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Promoting Positive Outcomes in K–12 Outreach through Design

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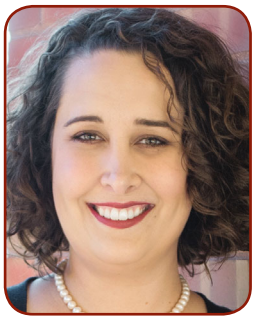

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Summer outreach camps in engineering and science are common across the United States. The goal of these camps may vary—some provide an opportunity to compare different disciplines while others simply strive to provide tangible examples of what a career in science or engineering might look like—but almost all of these camps aim to encourage matriculation in a science or engineering program, and are often especially targeted at underrepresented populations. Women, in particular, remain underrepresented in STEM (science, technology, engineering, and math) fields despite the fact that they are now more equally represented amongst college educated adults.

Many have considered the causes of this so-called gender gap, identifying a complex array of social and cultural drivers that are not easily addressed by singular outreach experiences. However, these studies have also shown that a woman's confidence in her professional competency is critical to both selection and long-term retention in STEM fields and that experimental or project-based experiences with STEM are especially effective in boosting this confidence. This would suggest then, that summer outreach camps must do more than expose young women to STEM-related fields—they must convince them that they are capable of succeeding in STEM professions.

First, we must acknowledge that these are, in fact, different outcomes. Then we can consider how to go about achieving such a distinction. As an example, consider the plethora of online STEM outreach resources. A motivated camp coordinator could easily assemble a week's worth of activities from these resources and be quite confident that they have exposed their campers to some exciting STEM concepts. In fact, for several years this was the model that was

GLAM campers work together to design the most efficient and economic composite brick.

followed by GLAM, Girls Learning About Materials, a week-long summer camp for 10th through 12th grade high school women that operates under the umbrella of the Worldwide Youth Science and Engineering (WYSE) Camps at the University of Illinois at Urbana-Champaign (UIUC).

By all of our metrics, the campers responded favorably to this structure—they enjoyed individual activities, they had fun, and the majority of campers indicated that they would consider a STEM degree in their post-camp surveys. However, when we looked at their overall perceptions and comments from the same survey, we found remarks like this one: "*There was not much in the way of connecting things—we'd learn a cool thing, do a lab, and then move on to a completely unrelated subject.*"

In our efforts to expose them to the breadth of materials science and engineering—to show them all the cool things they could do in our field—we had created confusion about how all of these ideas could possibly be connected. And we found that the campers did not tend to contribute this confusion to the organization of the camp, rather they internalized it, thus reducing their perceived competency in materials science and engineering, and perhaps in STEM as a whole. Structure and organization can and do make a significant impact on the intended outcomes of the outreach camps.

This realization prompted us to restructure the entire GLAM camp, the details of which were published in 2017.[1] During this process, we drew motivation from the much broader body of engineering education literature emphasizing the use of design in undergraduate engineering curricula. Design is integral to engineering regardless of discipline—so much so that it's a tenant of the accreditation processes for all undergraduate engineering programs. Besides the direct translation to the engineering workplace, use of design thinking and design projects in undergraduate classrooms has been shown to promote higher order knowledge/skills transfer, creativity, self-motivation, and confidence. But the question remained whether this insight could be effectively applied to the much more compressed schedules common to K–12 outreach camps. And if so, would some approaches to incorporating design be more effective than others? After all, design may be common across engineering disciplines but there are still many ways to define design thinking or the design cycle.

GLAM campers demonstrate their prototype and explain the design to a member of the UIUC MatSE faculty during a poster session.

To explore this, we did more than just change our own camp; we implemented a two-phase study. First we compared outreach camps that intentionally incorporated some aspect of design to those that had no formal design component; then we studied four specific camps at UIUC, each of which used design in a different way over the course of the week-long camp. In this second phase, we attempted to correlate how design was introduced to the perceived outcomes of the camp for both the campers and coordinators.

In the first phase, we used a combination of pre- and post-camp surveys to compare design-incorporated versus design-absent camps. We found that all participants felt they understood what engineering was following the camp. The design-incorporated camps had a more positive perception of engineering following camp, while the design-absent camp showed a statistically significant decrease in interest in engineering (as derived from questions such as "I want to be an engineer when I grow up" or "I think engineering is interesting"). This was a more dramatic outcome than we had

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expected, which prompted the more specific questions about how design was implemented in the second phase of the study.

The second phase compared four camps in the UIUC WYSE program, all targeted at 9th through 12th grade women. Girls Building Awesome Machines (GBAM) dedicated more than half of their camp time to a single, team-based design project that spanned the entire week—specifically to build a 3D printer. While GLAM also opted for a week-long, team-based design project, this was a smaller fraction of the total program relative to GBAM and did not predefine the final product. The Bioengineering Camp opted for a conceptual, team-based project, but no physical product was produced. Finally, the Aerospace Engineering (AeroE) Camp had many design projects throughout the week that were both team-based and individual projects.

The pre- and post-camper surveys included questions specific to design confidence and more general STEM confidence. From these surveys, GBAM, GLAM, and AeroE realized statistically significant increases in all design confidence questions following the camp. Moreover, these same camps all showed positive changes in responses to the question, "I believe I could be successful in a career in engineering/math/science." These are still very short-term perspectives, and much richer insight remains to be extracted from the coordinator interviews and video observations; however, they do suggest that when design is incorporated into outreach it can boost self-efficacy in STEM by providing opportunities for students to connect complex ideas, practice problem-solving, and improve their communication skills.

The breadth of, and within, STEM fields remains one of the biggest challenges for successfully developing, implementing, and even assessing outreach camps—especially when simply exposing students to STEM is likely insufficient to make a long-term impact on the workforce diversity of these fields. Our experience has demonstrated that thoughtful incorporation of design thinking and the design process can be used to boost positive outcomes across disciplines, by providing a unifying framework and boosting both self-confidence in and enthusiasm for STEM disciplines.

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Endnotes

1. K. Tyler, N. Johnson, and J.A. Krogstad, "Implementing Design Thinking into Summer Camp Experience for High School Women in Materials Science and Engineering," ASEE Conference Proceedings (2017).