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BOARD # 428: Preparing Ph.D. Graduates for Industry: Insights from a Research-to-Practice Model in Transportation Engineering

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Preparing Ph.D. Graduates for Industry: Insights from an IGE Research-to-Practice Model in Transportation Engineering

Project Overview

Research-to-practice (R2P) models provide a bridge between academic learning and real-world application, allowing students to be equipped for careers beyond academia without compromising the technical rigor of their program. In our NSF-funded Innovation in Graduate Education (IGE) grant, we have created a R2P graduate education model within the Civil and Environmental Engineering (CEE) graduate program through the incorporation of a non-academic mentor into the thesis / dissertation committee structure. While the traditional academic advisor ensures students are well-prepared to meet academic and research requirements, the non-academic mentor brings valuable practical insights, helping students address engineering challenges that are relevant to their projects and allowing them to understand the broader implications of their work outside of academia. The R2P model is grounded in the cognitive apprenticeship (CA) framework, which emphasizes how novices learn expert problem-solving techniques [1].

In this paper we seek to address the research question: *How are graduate students perceiving support from their academic and non-academic mentors?* To assess graduate students' perceptions of their academic mentors, students completed the Engineering Identity Inventory (EII), which examines their identities as scientists, engineers, and researchers, and gathers data on advisor relationships [2]. The EII was administered during both the Fall 2023 and Fall 2024 semesters. To assess graduate students' perceptions of their non-academic mentors, a modified version of the Maastricht Clinical Teaching Questionnaire (MCTQ) [3] was administered in the Fall 2024 semester.

This paper presents initial findings from the two aforementioned surveys to determine the perceptions graduate students have about their academic and non- academic mentors. Results from these surveys will provide insight into the impact of the two mentor-advisee relationships and identify potential areas of program improvement.

Background

Our R2Pmodel allows for CEE graduate students to understand the application of their technical knowledge, skills, and research to a broader context outside of academia. To accomplish this, we have grounded our R2P model in the CA framework [1], which outlines the content, methods, and strategies essential for fostering the development of expert problem-solving techniques.

Cognitive Apprenticeship

The CA framework has been widely applied in higher education, and has shown success in various contexts, such as application of ethical principles, improved problem-solving skills, and higher participation rates and test scores [4-6]. Specifically within engineering education, CA continues to gain popularity due to its effectiveness in advancing students' competencies and emphasis on contextual learning [7-8]. Engineering students involved in courses that used the CA framework have reported more positive attitudes toward the course, and a strong preference for CA due to its accommodation of diverse learning styles [9-10].

The CA framework aims to teach novices the problem-solving techniques used by experts through four dimensions: content, methods, sequencing, and sociology [1]. In this work we focus on the methods dimension. "Methods" is the largest dimension of the CA framework, as it focuses on the distribution and evaluation of the knowledge and skills required for expertise [1]. The Methods dimension contains six principles: modeling (model.), coaching (coach.), scaffolding (scaffold.), articulation (art.), reflection (reflect), and exploration (explore). The first three principles reflect typical apprenticeship through an expert providing a demonstration of the work, followed by a collaboration with their mentor to guide them in their execution, and provide feedback [1]. As individuals gain experience, the mentor assists them in progressing to more complex tasks though scaffolding. The later three stages focus on the individual articulating their approach, reflecting on their actions, and identifying their own tasks to complete individually [1].

The CA framework was implemented in the CEE Graduate program to improve students' technical competency, business and communication skills, leadership and team building, and networking skills. Both their academic and non-academic mentors play a role in the CA framework to assist students in gaining and developing these skills.

Academic and Non-Academic Mentorship

The R2P model developed for this study incorporates two mentor-advisee relationships for the graduate students. Academic mentors—typically the student's academic advisor—are primarily responsible for course and program requirements, modeling professionalism, and supporting the completion of the thesis/dissertation. Students were also matched with a non-academic mentor through a networking event. Non-academic mentors are typically industry professionals whose responsibilities include serving on the students' thesis/doctoral committee, providing practical engineering perspectives for the students' research project, and introducing students to industry-related concerns and considerations.

Methods

To assess graduate students' perception of their academic mentors (i.e. their academic advisor), the Engineering Identity Inventory (EII) was administered [2]. This instrument is tailored specifically to the graduate student population, and separately measures the students' identity as a scientist, an engineer, and a researcher. Additionally, the instrument measures a student's relationship with their academic advisor, resulting in a "relationship score" measured on a 5-

point scale. The survey was distributed to students during the Fall 2023 and Fall 2024 semesters (n=34). If students completed the survey more than once, only the results from their first attempt was collected to maintain consistency across data collection methods.

To assess graduate students' perceptions of their non-academic mentors, a modified version of the Maastricht Clinical Teaching Questionnaire (MCTQ) was administered. Originally developed to provide clinical educators with feedback from medical students during clerkship rotations, the MCTQ’s 24 items were carefully revised and rephrased to fit the context of engineering graduate students working with non-academic mentors [3]. Each of the items represent one of the six Methods Dimensions or a safe learning environment. This adapted version of the MCTQ was tested with transportation engineering students in a think-aloud protocol to identify areas needing further clarification. The finalized survey was administered in the Fall 2024 semester, where a total of 19 responses were obtained (n=19).

In addition to the above survey instruments, students are asked to respond to monthly reflection prompts regarding their experience in the program. The topics of the prompts varied; only those related to their non-academic advisors were used in this work. These reflections were interpretively analyzed by two researchers. Interpretive analysis involves cyclic reading and summarizing of the data until core themes/response types are identified [11]. In this work, the reflections were used to contextualize quantitative results from the surveys. Four students both consented to release of their reflections for research purposes and responded to relevant reflection prompts.

Results

This section will address *How are graduate students perceiving support from their academic and non-academic mentors?* Through the survey and reflection response prompts.

Academic Mentor

Student participants rated their relationship with their academic advisors an average of 4.40/5.00 (0.75 standard deviation), where 5 represented scores of “Strongly Agree” on all items. This is considered an above-average score. Advisor relationships scored particularly high on items “my advisor is easy to approach,” (average score of 4.53), “my advisor and I have a positive relationship” (4.50), and “my advisor provides advice in a timely manner,” (4.44). Lower scores tended to originate from items “my advisor has clearly stated their expectations for satisfactory participation in my program,” (4.29), “my advisor values my work,” (4.32), and “my advisor is knowledgeable about my research,” (4.35).

A Pearson’s r correlation analysis was conducted to evaluate the strength and direction of the relationship between each identity (scientist, engineer, and researcher) and the advisor relationship score. Normality of the continuous variables was checked and found to be within range. There was a statistically significant relationship between engineering identity and advisor relationship score, $r = 0.69$, 95% Bootstrap CI [0.46, 0.82], $p < 0.001$, $n = 34$. The effect size for this analysis was $r^2 = 0.48$, 95% Bootstrap CI [0.21, 0.67], indicating that 48% of the variance between engineering identity and advisor relationship score is shared in this data. This is a large effect size, and replications are likely to find a similar effect. Post hoc power analysis suggests that the test was adequately powered ($1-\beta = 1.00$).

These findings suggest that engineering identity and advisor relationship are closely related; as the relationship with the academic advisor improves, so does engineering identity. This supports the need for an academic mentor in preparing students for a role in industry [1]. However, the lower scores obtained imply that these students want greater clarity in communication with their advisor; understanding what their advisor needs from them, how their advisor can support these needs, and receiving praise when these goals are met.

Non-Academic Mentor

Students' responses to items on the MCTQ were evaluated on a 5-point Likert scale, where 1 represented "fully disagree," and 5 represented "fully agree" and descriptive statistics were determined (Table 1).

Table 1: Descriptive statistics for rankings of six Methods principles and Safe-Learning Environment in MCTQ (n=19).

	Model.	**Coach.**	**Scaffold.**	**Art.**	**Reflect.**	**Explore.**	**Safe Env.**
Mean	3.68	3.82	3.86	3.91	4.05	3.95	3.97
Std. Dev.	1.05	1.04	0.92	1.05	1.01	1.05	0.89

There are no statistically significant differences between the averages of the principles, however, the modeling principle received the lowest average rankings (3.68). When responding to reflection prompts about their industry mentors, one student identified the need for more communication, providing of sources, and general knowledge, which could explain the lower ranking for modeling. Later stages - articulation, reflection, and exploration - all had average rankings above 3.90. When responding to reflection prompts, one student mentioned that their mentor supports them by providing guidelines and knowledge, and pushes them to progress. Overall, students reported that engaging with their industry professionals has helped them link their academic learnings to current industry practices. This suggests that the non-academic mentors are providing practical perspectives for students and are exposing them to industry-related concerns [1]. However, results from the MCTQ suggest that there is room for improvement in non-academic mentors' roles in modeling, coaching, and scaffolding. As these three principles are the foundation of the Methods dimension and apprenticeship, students may struggle in learning and replicating the expert-level problem solving process [1].

Current Status and Future Work

Currently, graduate students are still completing monthly reflections and are meeting with their industry mentors. Moving forward, we plan to conduct follow up interviews with students who completed the MCTQ in the Fall 2024 to gain insight into the reasoning behind their responses. Additionally, we plan to interview the non-academic mentors to determine their perspectives on the projects, and improvements that can be made in the future.

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