Measuring the Effects of Precollege Engineering Education

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Measuring the Effects of Precollege Engineering Experiences

Abstract

The deployment of co-curricular and extracurricular K-12 engineering programs has expanded dramatically in recent years. Many states now explicitly or implicitly include engineering as part of their education standards, reflecting the increasing acceptance of engineering at the K-12 level and its potential value to students. In addition to promoting outcomes that benefit all students regardless of career aspirations such as increased math and science achievement and greater technological literacy, K-12 engineering programs have been identified as a means of recruiting and retaining potential students in engineering.

The growth of precollege engineering programs means that increasing numbers of incoming engineering students will have had some exposure to engineering prior to their enrollment in engineering programs. However, the impact of precollege engineering experiences on undergraduate engineering students is relatively unexplored. To address this lack of understanding, this study uses a mixed-methods exploratory approach to examine how exposure to precollege engineering programs affects the experiences of university engineering students. Phenomenographic interviews with cohorts of first year engineering students are currently being analyzed to identify the qualitatively different ways undergraduate engineering students experience the effects of precollege engineering. These results will then be used to develop an instrument to measure the extent of these effects in the larger population of undergraduate engineering students at multiple institutions.

Although a limited number of prior studies have demonstrated that exposure to precollege engineering can have a positive impact on students' performance in undergraduate engineering programs, much less is known about how these programs increase achievement and how students utilize the knowledge and experience gained from participation in precollege engineering programs in their undergraduate engineering classes. This research seeks to address this gap by describing both the extent of alignment between precollege and university engineering programs as identified by students and how misalignments can negatively affect students' experiences and their decision to persist in a university engineering program. Examining the demographics of the participants will demonstrate who has access to or is taking advantage of precollege engineering programs, and if the effects of precollege engineering vary across different demographic groups.

To date, most undergraduate engineering programs assume little to no formal exposure to engineering prior to matriculation. With the growth of precollege engineering programs, this is no longer a valid assumption. The results of this research will help engineering administrators, instructors and designers of undergraduate and precollege curricula adapt to students' changing needs and abilities. Research results will also guide undergraduate engineering programs in developing retention and instructional strategies to adapt to increasing numbers of students with engineering experiences prior to matriculation.

Background

The National Academy of Engineering report *Engineering in K-12 Education – Understanding the Status and Improving the Prospects*[1] identifies five main benefits of K-12 engineering education. These are 1) improved learning and achievement in science and mathematics, 2) increased awareness of engineering and the work of engineers, 3) understanding of and the ability to do engineering design, 4) interest in pursuing engineering as a career, and 5) increased technological literacy. This study focuses on pursuing engineering as a career, which typically requires a 4-year college degree in engineering. While the other benefits of K-12 engineering are starting to be explored[2], studies on the effect of K-12 engineering programs on university success remain extremely limited.

K-12 and higher education institutions both need information on the effects of precollege engineering programs on undergraduate engineering students. The persistence and grades of students that have participated in K-12 engineering programs and continued on to study in college engineering programs are possible measurable outcomes of K-12 engineering education programs. The NSF, the Departments of Education of many state governments, and private foundations invest millions of dollars in engineering education and outreach at the K-12 level, resulting in increasing numbers of incoming engineering students arriving on campus with prior exposure to engineering. Understanding the effect of these programs on university experiences would help guide higher education faculty and administrators in providing the best experience for those students and helping them to be more successful in STEM pathways.

Research Questions

1) How do college engineering students experience the effects of participation in precollege engineering programs in their introductory engineering classes?
2) How do college engineering students describe the alignment of precollege and college engineering programs? How does alignment between the programs affect their undergraduate engineering experiences?
3) How are precollege engineering students different from others in population characteristics such as socioeconomic status, race, or gender?
4) How does participation in precollege engineering affect academic outcomes, including disciplinary choice, performance, and persistence? Does the effect vary across different demographic groups?

Project Plan

These questions will be answered through an exploratory mixed methods research design, as shown in Figure 1. Exploratory mixed methods designs are appropriate when measures or instruments are not available to measure the phenomenon of interest, the potential variables are unknown, or there is no framework or theory to guide the research[3]. The instrument development model chosen for this research begins with the collection and analysis of qualitative data. We are trying to capture the breadth of student experiences' of the effects of precollege engineering, and to accomplish this chose a phenomenographic approach for our qualitative data collection. The results of the qualitative data analysis will be used to develop an instrument to measure the phenomena described in the qualitative data among a larger population. Once an instrument has been designed and its reliability and validity established, it will then be used to measure the degree and prevalence of the phenomena in a larger population. Utilizing both quantitative and qualitative methodologies will afford this study both the breadth and authority of a large sample and depth of understanding grounded in individual experiences.

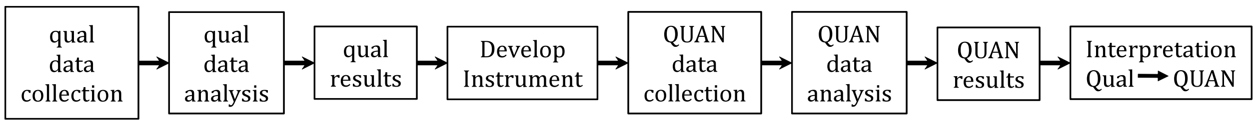

Figure 1: An Exploratory Mixed Method Research Design: Instrument Development Model. From *Designing and Conducting Mixed Methods Research* by J.W. Creswell & V.L. Plano Clark, 2007.

Participants

This study will focus on the experiences of first-year engineering students. These students are able to inform our research questions because they are the least removed from their precollege engineering experiences and from the transition to college engineering programs. To the extent that self-efficacy is important to persistence in engineering[4], the mastery experiences of first-year students will be more closely tied to their precollege experiences, whereas the mastery experiences of upper-level engineering students will be derived from their college engineering experiences.

Qualitative Data Collection

We administered a survey on students' demographic information and participation in K-12 engineering programs to four sections of approximately 120 students each of a first-year engineering program at a large public university to determine the prevalence of various K-12 engineering programs and identify potential interview subjects. Based on the results of this survey we interviewed a total of 23 students selected to maximize variation of demographic characteristics and types and level of participation in precollege engineering program and activities.

We interviewed the students using a three-part semi-structured interval protocol. The first part of the interview focused on students' experiences with engineering prior to university. The second part of the interview explored students' experiences in first-year engineering, and the third part of the interview focused explicitly on the transition from precollege to college engineering programs. We are currently analyzing the transcripts of these interviews to establish an outcome space[5] of the ways that students experience the effects of precollege engineering in a first-year engineering class.

Preliminary results suggest a wide variety of effects of precollege engineering on first-year engineering students. Many participants reported that they felt more capable of working as part of team, had better communication skills, they were able to deal with the academic intensity of a university engineering program as a result of their participation in precollege engineering. The participants also described technical areas that they were able to draw from their experiences, including design, comfort working with ill-structured or open-ended problems, using CAD and other software packages, and computer programming. Some negative outcomes reported by the participants included finding first-year engineering boring or not as fun as their precollege engineering experiences, not feeling prepared for the theory or level of integration of mathematics and science, first-year engineering being not as hands-on, and less fulfilling teamwork experiences. Overall, these preliminary results suggest a wide variety of positive and negative effects that students attribute to their experiences in precollege engineering programs and activities.

Quantitative Data Collection

Based on the results of the qualitative data analysis, an instrument will be developed to measure the effects of K-12 engineering programs on students' experiences in their first year of engineering coursework. Our development and validation of an instrument to assess the effect of precollege engineering will follow standard procedures for psychometric research. This will include identifying potential constructs/items from preexisting instruments that align with the factors identified through the interviews, creating new items, development of an "alpha" instrument, expert review of the "alpha" instrument and administration to a small pilot group, refinement of a "beta" instrument based on these results, and administration and factor analysis of the results of the "beta" instrument to develop a final instrument. This final instrument will then be administered across multiple institutions with varied approaches to first-year engineering.

Dissemination Plan

The primary focus of this research is the undergraduate student experience, so the primary stakeholders are faculty and administrators in engineering colleges. This research also has the potential to affect other stakeholders, including developers of K-12 engineering programs and curricula, and less directly government funding agencies and professional organizations.

The findings of this research can help answer several questions of interest to colleges, schools, and departments of engineering. Given that engineering has not traditionally been taught at the K-12 level, most undergraduate engineering programs have been designed assuming that their incoming students have little formal knowledge of engineering. With the growth of K-12 engineering programs, this is no longer a valid assumption and engineering administrators and engineering curriculum designers and instructors need to understand their students' prior engineering skills and abilities. Along with prior knowledge, the students may also have misconceptions or significant gaps in their knowledge of engineering theory and practice that need to be identified and addressed through instruction. If these misconceptions stem from a misalignment between engineering at the K-12 and university levels, they may lead to frustration or the decision to leave engineering. Identifying potential alignments is critical to ensuring a smooth transition between K-12 and university engineering programs.

The National Academy of Engineering has invested considerable time and resources to identify appropriate content and pedagogies for teaching engineering at the K-12 level with the goal of encouraging more students to pursue degrees and careers in engineering [1,6]. This research can inform those efforts. As the National Academy of Engineering, industry, and others give input to developing and refining K-12 engineering standards, our work can inform that process and support the NAE's goal of expanding the pipeline of engineering students.

We will also prepare and deliver research briefs targeted to each of the stakeholders and representative organizations. This will include organizations like the National Academy of Engineering and individual K-12 engineering programs like Project Lead The Way and FIRST Robotics. Finally, we will prepare journal articles and conference presentations targeted at undergraduate engineering educators.

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