122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #11505

Epistemological Foundations of Global Competencies: A New Theory to Advance Research on Global Competencies

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Introduction

Around the world, many influential stakeholders are concerned with increasing global competitiveness of engineering graduates by increasing their global competency. Recent books from the US, Australia, and Europe attest to growing interest in global engineering.[1] In sum,

> Whether working on multi-national project teams, navigating geographically dispersed supply chains or engaging customers and clients abroad, engineering graduates encounter worlds of professional practice that are increasingly global in character. This new reality poses challenges for engineering educators and employers, who are faced with the formidable task of preparing engineers to be more effective in diverse national and cultural contexts.[2]

The benefits of global competency are widely recognized. Of particular significance to engineering, are findings that productivity and innovation increase with greater global competency,[3] and that exposure to different cultures via study abroad increases creativity.[4] Yet, the actual individual cognitive benefits of global experiences are not well researched or understood.[5] Findings on the effects of global experiences are ambiguous and do not support definitive connections between a global experience and the development of global competencies.[6] Furthermore, the knowledge, skills and attitudes that constitute global competency for engineers are by and large not empirically or theoretically grounded.[7]

Given such findings, we propose that the construct of personal epistemology may provide an avenue for generating new, empirical, theoretically-grounded research on what constitutes global competency, and how prepared engineering students might be for global work experiences. The purpose of this paper is three-fold: 1) to introduce the concept of personal epistemology, 2) to argue that global competency has epistemological foundations by elucidating connections between personal epistemology and global competency, and 3) to explain the empirical origins that prompted this theoretical exploration. We begin with an overview of the importance of theory for engineering education research. Next, we summarize attempts to define or operationalize global competency, and then give an overview of the concept of personal epistemology before identifying relationships between global competency and personal epistemology. Following that, we describe how we arrived the theoretical exploration presented in this paper. The paper concludes by explaining how these theoretical ideas address limitations of current scholarship on global competency and by describing future research directions.

The Importance of Theory

The need for theoretically consistent and grounded research is increasingly recognized within education research generally[8] and within engineering education research specifically.[9] Theoretically grounded work can connect researchers, facilitate generalization across studies, and help the field avoid re-inventing the wheel.[10] Moreover, "theoretically engaged empirical

work allows broader and more complex discussion between scholars – one that extends beyond the particularities of individual empirical projects".[11] However, much engineering education scholarship is characterized by a lack of explicit and consistent theoretical engagement,[12] and when theory is used it is typically only in a limited fashion.[13] The lack of engagement with theory in scholarship on global competencies is thus reflective of trends observed in the field of engineering education more broadly. This paper represents one attempt to advance empirical research on global competencies by presenting a theory that may be valuable in guiding future research.

Operationalizing Global Competency

Despite the growing push for global competency and a wide range of attributes that scholars have identified as important for global engineers,[14] there is no consensus over a precise definition or list of attributes required for global competency.[15] Jesiek et al. recently conducted a comprehensive literature review and interviews with engineers who have participated in global technical work. They argue that the key dimensions of global competency can be divided into three categories*: technical coordination*; *understanding and negotiating engineering cultures*; and *navigating ethics, standards and regulation*.[16] Yet, the knowledge, skills, and attitudes required remain a subject of ongoing empirical research.[17] Moreover, the lists of attributes that have been developed suffer from methodological and theoretical concerns and are largely not grounded in empirical research.[18]

One broad definition of global competency is "the knowledge, ability, and predisposition to work effectively with people who define problems differently than they do."[19] As this definition highlights, global competency requires not only specific knowledge, but also the ability and predisposition to recognize that engineering problems are defined and solved differently in different cultural contexts. In other words, global competency requires understanding that engineering knowledge is different in different cultural contexts. The latter is an epistemological issue, meaning that it is related to perspectives about the nature of knowledge.

Personal Epistemologies

Personal epistemology (PE) is defined here as "the stances an individual takes on issues related to knowledge and knowing, such as what it means to know, what counts as knowledge, and what makes some knowledge true."[20] Personal epistemology is different from the less personal, normative epistemology pursued by philosophers. Personal epistemologies consciously and subconsciously affect the way people think about what they know, learning, and the validity and justification of arguments. It is widely recognized that PEs affect learning and achievement.[21]

Typically, PEs are defined in terms of beliefs along the following dimensions: (1) certainty of knowledge, (2) simplicity and structure of knowledge, (3) source of knowledge, and (4) justification for knowing (Hofer & Pintrich, 1997). We have added a fifth, *sociality of knowledge*,[22] and these five dimensions are summarized in Table 1. Foundational research in the personal epistemologies of college students has found that most students progress from believing knowledge is simple, certain and derived from authority, to believing it is manifold, context-bound and dependent on an individual's commitments among equally valid options.[23]

Table 1. Dimensions of Personal Epistemologies

Dimension	Issues
Structure	How is knowledge in [engineering domain] organized and related? What are the component parts and what are the larger structures?
Certainty	Is it possible to be absolutely certain in [domain]?
Source	Do individuals create their own knowledge in [domain]? What is the relationship between experts and learners?
Justification	How is truth or correctness defined and idenfied in [domain]?
Sociality of knowledge	Are different peoples' knowledge of [domain] different, and if so, how?

Inquiry into personal epistemologies in concerned with understanding what individuals think about issues, such as:

- *How possible is absolute certainty?*
- *How constant and unchanging is knowledge?*
- *What counts as knowledge rather than beliefs or opinions?*
- *How are areas of knowledge structured and related?*
- *How is knowledge created, and by whom?*
- *What determines the value of knowledge?*
- *What are the roles of consensus, evidence, repetition, and observation in determining the truth of knowledge?*[24]

It has long been known cultures and contexts can affect development of personal epistemologies,[25] and researchers are increasingly finding that an individual's epistemology itself (in addition to its development) may vary depending on context. This is supported by an interactional, context-bound theory of personal epistemology,[26] as well as domain-specific surveys that have proven to be more reliable and valid than similar domain-general instruments.[27]

Very little research has been conducted on engineers' or engineering students' personal epistemologies, although several studies have recently appeared in the *Journal of Engineering Education*.[28] However, the particular roles of authority (in the forms of codes and design standards as well as more experienced engineers), justification (including the personal and legal consequences of misjudgments) and certainty (as engineers are often in the position of ensuring capabilities or safety) make engineering practice an epistemologically unique and interesting field. Additionally, the dramatic underrepresentation of any group other than white males in most fields of engineering requires engineering education researchers to investigate possible sources of unintentional inequity in the system. Studies have suggested that epistemological issues – including beliefs about the possibility of certainty and the role of authority in determining truth – may affect different group's participation in engineering,[29] indicating a potential link between epistemological development and diversity. The increasingly rapid transition from a nationally-based undergraduate engineering education to a global engineering work context therefore represents a unique confluence of epistemological characteristics and factors that influence epistemological development.

Relating Personal Epistemology to Global Competency

Historians and sociologists of engineering have shown that engineering is practiced differently in different countries and that the actual content of engineering knowledge differs across countries.[30] The types of engineering knowledge examined in that body of work vary, but they span what has been called the *sociotechnical divide*. It is in fact not simply what is seen as social aspects of engineering that vary across time and space, but also what is typically seen as the technical. Interdisciplinary challenges that accompany attempts to introduce critical ideas from one field into another, combined with the dominance of the sociotechnical dualism in engineering (education), mean that these ideas may not at first be well received. However, such challenges also highlight an additional body of research that our theory may help advance: that challenging the sociotechnical dualism.

As noted, one definition of global competency for engineers is the "ability to work with those who define and solve problems differently."[31] How problems are solved is inextricable from how they are defined,[32] which varies for engineers in different countries. Thus, it is not only cultures that differ, but also engineering content and practices that differ around the world. Global competency therefore requires understanding that engineers in other countries have different knowledge, which in turn requires an epistemology that accommodates sophisticated knowledge beliefs. Furthermore, epistemologies also vary across national and cultural contexts,[33] suggesting that global competency requires understanding that others have different epistemologies. The construct of global competency is clearly epistemological, but exact relationships between the two have not yet been investigated.

Empirical Inspiration for Theoretical Exploration

Since 2011, we have been conducting interviews with twenty-seven current and former civil engineering students at a public university in the United States. Participants were students from their sophomore year of university through their first year as practicing engineers. The study was not originally designed with global competency in mind: its salience for global competencies emerged over the course of the study and through new research collaborations. The epistemological portions of the interviews asked participants to agree or disagree with approximately twenty-five epistemological statements and to discuss their answers. The interviews were semi-structured, and the participants' agreement or disagreement was taken as a beginning point for a more in-depth discussion of the epistemological statement. As an example, one statement was, "I create knowledge in my discipline." Whether they agreed or disagreed, the participant would be asked to clarify what they meant by knowledge, and how they believed it could be created. We were not defining "engineering knowledge" for our participants a prior. Our interest was in learning what participants themselves would discuss when asked about "engineering knowledge."

From preliminary analyses, we identified several ways in which our interview data were related to global competencies. Firstly, we identified interview questions that are particularly relevant to global competencies and that we will develop in our future work explicitly linking personal

epistemology to global competency. For example, participants were asked to agree or disagree with and comment on the following statements:

- World history affects the current understanding of [mechanics or fluids] engineering knowledge
- Knowledge is affected by who I am and where I grew up (location)
- Engineering knowledge would be different if created by different people
- Knowledge in [mechanics or fluids] is not universally accepted
- Who you are affects what you know in mechanics or fluids
- Most of my knowledge in mechanics or fluids wont ever change due to meeting new people

Secondly, we observed that other parts of the interviews facilitated discussion of engineering work that has relevance to global engineering. For example, one participant who moved to a new job in a different county told us that he needed to make fundamental adjustments to the ways he had understood and carried out his analyses and designs. His discussion was clearly related to global competency categories identified by Jesiek et al.,[34] in particular *technical coordination* and *navigating ethics, standards and regulation*. He found that his engineering design knowledge did not carry over to his new national context.

Thirdly, some participants used the assumption that engineering knowledge is the same in every country and across time as a centrally justifying element in their personal epistemologies. They would acknowledge the apparent value of more sophisticated beliefs about knowledge, but argued that, based on the international commonality of engineering knowledge, sufficiently technical knowledge is "just true" and does not change across contexts. This suggests that if students were taught about the historical, sociological and philosophical research on how engineering knowledge varies across countries, they could develop more sophisticated stances about the source, certainty, justification and sociality of knowledge, thus impacting their personal epistemologies.

Conclusions and Future Work

Despite a widespread and growing interest in global competency for engineering graduates, empirical research to operationalize what that means is still underdeveloped. Delineating the most pressing issues related to global competency attributes, Jesiek and colleagues assert that:

> There is considerable variability in how attributes have been developed, often accompanied by a lack of transparency and rigor. More specific shortcomings include a tendency…to generate lists of attributes based on relatively weak sources of empirical data, including prior literature (which itself often lacks empirical grounding), the experiences of the authors themselves, and/or pre-existing learning outcomes from relevant courses or programs…Still other concerns include limited grounding in relevant theoretical frameworks…and little discussion of how certain attributes might be developed through specific types of learning experiences…
>
> A second kind of concern centers on the limited theoretical understanding around the attributes themselves. Most notably, there is often a lack of clarity regarding how the

> target attributes are defined, much less what they mean in practice…The current state of engineering education literature calls for more systematic research that is grounded in theory and informed by extensive empirical data, including to address the following questions: what attributes are most important for global engineering, how are they related to one another, and how are they understood and experienced by students and practitioners?[35]

Our current research, and that which we are planning, is a new and important step in that direction, as it is both empirical and theoretically-grounded. Personal epistemology could prove useful in understanding the development of global competencies, particularly given findings that raise questions about the connections between international experience and global competency. Our aim in future work will be to provide systematic and empirical evidence of attributes that are important for global engineering, namely attributes related to personal epistemologies.

As discussed above, epistemologies vary across geographic contexts; however, what those epistemological differences might be in engineering specifically, and how they affect global engineering work on international collaborations is unknown. This paper is a first step toward elucidating the epistemological foundations of global competencies by introducing a theoretical exploration of the connections between personal epistemology and global competency. We are planning to continue to research the epistemological foundations of global competencies by designing a study that examines: 1) how engineers' personal epistemologies vary across national contexts, 2) how PE affects engineers' global work experiences, and 3) how global experiences affect engineers' personal epistemologies. The latter is important because findings about the effects of international experiences on global competency are ambiguous. It might be the case that PE is a better predictor of readiness for global technical work than prior experiences.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No.1361229. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We thank our participants for sharing their time and thoughts with us.

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