Interactions Between Engineering Student Researcher Identity and Epistemic Thinking

Dr. Lisa Benson, Clemson University

Lisa Benson is a Professor of Engineering and Science Education at Clemson University, and the Editor of the Journal of Engineering Education. Her research focuses on the interactions between student motivation and their learning experiences. Her projects focus on student perceptions, beliefs and attitudes towards becoming engineers and scientists, development of problem solving skills, self-regulated learning, and epistemic beliefs. She earned a B.S. in Bioengineering from the University of Vermont, and M.S. and Ph.D. in Bioengineering from Clemson University.

Dr. Courtney June Faber, University of Tennessee at Knoxville

Courtney is a Research Assistant Professor and Lecturer in the Cook Grand Challenge Engineering Honors Program at the University of Tennessee. She completed her Ph.D. in Engineering & Science Education at Clemson University. Prior to her Ph.D. work, she received her B.S. in Bioengineering at Clemson University and her M.S. in Biomedical Engineering at Cornell University. Courtney's research interests include epistemic cognition in the context of problem solving, and researcher identity.

Dr. Rachel Louis Kajfez, The Ohio State University

Dr. Rachel Louis Kajfez is an Assistant Professor in the Department of Engineering Education at The Ohio State University. She earned her B.S. and M.S. degrees in Civil Engineering from Ohio State and earned her Ph.D. in Engineering Education from Virginia Tech. Her research interests focus on the intersection between motivation and identity of undergraduate and graduate students, first-year engineering programs, mixed methods research, and innovative approaches to teaching.

Dr. Marian S. Kennedy, Clemson University

Marian Kennedy is an Associate Professor within the Department of Materials Science & Engineering at Clemson University. Her research group focused on the mechanical and tribological characterization of thin films. She also contributes to the engineering education community through research related to undergraduate research programs and navigational capital needed for graduate school.

Dennis M Lee, Clemson University

Dennis M. Lee is a doctoral student in the Engineering and Science Education Department and Graduate Research Assistant in the office of the Associate Dean for Undergraduate Studies in the College of Engineering, Computing, and Applied Sciences at Clemson University. He received his BA and MS in bacteriology from the University of Wisconsin, Madison. Prior to his studies at Clemson University, he taught introductory biology at Tri-County Technical College in Pendleton, SC. His research interests include the development of researcher identity and epistemic cognition in undergraduate STEM students.

Karina Sylvia Sobieraj, The Ohio State University

I am a third year Biological Engineering Student pursuing a minor in Biomedical Engineering. I am active in many clubs on campus including Make a Wish and the Society of Women Engineers and I am also an undergraduate researcher for en engineering education research group.

Cazembe Kennedy, Clemson University

I am a PhD candidate working in the realm of computing education research. I also work extensively on Engineering and Science Education research, with focuses on engineering students' researcher identities as well as epistemic argumentation in the field of biology. I have interest in Science Policy, specifically Science Education Policy, and have been working as a graduate research assistant to Clemson's Associate Dean of Undergraduate Education on projects involving tracking and analyzing data on student engagement in high-impact practices, proposing and writing grants for joint faculty curricula development, and revamping Clemson's general education requirements/curricula.

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Abstract

This paper describes a multi-phase, multi-institution project with the objectives of 1) exploring how undergraduate engineering researchers develop their researcher identities and build knowledge, and 2) proposing related practices that could be integrated into engineering courses and curricula. The first two project phases focused on quantitative and qualitative data collection and analysis to answer our overall research questions and culminated with the development of a grounded-theory conceptual model named the Dynamics of Researcher Identity and Epistemology Model (DRIEM). Elements of the DRIEM include research practices and social interactions (which in combination make up and are embedded in a research experience); knowledge of what research is, who researchers are and what a researcher does (which comprise students' epistemic metacognitive knowledge); and elicited emotions such as excitement or boredom (which can mediate the connection between a student's epistemic metacognitive knowledge and researcher identity). The DRIEM also represents that an individual's researcher identity exists with, and is affected by, their multiple other identities and/or future self. The collaborative, iterative process of developing this model led to identifying four propositions: 1) Researcher identity affects and is affected by reflection on research actions; 2) Researcher identity is fluid and can dissolve or solidify; 3) Researcher identity and interest in research are influenced by social contexts; and 4) Students' researcher identity and perceptions of research are influenced by their initial dispositions and beliefs about researchers. We further refined the DRIEM and our textual description of it, and demonstrated its validity, by testing it with individual cases from our data.

The third and final phase of our project involved developing a workshop aimed at introducing engineering educators to the DRIEM and identifying ways to incorporate our research insights and findings into engineering courses. Since a course setting, similar to a research setting, requires students to participate in activities related to the testing, building, justifying, and disseminating of knowledge, we theorized that researcher identity and epistemic thinking could develop and shift in course environments as well as in UREs. We refer to this project phase as research-with-practice, wherein engineering educators were asked to identify ways to translate this model into their courses, and in turn provide insights into ways we can more effectively communicate and represent our research findings. Outcomes of these workshops include not only ideas for modifying teaching practices in ways that would influence students' research identities and epistemic thinking, but also insights on how to refine our textual and visual descriptions of the DRIEM.

Introduction

This study presents the outcomes to date of an NSF-funded research project, *Student Researcher Identity and Transformed Epistemologies* (SPRITE) (Award # EEC-1531607 and EEC-1531641). SPRITE is a mixed methods study of the interactions between undergraduate engineering students' researcher identity and epistemic thinking. Although undergraduate research experience (URE) programs have been well-researched in terms of their effects on student learning, motivation, and academic performance [1] – [4], little is understood about how UREs affect students' views of research, being researchers and knowledge development. The

value of students' perceptions of research and their identities as researchers lies in the alignment of research skills they apply during UREs with important aspects of their epistemic beliefs, or ways of knowing engineering concepts and how to practice engineering.

Specific aims of this project are:

1. Understand how undergraduate engineering students conceptualize and construct what it means to be a researcher

2. Determine what these students perceive to be the factors that affect their researcher identity development

3. Understand how these students conceptualize and interpret epistemic frameworks of their fields (i.e. the nature of knowledge and knowing)

4. Understand how beliefs about the nature of knowledge and knowing develop within the contexts of students' research experiences.

In this three-phase, multi-institution project, we employed a grounded theory approach to develop a grounded theory conceptual model of identity and epistemic beliefs within the context of engineering UREs. In Phase I, open-ended surveys (n=154) were used to gather data on participants' views of research and being a researcher (RQ 1 and 2). Results informed interview questions and participant selection for semi structured interviews (n=20) to explore relationships between students' epistemic beliefs and identity in the context of participants' undergraduate research experiences (Phase II, RQ 3 and 4). Quantitative and qualitative data from Phases I and II were mixed throughout the research process, from data collection and handling to analysis and interpretation. Themes emerging from this mixed methods approach informed the model of students' researcher identities and epistemic beliefs as they engage in engineering research. This representations of this model, the Dynamics of Researcher Identity and Epistemology Model (DRIEM), was used in Phase III to present our findings and develop ways to integrate findings into engineering curricula through workshops for engineering educators. Our target population for Phase I and II included Mechanical Engineering (ME) and Biomedical Engineering (BME) undergraduate students who self-identified as having participated in research in some capacity. For Phase III workshops, the target population was faculty, staff, graduate students and post-docs involved with instruction and design of curricula and courses.

We have previously reported on outcomes of this project in terms of students' perceptions of research and researchers, which emerged from our analysis of open-ended survey data as four themes: 1) conceptualization of research as novel or new, 2) dissemination of research, 3) integrating research into society, and 4) self-regulation of research practices [5] – [7]. Additional results in terms of how students see themselves as researchers and how they perceive their interactions with knowledge in their field revealed the extent to which researcher identity is fluid and can change (both positively or negatively) as they gain experience and an understanding of what is involved with conducting research [8], [9]. Specifically, our results showed how some students recalibrated their self-reported researcher identity scores. This recalibration is also indicative of the fluid nature of identities, a finding that would not have been possible without

our use of mixed methods (both quantitative and qualitative data and analyses). We have also reported our research methods, specifically our quantitative [9], qualitative [10], and mixed methods approaches [12], [13], and our approaches to translate our research findings to instructional practice [14]. In this paper, we present the current version of our grounded theory model of interactions between students' perceptions of research, researchers, and epistemic thinking. We also describe how we used that model as the core content of a research-with-practice approach to propagate our findings to the broader engineering education community.

Our Findings: The Dynamics of Researcher Identity and Epistemology Model (DRIEM)

The DRIEM was developed through a grounded theory approach based on responses to an online survey and semi-structured interviews where engineering students discussed their researcher identity and their beliefs about knowledge and knowing (epistemic beliefs) in the context of their undergraduate research experiences. The data were analyzed iteratively, then axial coding to identify connections and relationships between the codes, and that included epistemic thinking as a "sensitizing concept" to guide our coding of data [15].

Important elements of the DRIEM include research actions, social interactions, knowledge about how research works, knowledge about what a researcher does, and researcher identity. These elements reflect aspects of epistemic thinking [16], [17], including epistemic cognition and epistemic metacognition. The DRIEM elements interact with each other in fluid ways that strengthen or weaken the model elements and that change over time. Details on what each element means and how they interact are as follows:

- Research experience includes research practices, or the things that students or others are doing in the research environment. Some of these are epistemic practices. It also includes social interactions, for example, asking questions or discussing their work with others in the research settings. Social interactions combine with research actions to build knowledge about how research works through students reflecting on both their actions and interactions with others.
- Knowledge of research and researchers includes students' beliefs and perceptions about what a researcher does, who does research, and what research entails (how research works).
- Students' identities are multi-faceted; for this project, we focused on students' researcher identity. Students come to see themselves as researchers (develop a researcher identity) by comparing their ideas about what a researcher does with what they are doing and seeing how closely the two match. They can also come to understand themselves as researchers through epistemic metacognitive experiences like feeling and emotions (excitement, frustration, etc.) while doing research. This researcher identity also feeds back to their actions while doing research. Researcher identity is perceived with respect to, and is affected by, their multiple other identities, such as their role or position in a

family, other role identities such as a student, or professional identity such as an engineer or scientist.

Epistemic thinking is imbedded throughout the reflective pathways in which students process knowledge and their experiences. Reflection itself is an epistemic metacognitive skill that is essential for forming student knowledge about how research works. Students' understanding of how research works includes knowledge about how knowledge is constructed in research (epistemic knowledge about research). Epistemic metacognitive experience comprises the social interactions with the researcher community as well as the process of comparing what a researcher does to their own research actions. Students' emotions or feelings after receiving feedback from others in their research community affects their researcher identity.

Phase III: Research-With-Practice

As we were completing the first two phases of our research project and finalizing the DRIEM, we began Phase III, in which we communicated our research findings to the broader engineering education community. We developed and conducted multiple workshops with engineering instructors, aiming to co-translate this research-based model into educational practice. Intended outcomes of the workshop included examples generated by participants of ways to re-envision current class assignments and activities based on DRIEM to build engineering students' researcher identities and to encourage them to engage more explicitly with knowledge and ways of knowing in their field. The workshops were designed to elicit ideas from practitioners through brainstorming, interactive reflection activities and open discussions about how to apply the model in their instructional practice. The workshop followed a propagation paradigm that sought to "engage with adopters early and often to understand their instructional systems and interactively develop a strong product adaptable to specific contexts" [18] (p. 35).Workshop materials included handouts with a graphic representation of the DRIEM, text descriptions of the elements of the DRIEM, and two proposed applications of the DRIEM that drew parallels between elements of the DRIEM and instructional practice[13]. One of the common points of feedback received from the workshop participants was that the idea of translating this research into practice was easier to envision through the concrete examples initially provided by the workshop facilitators. Another was the miscommunication that participants should be linking assignments with parts of the model instead of thinking about how students might transition between the DRIEM elements through completing assignments. By rewording the prompts and providing concrete examples, the workshop participants were then able to re-envision their own course activities by focusing on student collaboration, explicitly addressing the knowledge students are gaining, and student self-reflection on that knowledge.

Participant-generated ideas for applying the DRIEM in classroom contexts in specific ways. These included:

- Having students rephrase problems: In a typical engineering classroom, instructors pose and set-up problems for their students; workshop participants proposed that their students rephrase and set up problems after instructors introduce them. In this way, students could

think about activities that would build their knowledge about the problems, which allows them to take on the role of being a researcher as they solve engineering problems.
- Word choice when designing assignments: Participants proposed focusing on their wording when framing and introducing activities and assignments to students such that they include elements of the DRIEM. For example, instructors could ask students to report on their "findings" or "results" rather than a "solution," relating the assignments back to a research environment.
- Online reflection assignments: Implementing online reflection assignments was a proposed activity that would require students to explicitly think about how course activities could relate to elements of DRIEM, such as what a researcher does. Students would have the opportunity to make explicit connections between what they are learning and knowledge in their field, which in turn would build their researcher identities. These reflection assignments would also provide a record that students could refer to over time and observe how their identities might have changed.

Members of the research team who conducted the workshops took notes on participant discussions of how the DRIEM could be applied in practice in more general terms. Themes that emerged from these workshop participant discussions include:

- **Enhance perspectives on obtaining and using knowledge:** Participants discussed how students can obtain and use knowledge in their courses by restructuring course activities so students see them less as "busy work" but instead as training for gathering and evaluating knowledge for their assignments. Research can often be a self-driven process and classwork is usually more driven by the instructor. Designing assignments in a way that drives students to find the knowledge needed to solve classroom problems can leverage students' sense of ownership of their work, which is common in a research environment and affects researcher identity.

- **Be intentional about classroom discussions of knowledge.** One of the more prevalent parts of the workshop focused on reflection and its role in building and using knowledge, both in terms of common knowledge among practicing engineers, and knowledge that is changing and developing in their field. Thus participants focused on ways to incorporate reflection into the classroom. Participants recognized that collaborative classroom activities could provide opportunities for students to reflect on their collaborative work and how they worked together to construct and improve their knowledge. Instructors could also allot time for students to think about what they learned, how they learned it, and if there are ways to improve how they might try and learn something in the future.

- **Encourage students to share their findings:** Students in UREs typically have opportunities to share their findings with others who are also trying to develop knowledge for their field, but rarely have these opportunities in their courses. Activities such as having a poster session or giving lightning talks where students are responsible for conveying knowledge to their peers based on a common foundation would mimic what a researcher does, and provide a lens for the students to see themselves as researchers and doing research in a classroom setting.

- **Focus on responsive teaching and assessment: Participants recognized that their** assessment methods could contribute to students' researcher identities. Formative assessments to gauge where students are struggling while engaging in research and knowledge-building in the classroom can allow for instructors to make changes that enhance the process of building and using knowledge. This is yet another instance where reflection could be incorporated, prompting students to explicitly identify where they are struggling throughout assignments to draw their attention to their own practices and experiences as researchers in the classroom environment.

Workshop facilitators also gathered feedback from the participants and kept notes about questions that participants had about the DRIEM, its meaning, how we were representing it, and how it could be applied. They relayed outcomes and feedback from the workshop participants to the whole research team during our weekly meetings. Some feedback related to the structure and flow of the workshop itself, for example suggesting that more time be allowed for reflection on the workshop materials activities and ideas generated by other participants. Other feedback included suggestions for other venues for delivering the workshop, for example an interactive online format.

Perhaps the most transformative feedback from workshop participants were their points of confusion about the DRIEM itself, particularly with respect to terminology related to epistemic thinking. It was at this point that we recognized Phase III as not simply translating research to practice, or even propagating research findings to a broader audience of practitioners[17], but rather as a "research-with-practice" phase in which researchers made changes to how we represented and explained our research findings and research-based model. There were three main insights that came from this research-with-practice cycle:

- Our research team's initial representations of the DRIEM included terminology related to epistemic thinking, such as epistemic metacognitive knowledge and epistemic metacognitive experiences; these terms were confusing to workshop participants and were roadblocks to their understanding of the model's meaning. We have since refined how we represent and explain the connections between model elements and epistemic thinking, describing it as the lens through which the model was developed (our "sensitizing concept" [15]).

- Early versions of the model had arrows connecting various elements within the model, for example between researcher identity and other identities, and "what a researcher does" and researcher identity. Some arrows were double-pointed and some were single-pointed, but essentially we came to understand that the arrows were too narrowly representing the meaning behind the DRIEM. It was only through testing and presenting the model graphic to educators, most of whom were not education researchers, that we were able to strengthen and refine our model's representation, terminology and explanation.

- Our description of the DRIEM did not initially focus on connections between knowledge building in a research environment and knowledge building in a classroom; we were

focused instead on fully describing our findings. As participants posed questions about how to translate findings related to the research environment to a classroom environment, we realized that they were seeing the model as something that was static and immutable. Once the facilitators developed parallel descriptions of how instructional practice could move students through the various stages of the model, instructors felt comfortable in translating the model into their classroom activities.

Conclusions

Our research demonstrates that transformation of students' epistemic thinking can be influenced by and influence the student's existing and developing engineering and researcher identities. Findings from this project indicate that undergraduate students see research as being related to the building of new knowledge. Students described the process of building knowledge within research as being the development of knowledge and included activities related to the testing, building, justifying and disseminating that knowledge.

The outcomes of this work have informed ideas about engineering education experiences that leverage our understanding of how undergraduates develop researcher identities and epistemic beliefs. We propose educational experiences in both traditional and research-based learning environments, and describe how researchers can learn from practitioners and vice-versa within a research-with-practice model of propagating our findings.

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