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CAREER: Cognitive Models of Conceptual Understanding in Practicing Civil Engineers and Development of Situated Curricular Materials

Dr. Shane A. Brown P.E., Washington State University

Dr. Shane Brown conducts research on cognition and conceptual change in engineering. He received his bachelor's and Ph.D. degrees from Oregon State University, both in Civil Engineering. His Ph.D. degree includes a minor in Science and Mathematics Education. His master's degree is in Environmental Engineering from the University of California-Davis. Dr. Brown is a licensed professional civil engineer and has six years of experience designing water and wastewater treatment facilities in central California. He was the recipient of the NSF CAREER award in 2011. Dr. Brown's research focuses on theoretical approaches to understanding why some engineering concepts are harder to learn than others, and how the concepts are embedded in contexts.

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Introduction

Developing conceptual understanding in science, mathematics, and engineering students has been identified as a priority by the National Research Council, with the theoretically founded expectation that it will result in students who are more capable of innovative design and skillful application of foundational knowledge to diverse contexts [1 pg. 78]. The development of conceptual understanding is addressed by learning theorists as the process of moving from naive cognitive models of conceptual understanding to ones that match those of experts. Cognitive models consist of a complex set of interwoven components, from concepts to personal epistemic beliefs [2] and the role of epistemic beliefs plays a central role in conceptual change [3, 4]. Progress in conceptual change research relies on developing target models of experts' understandings of phenomena. Both naïve and expert cognitive models can engage both individual and socially shared cognitive processes [5], and knowledge of both processes is necessary to characterize knowledge in a field.

Situated cognition experts contend that knowledge only exists in context and has very limited meaning and usefulness when taught out of context [1, 6, 7]. An educational need exists to better integrate engineering students within the context of engineering practice and to develop and implement curricular materials that represent this integration. The lack of a target cognitive model and associated situated and research-based curricular materials impedes students' abilities to be prepared to be productive and innovative engineers in the workforce.

Research Objective and Specific Aims

The <u>*research objective*</u> is to develop a situated cognitive model of conceptual understanding in civil engineering practice, including misconceptions. The <u>*educational objective*</u> is to develop and implement curricula targeted at core engineering concepts that are situated in and relevant to engineering design contexts in sophomore through graduate level engineering courses.

The three <u>*specific aims*</u> of the Research and Educational Plans are to:

Research Aim I: Characterize practicing engineers' cognitive models of civil engineering concepts. About 400 practicing civil engineers across the country will complete existing concept inventories (CI) on concepts related to civil engineering, in subjects including, but not limited to fluid mechanics, mechanics of materials, probability and statistics, and statics. Approximately 100 practicing civil engineers will be interviewed using validated clinical demonstration interview techniques [8] on their conceptual understanding, reasoning, and epistemic beliefs related to concepts strategically selected from CI results to illuminate the relevance of these concepts to engineering design.

Research Aim II: Develop a situated shared cognitive model of conceptual understanding in civil engineering practice. Understanding the shared meanings that engineers have and developing a model of core engineering concepts requires collecting data through more long-term and thorough research methods. A graduate student will spend one year working as an intern for a civil engineering design firm to conduct ethnographic research on engineers' shared and situated knowledge of fundamental civil engineering concepts.

Education Aim: Develop and implement research-based curricular materials situated in engineering practice. This project will utilize results from specific aims 1 and 2 to develop curricular materials, including assessment instruments, for conceptual understanding present in engineering practice, aimed at guiding students to the development of conceptual understandings that are appropriately situated within engineering design environments. Materials will be implemented in sophomore to graduate level civil engineering courses broadly.

Activities

The activities completed to date are related to Research Aim I. A website has been developed to facilitate the participation of practicing civil engineers in this project and collection of results from engineers completing concept inventory instruments. The website was developed using a semi action-research approach. We conducted several focus groups and interviews with practicing engineers to better understand how to maximize participation by engineers in this project. The focus of this data collection was on the role of incentives for engineers, how to structure the website, provide access to the concept inventories, and share our results with participants. About 20 engineers have completed 1-2 concept inventories and we have collected feedback from these participants on this experience. We are ready for broad scale implementation of concept inventories to practicing engineers in the next two months.

Publications

No publications have resulted from this work yet.

Project Outcomes

The *expected outcomes* of research efforts are a rich and detailed discipline specific cognitive model of conceptual understanding in civil engineering and a generalized approach for conducting this research approach in other engineering disciplines. The *expected outcomes* of educational efforts are a tested and easily implementable set of curricular materials and assessment instruments that can enact conceptual change of value to the field of engineering and be used in multiple courses by civil engineering courses nationally.

Expected Significance

National interest exists to investigate student preconceptions and the link between these preconceptions and disciplinary knowledge [9]. In engineering education this call has resulted in extensive work in the development of concept inventories in several engineering subjects; including statics, mechanics of materials, thermodynamics, and fluid mechanics, and work on investigating students' conceptual understanding of engineering topics e.g. [10, 11]. However, existing work has largely ignored conceptual models of engineering experts. Given one of the primary objectives of engineering education is to train engineers for the engineering workplace, it is vital to determine what concepts are important to engineering design. *This study is significant because it fundamentally advances the field by developing a cognitive model of conceptual understanding in civil engineers.* Research on practicing engineers will yield a dramatic impact on engineering educators and researchers by prioritizing the importance of certain concepts and evidence of how they support/interfere with civil engineering design.

The NRC suggests that "In areas in which curriculum development has been weak, design and evaluate new curricula, with companion assessment tools, that teach and measure deep understanding." [9, pg. 38] There has been a consistent concern over the effectiveness of current practices in engineering education to prepare engineering students for the engineering workplace [12]. None of the existing educational materials based on misconceptions research that have been shown to improve conceptual understanding [13-15], or are based on what conceptual understanding looks like in engineering practice. This study's contribution is significant because it will provide the first research-based curricular materials designed to inspire conceptual changes of particular importance to engineering practice, and thereby provide a framework for similar research and curricular materials development in other disciplines.

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