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Board 362: Reimagining Civil Engineering Graduate Programs: A Research-to-Practice Approach for Shaping Future Transportation Engineers

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Reimagining Civil Engineering Graduate Programs: A Research-to-Practice Approach for Shaping Future Transportation Engineers

Project Overview

The existing curriculum and models for civil engineering graduate programs assume that graduating students will primarily pursue career opportunities in research or academia, but recent data suggests that there will be insufficient positions to meet the number of graduates. The NSF National Science Board reported that the number of civil engineering Ph.D. graduates increased 33% from 2007 to 2017 [1]. However, the Bureau of Labor and Statistics (BLS) predicts only a 9% growth rate in new engineering faculty opportunities over the next 10 years, not keeping up with the rate of Ph.D. engineering graduates [2]. As a result, graduate students will need to seek non-academic roles in industry or the government upon graduation.

As part of a research study funded through the NSF Innovations in Graduate Education (IGE), we are seeking to build upon an existing transportation engineering graduate program through the integration of a research-to-practice model based upon cognitive apprenticeship. As part of this model, we include practical experiences that we believe will prepare students for non-academic roles while maintaining the program's current level of scientific rigor. We will evaluate the success of the new graduate program by investigating the following research questions: 1) How does the cognitive apprenticeship framework prepare graduate students for professional practice in transportation engineering? 2) What impacts does the research-to-practice graduate model have on the development of transportation engineering graduate students' professional identity?, and 3) What impacts does the research-to-practice model have on student motivation to complete an advanced degree in transportation engineering?

Any student currently enrolled in the Civil and Environmental Engineering (CEE) masters (14 total students) or doctoral program (20 total students) was eligible to participate in the research components of the study. Proper human subjects' approval was obtained prior to conduct of research. This paper reports the findings from the initial phase of the project.

Project Focus Areas

As outlined in the provided research questions, this study focused upon identifying how a cognitive apprenticeship model built into an existing CEE graduate program would help enhance students' preparation for professional practice in non-academic roles. We were also interested in whether the changes to the curriculum would have any impacts on students' professional identity or motivation.

Cognitive Apprenticeship

As part of this research, we have chosen to focus upon a cognitive apprenticeship model to help prepare students for the professional community. Cognitive apprenticeship is composed of four dimensions: content, method, sequencing, and sociology [3]. Specifically, this study focuses on the methods dimension, which is the largest dimension in the cognitive apprenticeship framework [4]. Methods elaborates on the modeling, coaching, and scaffolding found in typical apprenticeship by adding on approaches that aid in focusing on observations of problem solving, and encouraging learner autonomy. Methods is categorized into six principles: modeling, coaching, scaffolding, articulation, reflection, and exploration [4].

The application of the cognitive apprenticeship framework in engineering education has continued to gain popularity due to its ability to transition students' low-level competency to higher levels, and its focus on learning in context [4]–[6]. The integration of cognitive apprenticeship into engineering classrooms has been found to cover a broader range of learning styles, and has shown an increase in overall teaching effectiveness compared to traditional teaching approaches [7], [8]. Students exposed to cognitive apprenticeship in their classrooms express more positive attitudes about the course, as well as increased class participation, motivation, and pass rates [9], [10]. While the cognitive apprenticeship framework has proven successful when applied to both undergraduate and graduate levels, its utilization in modeling an entire engineering doctoral program has yet to be done.

To measure how students were benefiting from the integration of the cognitive apprenticeship model we adapted the Maastricht Clinical Teaching Questionnaire (MCTQ) developed by Stalmeijer et. al [11] for use in providing clinical teachers feedback from medical students involved in a clerkship rotation. The MCTQ is a 24-item instrument where items represent a principle of the Methods dimension and are rated on a Likert scale. In preparation for using the MCTQ in the CEE graduate program, survey items were reviewed and rephrased to align with an engineering graduate student setting. We then asked CEE graduate students to participate in a think aloud study to determine (1) the effectiveness of the adapted MCTQ for measuring graduate students' perceptions of cognitive apprenticeship in their program, and (2) student's initial perceptions of cognitive apprenticeship based on their exposure to industry mentors in their coursework. The think aloud study consisted of students verbalizing their thought process as they responded to the adapted MCTQ. Participants were asked to rank each item within the adapted MCTQ and were asked follow-up questions to further capture their thought processes and factors which influenced their selections. Data collected from the think aloud interviews included audio recordings of the interviews, as well as notes collected by a member of the research team during the interview. Of the 34 eligible students, three consented to participate in the cognitive apprenticeship think aloud, however it was later learned that only one student was working with an industry member at the time of the think aloud study.

Preliminary results from this study highlighted the importance of modeling, coaching, and exploration when working with their industry mentor. When responding to questions about observing their mentor, the student described that interactions with their industry member always provided them with information they could apply to their area of research. This was repeated when responding to a question about their industry mentor helping them understand which aspect they have to improve upon, saying that they often get new ideas to apply to their research from their meetings. Similar themes were identified when the student was responding to a question about their industry mentor encouraging them to form their own learning goals. The student found value in their interactions with their industry mentor, stating there is "*always a learning outcome that comes out of these meetings that I could apply to my research.*" These preliminary findings show that through the use of the "learning-through-guided-experience" model the cognitive apprenticeship framework is based on, students may be gaining a deeper understanding of knowledge in their selected field, and have the ability to apply content they learn from their industry mentors to their research projects [4].

Professional Identity

The development of a professional identity within engineering, known in the engineering education field as "engineering identity", has been identified as a construct to predict which students might persist in engineering [12], [13]. Those with a stronger engineering identity are more likely than those who have a weaker engineering identity to successfully complete their education [14].

Students in the CEE graduate program were prompted to complete brief writing assignments relating to their experience in classes, seminars, and other activities relating to their professional development. Over the course of the study, there have been a total of 8 writing assignments assigned. The prompts for these writing assignments are developed to function as responses to specific events or activities. For example, the first writing assignment (distributed early in the students' first semester as a graduate student) included the prompt "*What does it mean to be a professional in transportation engineering?*" A writing assignment following a DEI seminar included the prompt "*What did you learn that surprised you? Why?*"

Written reflections are reviewed by members of the research team and summarized using an analytic memo approach, where members of the research team independently review and summarize the written reflections and begin to identify emerging themes [15]. These memos are then further analyzed using Godwin's engineering identity framework [16]. Using this approach, researchers are able to examine changes exhibited by individual students, changes exhibited by the entire cohort, and responses to specific events and activities. Of the 34 eligible students, 14 completed at least one of the writing assignments with the average student completing 3 of the 8 assigned writing assignments. Unfortunately, only 2 consented to participate in the research component of the study.

Analysis of the two students' first year of reflection assignments indicate that CEE graduate students appear to identify with the labels of "engineer" and "researcher" as students identified themselves in reflections as such both prompted and unprompted. However, the strength of identity with these terms appears to vary over time; of the two students examined in the preliminary results, one became more vocal about their identity over time, while the other pushed their identity into the future, only referencing themselves as someone who "will be" rather than someone who "is." This might indicate that the student in question is, through graduate education, learning to identify their own weak points, and therefore might temporarily identify less strongly with the terms "engineer" or "researcher." However, despite changes in label usage over time, the participants frequently express enjoyment of / interest in relevant activities and skills and describe the ways in which they steadily improve these skills. This indicates that, regardless of label usage, the CEE graduate students are developing their engineering identity through the fellowship experience [16].

Motivation

Graduate student attrition is a complicated phenomenon with many contributing factors. One factor that is often considered in studies regarding attrition is motivation, both internal and external [17], [18]. While graduate programs can offer external motivation in the form of coursework and deadlines [19], internal motivators are also critical to student success and persistence [20]. The Expectancy-Value Theory (EVT) of motivation considers social, cultural, and psychological factors which may impact an individual's motivation towards a particular goal [21], such as completion of a graduate degree.

An engineering graduate motivation instrument was created by adapting the engineering specific Expectancy-Value Theory instrument developed by Brown & Matusovich [22]. This instrument was originally designed to measure undergraduate engineering students' motivation toward their engineering degree completion, and career choices through five motivational factors: Interest Value, Attainment Value, Utility Value, Self-Efficacy, and Cost. Interest Value measures how interested students are in obtaining their degree, Attainment Value measures the importance of obtaining their degree, Utility Value measures how useful the degree is to the students, and Cost refers to the amount of resources, such as time or money, which are required to obtain their degree [20], [23]. Self-Efficacy refers to the confidence students' have in obtaining their degree [24]. The 35-item likert scale questions (range from 1 – strongly disagree to 7 – strongly agree) were updated to reflect a graduate student setting and then finalized through a think aloud protocol [23]. Survey data were collected from a sample of 28 students of the eligible 34 students in Fall 2023. Reliability of the instrument constructs was verified through the use of Cronbach's

Alpha, with values ranging from 0.617 for Attainment Value, to 0.909 for Cost. The three remaining constructs obtained a Cronbach's Alpha value above 0.7 [25].

Results from the engineering graduate motivation instrument are summarized in Table 1.

Table 1. Graduate Student Ratings of Motivational Factors Toward Degree Completion (Scale ranging from 1 - Strongly Disagree to 7 - Strongly Agree)

Survey Construct	**Construct Mean**
Interest Value	6.24
Attainment Value	6.22
Utility Value	5.28
Self-Efficacy	6.29
Cost	4.70

Interest Value, Attainment Value, and Self-Efficacy were all ranked between "agree" to "strongly agree," meaning that these students believe obtaining their graduate degree is important, they are interested in obtaining their degree, and they believe they have the ability to achieve this goal. Utility Value was ranked between "somewhat agree" and "agree," meaning that students see some value in what they are learning as part of their graduate degree, but may not necessarily be able to connect it directly to their careers. Difficulties with making connections between graduate program components and future careers was identified as a potential weak point in students' motivation towards degree progression [26] and is an important area we hope to address through the integration of the cognitive apprenticeship component. Cost was ranked between "neither agree nor disagree" and "somewhat agree," meaning that money, time, and other resources are somewhat impacted by obtaining their graduate degree. It is important to note that a higher ranking would have indicated that students found the cost of attaining a graduate degree to be more than its inherent value. Other research has shown that graduate students may reach a point where their investment into their program is at such a level that they cannot afford to walk away from the program [27]. Changes in the cost construct will be an area that will be examined as we continue to monitor students' motivation towards degree completion to ensure that students have the best possible experience and do not feel pressured towards degree completion.

Current Status and Future Work

By the end of the Fall 2023 semester, all CEE graduate students had met with an industry member and were in the process of appointing graduate committees that explicitly included an industry member. Moving forward, we plan on continuing to monitor CEE graduate student professional identity development through periodic written assignments and will measure changes in students' motivation and perceptions of the cognitive apprenticeship components of their program on an annual basis. Consent forms will be distributed again to students based on human subjects' review board specifications in hopes that we can increase the number of students willing to participate in the research component of this study. Interviews with students after reviewing their survey results will also be completed to better understand any trends identified in the results.

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