a five-day summer camp focused on multi-disciplinary building design was held at (insert university name). The camp curriculum included hands-on, design-oriented projects from several disciplines: architecture, mechanical, structural, construction, sustainability, acoustics, and lighting. In addition, tours of several buildings on campus were conducted along with after-hours relaxation time for campers. The implementation of activities and the well-designed hands-on projects not only increased the students' satisfaction, but also improved their self-confidence and their interest toward engineering buildings. This paper will focus on various core attributes of the development and rationale behind the summer camp such as core topics, schedules, recruitment, etc. Additionally, survey results designed to assess the campers' satisfaction were deployed. Survey results clearly indicated students enjoyed the topics and activities central to building design to the extent where they hope for more in-depth topics in the future. From an energizing perspective, results indicated that students felt stronger towards engineering and buildings, while better appreciating the buildings they are typically around. Faculty and programs similarly concerned with motivating high school students towards building design should find the paper meaningful in their efforts to create similar experiences.

Keywords: STEM, Summer Camp, Building Design, Architectural Engineering, K-12 Engagement

The need to promote AE and Building Design

The U.S. construction sector market size of was valued at around 1.6 trillion U.S. dollars in 2021 and it was expected to increase further in the next year which includes both residential and non-residential rose over 8% between 2020 and 2021[1]. With an industry of this size, approximately 4.8% of the U.S workforce works in construction that equates to 7.5 million employees as of January 2022 [market]. Given that the building industry is perhaps the largest industry outside of technology, it's impact on society of massive both from an economy perspective but also human occupants and the climate.The building sector is considered as the biggest single contributor to world energy consumption and greenhouse gas emissions [2]. According to the 2011 Buildings Energy Data Book [3], buildings consume approximately 40% of the nation's energy. Approximately 56% of this energy is used for space heating and cooling as well as lighting applications, while 25% to 35% of this energy is wasted due to inefficient windows [3-4]. Given the large number of buildings in service, their rehabilitation contributes both to their durability and sustainability [5]. Indoor air quality concerns of owners and occupants are also at the forefront of building design that need addressed but knowledge designers are limited [6].

Knowing the scope, scale and impact building have on the occupants and climate, it is important to have a robust workforce for building design and construction. That said when looking at post K-12 education, most high schoolers are exposed only to trade school education. While important for the building community as a whole those programs focus on the construction labor side and not the design side. If typical engineering degrees, K-12 students are drawn to mechanical, electrical, civil and other programs. While these three majors can support building designs, very few focus on the building side within their curriculum. One major that does explicitly focus on building design is architectural engineering. However, there only exists 25 ABET accredited Architectural Engineering programs in the United States and a total of 30 worldwide [7-8]. Because of this limited number of programs, Architectural Engineering degrees become discovery majors. The intent of our summer camp is to kick start the discovery of the Architectural Engineering major and excite K-12 students into wanting to be part of this engineering community.

The need for and importance of K-12 Engineering Summer Camps

In order to meet the growing labor force needs in science, engineering, and technology it is projected that the U.S. must increase the number of undergraduate STEM (Science, Technology, Engineering and Math) degrees by about 34% annually [9-10]. For almost the last 20 years, the United States has faced a shortage of engineers [11]; part of the reason is exposure in the K-12 Settings [12]. Over this same time period, a significant number of Pre-college STEM initiatives have been established to stimulate interest in STEM disciplines and improve the coordination of efforts between K-12 and higher education. Of the many established initiatives, effective recruitment tools for STEM majors include: K-12 school outreach, University open house sessions, hands-on workshops, competitions and demonstration, and summer camps [9].

The idea of using summer camps to promote STEM disciplines is not new [12]. A review of the STEM summer camp literature by Kuyath [13] yielded several themes related to the planning, implementation, and assessment of summer STEM camps. Summer camps not only promote STEM through engaging hands-on activities but reinforces learning and/or reducing learning losses in a student during the summer months [14]. STEM camps have many positive attributes including but not limited to: the promotion of STEM majors; allow for significant learning; simulate, in a hands-on manner, what careers could look like; create new friendships and social skills; and can be made affordable with grants, scholarships, and financial assistance [14-15]. A study by Cooper et al. [16] examined the effects of summer vacation on standardized achievement test scores that concluded that on average children's tests scores were at least one month lower then when they left in spring and didn't have a summer camp [14].

Within the engineering sector, summer camps have shown to provide an outlet for children of varying age levels, racial, and ethnic backgrounds, with similar interests, to interact with one another [15]. This is particularly important as studies have shown that with engineering awareness certain children groups need more exposure to the topic. Within those who do enter engineering, white female, African American, Latino, and Native American high school students traditionally have had little encouragement in pursuing careers related to these subjects [17-18]. Given early 2000's work, there has been an increase in women's representation in all STEM fields, yet they remain significantly underrepresented [19-20]. STEM summer camps who have coordinated efforts to recruit women and minority populations to develop an awareness of engineering is a common practice and has been shown to successfully influence decisions to pursue engineering [9,21]. Chen [22] noticed that most students came to the camp with a high level of interest in engineering; however, they observed the distribution of males and females was skewed with males already certain of engineering while females were still deciding. To capture minority males, it may be needed to target middle schoolers rather than high schoolers [14, 21]. Longer-running camp events and/or those with more involved activities have also been shown to positively influence a student's perception and desire to pursue engineering [9, 23].

These ideas and other presented within STEM summer camp literature was influential to the establishment of the AE summer camp that would promote both the major and the importance of the building design and construction industry.

Recruitment and Selection of Campers

To kick off the creation of the camp, and with no prior camp offerings, marketing was a vital first step to the camp's success. The AE summer camp was initially promoted through email using Penn State's

Architectural Engineering (AE) alumni network in conjunction with an in-department generated list of architecture, engineering, and physics K-12 teacher network within Pennsylvania. Penn State's College of Engineering featured an article promoting the camp on their website with camp details beside the long-standing summer camp for all of Penn State (i.e. Science U that focuses on natural sciences). These materials were part of their email distributed monthly newsletter. Throughout the marketing process, efforts were put forth to identify and invite underrepresented groups to participate. This was important to be inclusive but also Penn State regularly provides those students scholarships to be able to attend educational camps in STEM.

To provide opportunities for students from different backgrounds and locations to attend the camp, the AE camp secured multiple sources for scholarships. First, the Washington Building Congress (WBC) helped identify underrepresented students in the DC area and provided a scholarship for those students to attend. The Philadelphia ACE (Architecture, Construction and Engineering) Mentor Program helped identify underrepresented students from the Philadelphia area and provided scholarships, along with the Penn State's AE department to supplement those student's attendance. The AE department also awarded internal scholarships to underrepresented and economically disadvantaged participants as needed and funds permitted.

With advertising completed, registration opened at the beginning of February (before that summer the camp was held). During the open registration process, a cap of 24 students was set to provide a balance of anticipated camp workers, activities, and costs. Additionally, this size was deemed manageable give the outreach specialist's prior background and this being the first camp for AE. Within 2 months, all 24 slots had been filled. Initially, 16 students enrolled in an open registration through Penn State's Cvent Registration program. The cost for the five-day camp was $1050 per student. As the camp filled quickly, we realized that there was interest in the camp and decided to increase enrollment to 24. The final 8 slots were reserved for young women and unrepresented groups. The goal of the camp was to have a 50/50 enrollment of young women/men which we succeeded in doing. Students attended from around the U.S., as five states / regions were represented: Pennsylvania, New Jersey, Washington DC, Virginia and, Florida. Registration was closed for the camp in early April, with 18 names on the waiting list. This waiting list served us in the event another camper needed to pull out due to after registration conflicts.

Organization and Camp Leadership

This camp was developed with the coordinated help of Penn State AE graduate students, faculty, and staff, and was organized by the department's outreach specialist, whose purpose was to increase K-12 interest and understanding of AE. For our experience, the outreach specialist acted as the camp's director, organizing all aspects of the project and was the point person for communication to families, training for camp employees, and following all university regulations when working with youth. The outreach specialist created an oversight committee of three faculty, the outreach specialist, and six graduate students.

Early on it was decided amongst the oversight committee that a manageable amount of time to host 9-12th graders and hire staff to work at the camp was five days. A multi-day camp permitted deeper exposure to camp topics. When selecting which week to host the event, we considered when high school students would be out on summer break, but also when our own faculty, staff, and graduate students would least likely be on vacation. A mid-June week was selected, with the camp beginning Sunday at 4:00pm and ending Friday at noon.

Graduate students filled the role of daytime mentors (counselors) who supervised all aspects of the campers from 9am to 5pm with the outreach specialist's oversight. These AE graduate students volunteered early to assist in curriculum development and scheduling, then later acted as mentors during camp. A separate group of nighttime mentors were hired to take the group to the evening activities, as well as, to stay and supervise the campers in the dorms overnight. These were Penn State undergraduate students who applied for the evening mentor positions and were selected to manage the students overnight. The ratio of counselors to students was dictated by Penn State regulations, with one counselor supervising no more than eight campers.

Camp Format, Arrangement, and Activities

When looking to determine what aspects of building design to include, the oversight committee reflected back to the AE curriculum at Penn State which is divided into four distinct disciplines: Construction, Structural, Mechanical and Lighting/Electrical. These options made for a balanced progression of activities as well as a broad exposure to buildings during the camp. Camp was designed to have activities and tours that logically progressed through how a building is designed then constructed. Over the camp's 5 days the focus on each day was:

- Day 1 consisted of an introduction to the 3D modeling software SketchUp, structural engineering activities, including a lesson on the sustainability of concrete and a concrete pour, followed by a structural tour of Beaver Stadium, Penn State's famous football stadium.
- Day 2 consisted of campers participating in a structural truss activity in the early morning, followed by mechanical-focused activities, that included making a simple cardboard building and testing different insulation R-values using heat lamps and temperature sensors. The group then toured the construction site of the new Penn State engineering buildings.
- Day 3 consisted of campers studying sustainable building by touring Penn State's Morningstar house (ultra-sustainable tiny house), guided by a faculty member who was part of the undergraduate team who created the final design.
- Day 4 centered on acoustics and lighting and electrical morning, where students experienced the AE's lighting lab and an acoustic anechoic chamber.
- Day 5 was the final day where campers tested their concrete (poured on Day 1) for strength and presented their group activities to their families.

When organizing these daily activities for the campers, the activities and events used for educating the campers included tours, labs, and projects, with little lecturing and no panel discussions, with the aim to make it different from their typical school experience. When needed, building content was taught to students, but was restricted to the material that students needed to work on their activities. Each day included activities led by AE graduate students or faculty, and a tour, with an engineering professional or faculty member as their guide. The campers were encouraged to ask questions, test different ideas, and freely explore engineering building concepts. The intention was that the campers would learn about engineering through their own natural interest when they questioned the activity lead, versus a pre-determined discussion. For example, the tour of a construction site was hosted by the construction project manager, who explained the details of designing and erecting a university building, but also communicated his experience working as an engineer in a construction environment, a field that many of our AE students find careers.

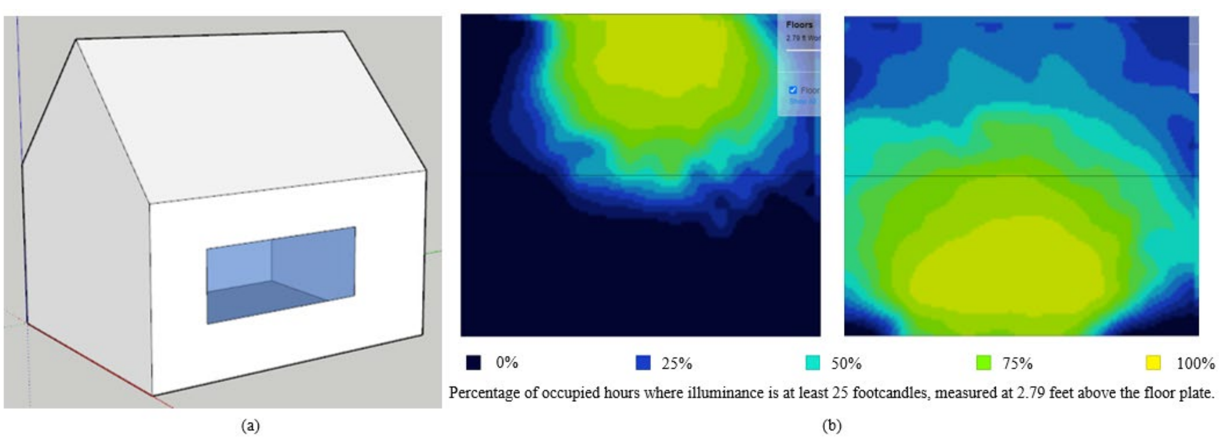
Central to the camp activities was a multi-day group project where students would design and build a house employing the knowledge they gained during each day. To provide group design experience, similar to the building industry, campers worked in small groups of 2 or 3, and considered the position of the sun, air flow, insulation, aesthetics, and functionality in their houses. Campers presented their houses to the whole group, explaining the details of the building, and later presented the houses to their families to celebrate their work. Originally, the evenings were designated for non-engineering fun activities, like laser tag, a farm league baseball game, and a game room day. When the project was introduced on Day 3, the campers asked to spend time working on their project when a baseball game was rained out. The students were highly motivated to use the knowledge they had gained from their camp experiences and created a sophisticated building design. The campers were given four hours on day 3 and five hours on Day 4 to complete their projects and nearly all wished they had more time to work on it. These final work sessions saw the most of the time was spent physically mocking up their houses using foam board where they could consider all they learned about AE.

Daily Topic Development

While the camp was planned by the oversight committee, each AE graduate student oversaw at least one activity that they designed and taught. They were encouraged to make each activity a project-based learning experience. The activities and labs took place in different locations throughout engineering buildings on campus to showcase Penn State facilities and keep each day novel and interesting for the campers. Approximately once every month the oversight committee would review the content for consistency, complexity, and ability to complete them knowing both the camp duration as well as the knowledge of the high schoolers. The remainder of this section of the paper summarizes each of the major AE building focused activities.

Architectural

The architecture portion of the AE camp focused on the influence of early design decisions by relating the total energy use and daylighting performance of buildings. Students explored this by learning how to model in SketchUp and conduct simulations using the plugin Sefaira. Here, students performed an activity that investigated the influence of insulation thickness, window to wall (WWR) ratio, and windows' orientation on the annual energy use and climate-based daylighting metrics. This study mimicked what designers would do early in a building conceptual process. The task was to model a simple house with one side-window and evaluate its performance in different climate zones and with different combinations of design variables. For example, students were asked to evaluate the performance of south-oriented and north-oriented windows in hot and cold climate zones and identify the most critical design factor in each zone (Fig. 1). Another simulation run aimed to evaluate the impact of window size on energy and daylighting performance. Students were able to observe the impact of these early design decisions on buildings' environmental performance and link it to the sun movement and sun path diagram. Students were also encouraged to use SketchUp and Sefaira to evaluate the performance of their group project and make design decisions. However, time dedicated to group projects was barely enough to apply what they learned during the summer camp on a foam board physical model. Students showed more interest in creating a physical model rather than creating a digital one.



a) A simple house model in SketchUp, b) Daylight simulation for a north-oriented (left) and south-oriented windows (right) of a simple house model in New York, US.

Figure 1: Sample student daylight simulation model.

Mechanical (HVAC)

The mechanical lesson of the AE camp focuses on the heat transfer in buildings through three building operation components: insulation, space conditioning, and controls. The overall lesson features one short lecture, three demonstrations, and one main experiment. The first demo highlights the concept of insulation by having students feel the temperature of the ice water while wearing gloves (zip-lock bags) insulated each with cotton (cotton balls), air (bubble wrap), foam (packaging foam), and fiber (pillow stuffing), shown in Fig. 2a. The second demo helped students understand the basic principles of an air-conditioning (AC) unit, by having them trace the vapor compression loop and feel the temperature on the evaporator and condenser side on a refrigeration cycle training unit (R134a). The third demo highlighted the concept of basic AC control logics, with a mini peltier cooling device coupled with a temperature controller module, as shown in Fig. 2b. The module turns the peltier cooling device on and off based on the temperature readings of its sensor and a pre-set set point temperature.

a) Demo 1 insulated gloves and   b) Demo 3 peltier cooling with a temperature controller

Figure 2: Mechanical Demos

The main mechanical experiment synthesizes the concept of insulation, space conditioning and controls by simulating the operations of a heating device in a mini house made of chipboard as shown in Fig. 3. Here, students assembled the mini house, using pre-laser cut pieces based on their digital house design completed in SketchUp. Each house is insulated with a unique configuration pre-selected from Table 1, with either no insulation, expanded polystyrene (eps) or extruded polystyrene (xps) at different thicknesses. To simulate a heating event, students performed a manual control (switch on and off) on a 15-W light bulb glued to the inside ceiling of the house, in response to the temperature readings from a wireless temperature sensor also placed inside the house. Students conducted 15-minute heating simulations, with a temperature dead band, while recording the total amount of time the heater (light bulb) stays on. Temperature data (selected cases) were plotted in Fig. 4 and the impact of insulation on energy consumption and thermal comfort were discussed. Overall, students demonstrated excellent ability to apply basic concepts in heat transfer to analyze and interpret their experimental data. Similar to previous sections, students could benefit from more time to post-process their data and explore the demos.

Figure 3: Example set up of the insulated mini house experiment.

Table 1: Insulation configurations for the mini house experiment

Group	House configuration	R-value	Foam thickness
1	no insulation	-	-
2	eps	R1.9	0.5
3	eps + seal edges & corners w/tape	R1.9	0.5
4	eps	R3.8	1
5	xps	R5	1
6	xps	R10	2

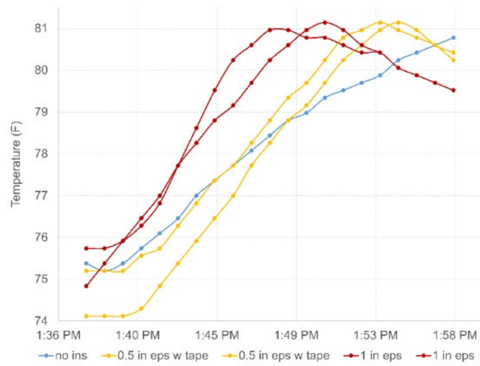


Figure 4: Selected temperature profiles from students' simulated heating event in the mini house.

Construction

The construction section introduced campers to the basics of concrete mixing. The exercises within this activity aimed at providing learners with the basic understanding of the major construction materials and how these can be used to achieve structurally sound construction. Students further learned about the concrete industry as it relates to building engineering, and their corresponding carbon emissions. A detailed introduction into the use cases and mixing of concrete was shared with the students and followed by a hands-on concrete batching and placing activity resulting in creating concrete cylinders. For the activity, students were divided into teams, where each team was tasked with making slightly different cement mixes. The first group worked with the conventional concrete containing Portland cement, sand and aggregates while the second group replaced 20% of the Portland cement with metakaolin – a sustainable supplementary cementitious material in concrete production. Safety precautions were adhered to during the mixing exercise as a demonstration of the importance of safety precautions in a typical construction site and the need for construction safety standards within the industry. The mixing of the cement, sand, aggregate and supplementary cementitious components was done by hand following guided batching exercises. On the fifth and final day of the camp, students broke the cylinders, following an industry standard to determine the structural capacities. Table 2 shows a sample of the strength of cylinders on day 5 as measured during the cylinder breaking exercise.

Table 2: Concrete strength at day 5 during the cylinder breaking exercise

Group A Standard mix	Strength (psi)	Group B Metakaolin mix	Strength (psi)
1	2,275	2	2,004
3	3,118	4	3,182
5	2,577	6	2,720
7	2,354	8	3,309

In addition to concrete mixing, students got to visit an on campus building that was under construction along with a talk by the construction managers and workers on what goes into building. The project and tour consisted of approximately a 15-minute talk followed by a 45-minute tour of a new innovative and collaborative multi-disciplinary engineering building. This project was 4 stories and has a meaningful design to promote engineering on display which provided an advantage to the tour as campers could see many of the building systems.

Structural

The structural engineering portion of the AE camp consisted of two different components; first it integrated with concrete on the structural size of the concrete they had mixed earlier through structural testing (Fig. 5a), and the second component was making and breaking balsa wood truss structures (Fig. 5b). These components were selected to provide students with two hands-on activities with building materials and structural systems, while reinforcing the concept of structural strength capacity. Both concrete structures and truss systems are very common in the built environment.

The balsa wood truss activity introduced students to different types of wooden trusses commonly designed in residential buildings. Here, students were tasked with creating their own truss made out of balsa wood, and then load test the trusses to assess their strength capacity. Overall, students responded well to the activities, however, not enough time was allotted to tabulate and plot the structural strength to analyze trends with the concrete cylinder and truss activities.

a) Loading a concrete cylinder specimen b) loading a balsa wood truss.

Figure 4: Representations of Structural Activities

Acoustics

The acoustics portion of the AE camp focused on acoustics fundamentals and how acoustics relates to building design. For both concepts, hands-on activities and demos were presented. For acoustics fundamentals, three main topics were covered: sound propagation, wavelength/frequency, and amplitude/ loudness. For sound propagation, the key concept was how sound waves propagate through air. Activities included using a slinky, tuning forks in beakers full of water, and ping-pong balls in tanks to visualize wave phenomena (Fig. 5). For wavelength and frequency, the key concept was to understand the wave motion, and how pitch changes with different objects. Activities included various types of mass-spring systems, boom whackers, individual organ pipes, standing wave generators, and tuning forks. The students were able to observe and feel how the materials and physical properties of the medium effected sound behavior. For amplitude & loudness, the key concept was to observe changes in loudness. Activities included using a ping-pong ball with a tuning fork, and a wearable sound level meter (SLM).

For connecting acoustics into building design, students were divided into two groups for different audio demonstrations after a brief introduction to AE acoustic ideas. Half of the group had audio demos of reverberation sound isolation, and binaural recordings and playback, while the other half of the group explored the anechoic chamber and its properties. The second group visited an acoustic anechoic lab (AUralization and Reproduction of Acoustics Sound fields (AURAS) facility), where they were given concert hall, transportation noise, and other demos. Overall, the students enjoyed the demos and requested that more time was spent in the anechoic lab.

Figure 5: Representative Activity showcasing Acoustics

Sustainability

To introduce the concept of sustainability and how to create sustainable buildings, campers were asked to draw on a paper 'What is a home?' giving them the opportunity to explore how they define a 'home' and share their depictions. Next, campers were asked to draw 'What is a sustainable house?'. The group shared their thoughts and understanding of what makes a house sustainable. The exercise gave the students an opportunity to examine their current understanding of sustainable building practices. The group next traveled to the MorningStar solar home, a net-zero home built for the 2007 Solar Decathlon. A member of the AE faculty who helped create the home for the competition guided the campers through the home and explained the team's considerations when designing the net-zone house. Campers learned about the energy efficiency standards in passive house designs and how they can be implemented in today's building environments.

Lighting

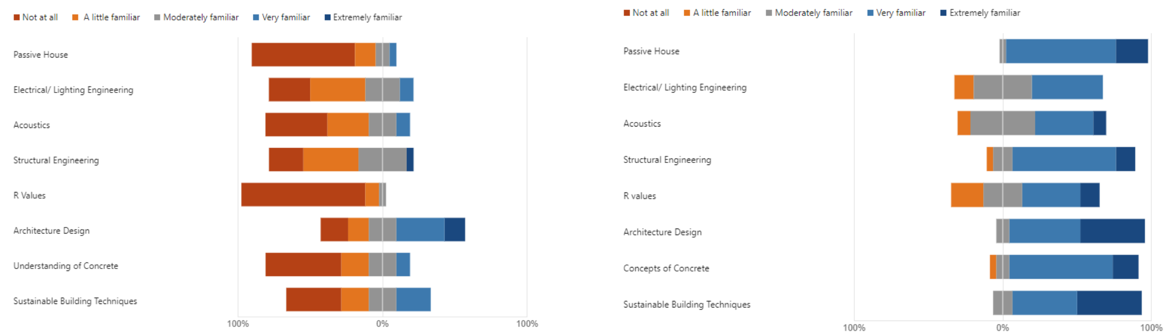
The lighting design portion of the summer camp consisted of a short interactive lecture using visual demonstrations with Top Hat to facilitate discussion, reflection and engagement with the lecture. For the hands on activities, students went to a nearby off campus community space with a highly customizable and easily interactive lighting system above to be controlled and changed with ease. Students were grouped according to their preferred building "zones", which included an art gallery, dance hall, stage, foyer, and main entrance. They were then provided access to control existing light fixtures, which included 55 full-color programmable LED fixtures and 15 aimable track heads. Each group was guided by a trio of design prompts based on actual use cases and upcoming events at the community center. Doing this allowed camper to create functional but also artistic quality lighting solutions (Fig. 6).

Figure 6: Representative Activities showcasing lighting design in buildings.

Camper Thoughts

Before the start of the camp, an optional pre-survey was distributed to see campers' knowledge of building design. At the end of the camp, a similar survey was distributed with further open-ended questions to capture feedback on the camp for possible future iterations. The intent of the pre- and post-camp surveys was to measure the value of offering a summer camp for high school students and obtain feedback from the campers about their experience. 21 students took the pre- survey while 23 took the post survey. Within the camps the breakdown of the campers from a grade perspective are: 14% for 9th grade, 24% for 10th grade, 29% for 11th grade, and 33% for 12th grade.

To evaluate the camper's understanding of AE and engineering topics, the question 'How familiar are you with the following engineering concepts?' was asked in both the pre- and post-camp surveys using a Likert scale. Fig. 7 shows that the campers were largely unfamiliar to limited familiar to the camp concepts but afterwards their perception of camp knowledge grew a lot. The means of six of the topics grew substantially. This set of simplistic responses showed the camp had a measurable impact of their present understanding and actually took away new knowledge.



a) Pre-camp responses b) Post-camp responses

Figure 7: Camper response to 'How familiar are you with the following engineering concepts?'

From an open-ended question standpoint, the post survey captured rich information for feedback on the camp. Here the focus of these questions was what enjoyable within and camp, what could be improved and the amount of time to spend on different areas of the building industry. Fig. 8 provides a discipline snapshot of key building domains and camper perceptions on what should be increased and decreased. While informative, a richer context into their responses was document within Tables 3 and 4. Table 3 provides a summary of favorite daytime and nighttime's events while Table 4 provides a summary of what they learned that surprised them and their suggestions for more and less activities if they were to redo camp.

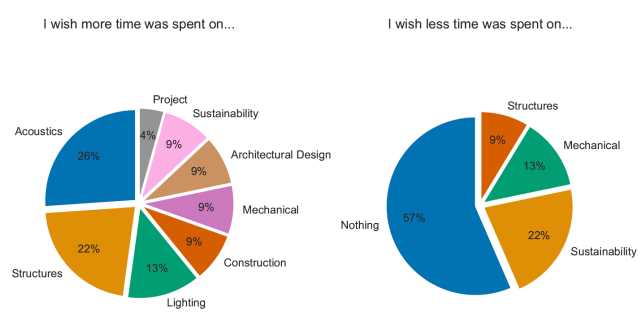


Figure 8: A discipline perspective of more and less time within the camp (from a camper perspective).

In examining what they enjoyed most, a common trend is in the building tours as they got to see building of a scale they never visited before and learned how they worked or they got to see what went into building a building. Lighting was commented on due to its interactive nature and customization ability to their personalities. The results also align well with your observations on the importance of the project. Lighting, color and sustainability was most surprising, which could be expected as they are not commonly taught in K-12. Ventilation, acoustics also surprised them as they likely heard of these but never knew what they were. From Table 4, the more and less activities were not surprising as they tended to match the level of active engagement vs passive talks. What was interesting was the inclusion of more structural, which we considered early but for time purposes trimmed down. Most unexpected was the request for electrical side of the building. We ignored this as it hard to engage with due to safety but also “boring” as you need math to establish basis at the building scale.

Table 3: Camper open-ended replies to favorite camp activities.

What was your favorite daytime activity during the camp?	What was your favorite evening activity during the AE camp?
• Visiting the indoor track and Beaver Stadium to see the scale of building and their systems (3). • The construction site tour because i love seeing behind the scenes look at everyday things (4). • The lighting classroom /lab due to the cool system and programming it (4). • Building the sustainable house project since we applied what we learned (6).	• Game night at the dining commons community center (15). • The laser tag event (6).

Note: Values in () indicate number of responses with that item

Table 4: Camper open-ended replies to topical learning materials within the camp.

What is something that you learned that surprised you?	Topics we should have spent more time on?	Topics we should have spent less time on?
• How lights and color works and impacts our perceptions (5). • What is natural ventilation and why it’s important (3). • The need for insulation (3). • Sustainability and passive home performance / needs (6). • That building acoustics is important (3).	• More on lighting design (3). • More on building acoustic side (5). • More on structural engineering (5). • Provide some electrical power side of buildings (3). • More time for the project build and test (4).	• Less R values (2). • Less sustainability / passive {too inactive / boring form} (3).

Note: Values in () indicate number of responses with that item

Seeing these results captured from the campers and parents/guardians’ reactions, the camp was deemed a success by the oversight committee. Campers left with a greater understanding of AE and new experiences to grow their interests in the major. When campers first attended they were ask their relative interest in how likely they may pursue STEM related fields then again after the camp. Fig.9 shows the results which match well with other summer camp literature on attendees already have some interest and the camp is either solidifying or changing their opinions. After the camp concluded, emails asking about next summer’s camp arrived within several weeks of that camp being over. So far 2 of the juniors who attended camp have inquired about how to apply to Penn State for AE as their intended major.

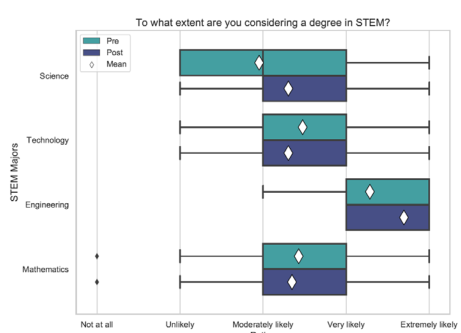


Figure 9: Camper Pre- and Post- Interest in STEM Careers

Takeaways for Others

After the camp concluded, the oversight committee reflected back on the establishment and deployment of our first offerings. Camp was offered at a time when the summer just started to reemerge after many of the strict Covid-19 pandemic restrictions had been lifted (2022). This permitted more open engagement with the concerns of sickness and spread of Covid-19. Campers in attendance had been part of their schools' virtual learning environments over the two few years and had participated in limited hands-on labs or activities within their school. It became clear that the students were not interested in using computers at all to do their camp activities. Although they were given the opportunity to use SketchUp when designing their project houses, each group chose to use paper and pencil to sketch their ideas and collaborate. These students enjoyed the experience of designing and building something with their hands, not virtually. Knowing this, the SketchUp tutorial will be dropped for next camp offering.

The camp's original schedule allowed for the campers to have non-engineering fun experiences. Part of the intent of these non-engineering experiences each evening to enjoy their time with their new friends while it also serves to reset their working knowledge from the engineering tasks. As the camp progressed, to our surprise, the consensus of the campers was they would have enjoyed evenings working on engineering projects over the planned fun activities. Pivoting mid-camp, their suggestions were taken into account by making "working evenings". These "working evenings" included music and snacks, as well as the freedom to test and build at a slower pace. Future AE camps would include more free-build evenings for the campers to try new ideas.

To help others establish similar building related summer camps, the oversight committee reflected back on six questions. Our answers to these questions can provide a starting point for others.

<u>Reflection 1</u>: Was the camp the appropriate length for what we did? Too long to short?

> Based on our success in planning a 5 days camp with activities, and with "problems" finding personnel to work at the camps (in particular the evening mentors), the five-day camp worked well to balance both. This 'weeklong' university delivered academic camp remains a common duration based other camps. Another balancing point here is that the longer it becomes the more it will cost due to housing, food, and personal requirements. There's always more that could have been added, but the week provided a solid exposure to AE.

<u>Reflection 2</u>: Based on what we did, should we have fun evening activities or just worktime moving forward?

> The short answer to this is keep both. Evening breaks allowed the campers to unwind and experience a perspective of 'college life'. As the campers understood the AE concepts and started thinking about their group project, that is when evening work time would be appropriate. An issue/problem with doing AE projects/activities at night that emerged was that the daytime mentors/grad students stayed longer to help the students, making for much longer days for them as the night mentors did not know AE material proficiently.

<u>Reflection 3</u>: Was the amount of teaching vs doing correct for us?

> Keeping the camp as a project-based learning environment created a unique experience, different from their traditional high school experience. It does require the mentors to feel comfortable with the campers trying unusual things, even if the mentors know it won't be successful. Campers liked some of the lectures when they were short or had intermediate activities. The "boring" lectures were

when the discussion dragged on. Campers continue to learn with failures as long as they are educated in real-time on what failed and how to fix it or scope it to real life.

Reflection 4: Did we have too many or too few topics?

Our reflection indicated we have the greatest number of topics we could have provided and still give time for the project and to explore their ideas. Some activities should be cut short because we ran out of time or campers stated they were lower on their interest level. This would take a less is more approach.

Reflection 5: Any recommendations on planning and finding students we should inform other people that might be good best practices?

If a camp is looking to target underrepresented or women in engineering, we would recommend to other camps to not go about an all-access open enrollment. We had 16 camper slots that were first come, first serve. The final eights slots were used to identify at need students who received scholarships and invite female campers so we could have a 50-50 mix of female to male campers. In both cases each set of slots filled fast when we worked with marketing and our University's broader relationship groups.

Reflection 6: If a third-party coordination party is possible should we outsource more of the mentoring, organization and safety aspects moving forward?

At our university there is an internal third party called: Hiring Conferences and Institutes (C&I). The benefit of using a group like C&I is they understand the restrictions and regulations associated with our university. The problem is they are expensive and have a standard template that is used for camps, sports to academic camps. Personalizing your camp might be difficult using C&I. Additionally, the department would still need to create a curriculum and provide a faculty advisor to oversee the program and either provide daytime mentors or train the ones who are hired by C&I.

References

[1] https://www.zippia.com/advice/us-construction-industry-statistics/

[2] https://www.ibisworld.com/industry-statistics/market-size/commercial-building-construction-united-states/

[3] U.S. Department of Energy (US DOE). (2011a) 2010 Buildings Energy Data Book. Prepared for U.S. Department of Energy Office of Energy Efficiency and Renewable Energy by D & R International, Ltd. Silver Spring, MD. March 2011. Obtained from http://buildingsdatabook.eren.doe.gov/docs%5CDataBooks%5C2010_BEDB.pdf on 6/24/2013.

[4] Jafari, A. and Valentin, V. (2016). "An Investment Allocation Approach for Building Energy Retrofits", Construction Research Congress (CRC), May 31- June 2, 2016, San Juan, Puerto Rico, USA http://dx.doi.org/10.1061/9780784479827.107

[5] Fernandes, C., de Brito, J.M., and Cruz, C.O. (2016). "Thermal Retrofitting of Façades: Architectural Integration of ETICS", Journal of Performance of Constructed Facilities, Volume 30 Issue 2, April 2016. 06015002-1

[6] Levin, H. (1991). Critical building design factors for indoor air quality and climate: current status and predicted trends. Indoor air, 1(1), 79-92.

[7] Raebel, C.H., Hasler, F., Erdogmus, E., and Parfitt, K (2019). "State of the Art of Architectural Engineering Education as a Contribution to the Foundation for the National Agenda: A Snapshot of Four Programs", 2019 AEI Conference, April 3-5, Washington DC

[8] ABET: Accreditation Board for Engineering and Technology - Website. [Online]. Available: https://amspub.abet.org/aps/name-search?searchType=program&keyword=architectural+Engineering
[9] Krapcho, K. J., & Furse, C. (2014, June), *Lessons Learned Developing an Engaging Engineering Summer Camp* Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana. 10.18260/1-2—20752
[10] Clark, J.V., Minorities in Science and Mathematics: A Challenge for Change, Virginia Parent Information
and Resource Center, 2000
[11] Hartman, J. C. (2016, March), *Summer Camps for Future Engineers* Paper presented at 2016 EDI, San Francisco, CA. https://peer.asee.org/27391
[12] Sharer, D., & Murphy, D., & Kuyath, S. (2005, June), *Summer Camps In Engineering Technology* Paper presented at 2005 Annual Conference, Portland, Oregon. 10.18260/1-2--15526
[13]. Kuyath, S.J., Diversity in Engineering Technology: An NSF Project, Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education, Session 1148, Salt Lake City, UT, June 2004
[14] Shepard, T., & Altobell, C. T. (2012, June), *Engineering in Summer Camps: Tapping the Potential* Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. 10.18260/1-2—21308
[15] Stansbury, R. S., & Behi, F. (2012, June), *Inspiring Interest in STEM Through Summer Robotics Camp* Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. 10.18260/1-2—21542
[16] Cooper, H., Nye, B., Charlton, K., Lindsay, J., Greathouse, S. (1996). The effects of summer vacation on achievement test scores: A narrative and meta-analytic review, Review of Educational Research. 66, pp. 227-268.
[17] Rudman, C.L. (1994). A review of the use and implementation of science field trips. School Science and Mathematics, 94(3), pp.138-141.
[18] Kuyath, S.J., Murphy, D.L., and Sharer, D.L., "Summer Camps in Engineering Technology," Proceedings of the 2005 American Society of Engineering Educators Annual Conference and Exposition, 2005, Portland, OR,
[19] Naz, A., & Lu, M. (2017, June), *A Summer STEM Camp for Girls* Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. 10.18260/1-2--27521
[20] 1a. https://www.census.gov/newsroom/releases/archives/american_community_survey_acs/cb_12-175.html
[21] 3 Alexander, K.L., Entwisle D.R., & Olson L. S. (2007). Summer learning and its implications: Insights from the Beginning School Study, New Directions for Youth Development, 114, pp. 11-32.
[22] Chen, K. C., & Schlemer, L. T., & Smith, H. S., & Fredeen, T. (2011, June), *Evolving a Summer Engineering Camp through Assessment* Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC. 10.18260/1-2—17939
[23] Gordon, E.W., Bridglall, B.L., Meroe, A.S. et al. (2005). Supplementary Education: The Hidden Curriculum of High Academic Achievement, Lanham, Rowman & Littlefield Publishers