CAREER: Mathematics as a Gatekeeper to Engineering: The Interplay between Mathematical Thinking and Design Thinking

Project Summary

While there is some debate related to the importance of and role of mathematics in engineering practice, mathematics continues to be central to engineering education, as well as a distinct gatekeeper to participation in engineering education. Students must achieve a certain math SAT or ACT score and must complete a certain number of mathematics courses with a sufficient grade in order to be admitted to engineering programs at most universities. Meanwhile, research shows that female students as well as underrepresented minorities-- the students we hope to attract to engineering as we aim to increase diverse participation in engineering-- tend to enter college with a lower level of mathematics preparation.

This project explores an additional facet of "mathematics as gatekeeper to engineering": the relationship between mathematical thinking and design thinking. The hypothesis guiding the research, informed by the investigator's experience with teaching first-year engineering students, is that the mathematical thinking processes that students develop in their precollege education (and which qualify the students to participate in undergraduate engineering education) actually serve as cognitive obstacles that students must overcome in order to develop the design thinking skills that are critical for engineering practice broadly as well as for creativity and innovation. This hypothesis will be investigated through a verbal protocol study, where undergraduate students will be asked to "think aloud" while attending to a design task, allowing the researchers to video record the students' though processes and then analyze mathematical thinking and design thinking patterns, such as convergent and divergent thinking; fixation; estimation and modeling; and responses to ambiguity and uncertainty. Students from a variety of mathematics, design and engineering backgrounds will be asked to participate, to capture possible differences between approaches taken by students with more/less mathematics background and more/less design background. The verbal protocols data will be augmented by interviews with the students that will capture additional insights related to the design task as well as the students' other experiences, beliefs and attitudes.

The educational plan for this project will build on both the data (the videos and interview transcripts) and the findings from the research study. The video data will be used in the form of excerpts in a first-year engineering class as a teaching tool to help students develop design thinking skills, and will be used as a teaching tool in graduate engineering education courses to help graduate students develop research skills. The video data (and research findings) will also be shared with other engineering educators and engineering education researchers in workshops at engineering education conferences. Finally, the research findings will be disseminated broadly, through conversations with the Science Museum of Minnesota and EPICS High as well as conference and journal papers, in order that the findings might inform other engineering educators' and researchers' educational innovations and future research.

Intellectual Merit: The findings from the study will provide educators and researchers with crucial information on students' thinking processes that will help us to take research-informed approaches to helping students develop both mathematical and design thinking skills. In particular, the findings from the research will help us to understand the ways in which mathematical thinking may hinder students' development of design thinking skills, and how educators might better balance and integrate mathematics and design instruction. This will also help us to consider the role that mathematics might play in providing (or preventing) access to an engineering education.

Broader Impacts: This work will use a research methodology commonly used by the design research community and accepted by the engineering education community, but also used by cognitive engineers, to facilitate sharing of the research findings across research and educator communities. The research findings will inform not only my own teaching practices, but will also be shared with other engineering educators as well as pre-college educators. Additionally, as we reconsider the role that mathematics plays as a gatekeeper to engineering education, we can identify opportunities to make engineering more accessible to students from diverse backgrounds (including female and underrepresented students, but also students who may have strong design and problem solving skills but weaker mathematics skills).

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