Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #47423

BOARD # 404: NSF ER2 Project: Exploring the Variation in Understanding and Experiences with Ethical Engineering Research among Faculty in Biomedical Engineering

Dr. Justin L Hess, Purdue University at West Lafayette (COE)

Dr. Justin L Hess is an associate professor in the School of Engineering Education at Purdue University. Dr. Hess's research involves exploring and promoting empathic and ethical formation in engineering education.

Dr. Nicholas D. Fila, Iowa State University of Science and Technology

Nicholas D. Fila is an assistant teaching professor in the Department of Electrical and Computer Engineering at Iowa State University. He earned a B.S. in Electrical Engineering and a M.S. in Electrical and Computer Engineering from the University of Illinois-Urbana-Champaign and a Ph.D. in Engineering Education from Purdue University. His research interests include empathy, ethics, design thinking, and course design.

Dr. Andrew O. Brightman, Purdue University at West Lafayette (PWL) (COE)

Andrew O. Brightman is Professor of Engineering Practice in the Weldon School of Biomedical Engineering. His research background is in cellular biochemistry, tissue engineering, engineering ethics, and diversity, equity, and inclusion in engineering education. Professor Brightman is an inaugural Fellow of the Online Ethics Center for Engineering and Science and is developing a Community of Practice around Ethics Education in Biomedical Engineering to develop and disseminate best practices for ethics training for the field of Biomedical Engineering.

Dr. Alison J Kerr, Colorado School of Mines

Alison J. Kerr has a doctoral degree in Industrial-Organizational Psychology from The University of Tulsa. Dr. Kerr's research interests include training development and evaluation as explored across a variety of academic disciplines and organizational se

Sowmya Panuganti, Purdue Engineering Education

Sowmya Panuganti is a graduate student at Purdue University in the Engineering Education department. She is passionate about understanding engineering culture and the effects it has on engineers' mental health and well-being.

Tyler A Ramsey, Purdue University at West Lafayette (COE)

Ethical and Responsible Research (ER2): Exploring the Variation in Understanding and Experiences with Ethical Engineering Research among Faculty in Biomedical Engineering

Introduction

Understanding and promoting ethical and responsible engineering research have become core research and education foci given the pervasive role of ethics in technology innovation and the need for academic researchers to consider long-term and broad range implications for society. Yet, as a multifaceted phenomenon, the specification of ethics varies by context and discipline, as do strategies for promoting ethical formation. For example, Davis and Feinerman [1] suggested that engineering ethics codes and standards ought to be emphasized in engineering ethics instruction, particularly when striving to prepare engineering students for future engineering *practice*. Conversely, in science and engineering *research*, CITI training is often the primary approach to ethics training [2]. Accordingly, these two modalities of instruction may be viewed as primary vehicles for ethical formation in *ethical engineering practice* and *ethical engineering research*, respectively.

As a result of the complexity of ethics and its potential for variation by discipline, frameworks intended to operationalize ethics, writ broadly, can de-emphasize critical facets of ethics formation particular to a specific domain. Thus, promoting ethics within a specific disciplinary context requires a thorough understanding of ethics as it manifests therein. To develop this understanding, we need to investigate the variations in ways of experiencing ethics within that context. In this project, we have chosen to develop a better understanding of ethical research in biomedical engineering given its interdisciplinary nature and its significant potential to affect human life and well-being [3, 4]. This project continued our teams' efforts in the domain of biomedical engineering ethics, here bringing methods and findings from previous studies in industry [5] to academic contexts. **Figure 1** provides an outline of our guiding research questions (RQ), associated Community of Practice(CoP) activities, and expected CoP and project outcomes.

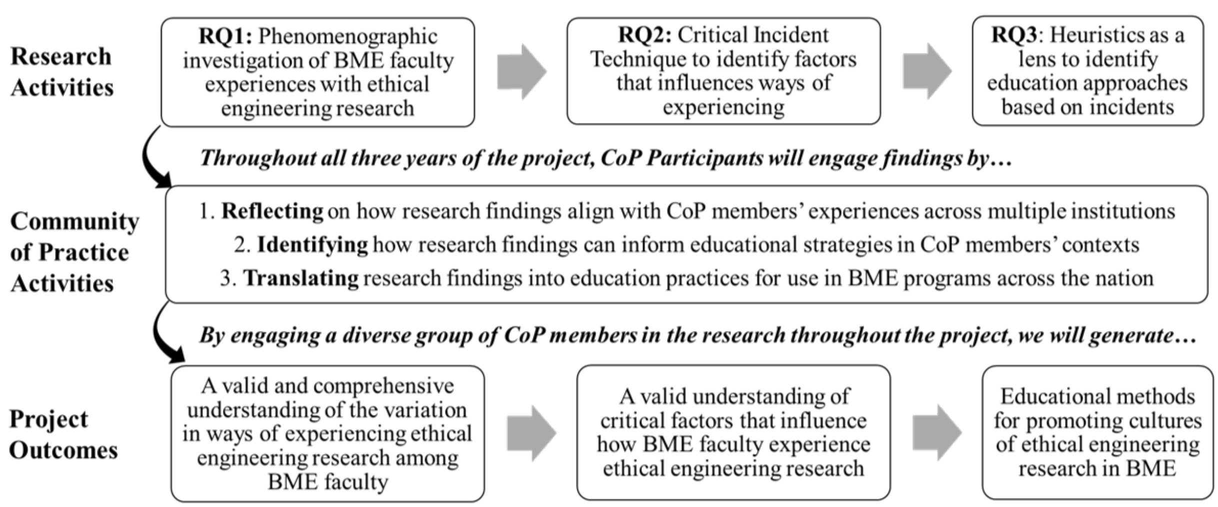

Figure 1. Overview of ER2 Project

As depicted in **Figure 1**, we first aimed to develop a comprehensive understanding of how ethical engineering research manifests among biomedical engineering faculty through phenomenography. Second, we sought to understand what experiences or factors contribute to the ways faculty members in biomedical engineering experience ethical engineering research. Third, we aimed to discern how faculty can promote ethical engineering research by generating Ethics Heuristics based on critical incidents. Throughout these research activities, we have engaged a Community of Practice (CoP) of biomedical engineering faculty who have a committed interest in engineering ethics education. This CoP provides feedback on results while considering how findings can translate to their own contexts. Together, these project components will enable us to create knowledge and strategies for promoting ethical engineering research in higher education.

Part 1: Phenomenography of Ethical Engineering Research in Biomedical Engineering

We began by investigating the research question, "What are the qualitatively different ways biomedical engineering (BME) faculty members experience ethical engineering research?" We employed phenomenography [6, 7] to identify categories of description (i.e., distinct ways of experiencing ethical engineering research) and structural relationships between those categories of description. We conducted and analyzed semi-structured interviews focusing on the experiences and conceptualizations of 25 BME faculty members from diverse roles and backgrounds. To date, we have identified six categories of description, summarized as follows:

1. **Conducting Research within Approvals**: Following regulations and guidelines to promote safety, good, rights, and care of/for human and animal participants and stakeholders. Recognizing the reason for rules and pushing back when relevant.
2. **Following a Rigorous Research Process**: Following best practices for designing research, collecting and analyzing data, and communicating findings. Recognizing the need for strong communication and research environments in light of external pressures.
3. **Promoting Equitable Research:** Aligning research direction and practices to benefit overlooked groups. Navigating tensions between the extant research system and one's research practice by questioning, following morals, and creating safe environments.
4. **Stewarding a Contributing Lab**: Contributing to society by producing good research and good researchers. Providing leadership by following one's principles, respecting others' principles, working within responsibilities, and creating cross-pollinating lab spaces.
5. **Upholding Research and Researchers**: Promoting ethical actors and practices while mitigating unethical actors and practices. Following a robust and fair process that considers multiple viewpoints to ensure good outcomes for researchers and the research system.
6. **Nudging the System**: Acknowledging extant and potential systemic issues and promoting incremental progress through research action, mentorship, oversight, or communication. Engaging with and thinking critically based on societal values and needs.

Next steps involve finalizing and detailing the categories, identifying the relationships among the categories, and depicting these relationships in a descriptive outcome space.

Part 2: Critical Incidents Informing Ways of Understanding Ethical Engineering Research

We next investigated the second research question, "What critical factors influence ways of experiencing and understanding ethical engineering research by faculty members in biomedical engineering?" We employed critical incident technique [8, 9]. Two coders independently extracted critical incidents from each of the 25 phenomenographic interviews, discussed extracted incidents, and agreed that 145 extracted incidents met extraction criteria, ranging from a minimum of 2 incidents to a maximum of 11 incidents per participant. By grouping incidents, we identified 14 representative incident types, which we then grouped into five overarching categories:

1. **Professional Immersions**: Interacting with other disciplinary or academic cultures and backgrounds, learning to adhere to their cultural norms and rules. For example, abiding or discovering rules of compliance can lead to a better understanding of such rules.
2. **Ethical Actions**: Acting or observing ethical behavior or ethically questionable behavior. For example, self-action may reinforce one's own ethical behavior and beliefs, providing positive guidance and examples for ethical practice in the future.
3. **Novel Perspectives**: Interacting or communicating with others to inform or obtain new perspectives, insights, and thoughts. For example, discovering a local community's perspectives on BME research can generate new ideas for conducting ethical research.
4. **Training Events**: Providing or receiving teaching, training, or mentorship. Such events can influence current students to be ethical and then influence one's own ethical behavior or beliefs.
5. **Reflection Associations**: Reflecting upon a phenomenon or critical moments in one's own research journey. Through such reflection, one can reinforce one's own research approach and beliefs or come to acknowledge others' values and approaches.

Following this analysis, we completed a second interview with 23 of the 25 participants. These interviews focused primarily on exploring critical incidents (rather than ways of experiencing ethics, more broadly) and prompting participants to interrogate the current set of incident types. Future analyses of these CIT-focused interviews may refine the above categories and inform the development of some additional incident types.

Part 3: Education Heuristics for Promoting Ethical Engineering Research

Our third research question asks, "How can faculty members' experiences with ethical engineering research inform more effective educational heuristics for preparing ethical engineering researchers?" We have begun generating heuristics representing what faculty members have done, have observed or experienced, or aspire to do to promote learning related to ethical engineering research. Based on the concepts of Design Heuristics [10] and course design heuristics [11], these ethics education heuristics represent strategies or principles that are (1) based in expert practice or (2) reverse-engineered from effective outcomes. Final heuristics can be used as ideation prompts for generating new learning activities in courses, research labs, or other learning spaces.

Two coders independently extracted heuristics from critical incidents, discussed extracted heuristics together and with the full research team, and organized heuristics into interim categories. Based on coding of critical incidents, we have identified 800+ potential heuristics organized by fifteen categories. Currently, the three most common categories are:

1. **Ethical Conversations**: This category encompasses strategies for encouraging awareness and engagement with ethical research practices through distinct types of conversations. One example heuristic is to *have consistent conversations*, wherein one organizes frequent/regular conversations among learners to (1) familiarize them with ethics as a topic and/or (2) ensure they feel comfortable bringing up ethics issues independently. Another example heuristic is to

communicate ethical expectations, which can enable faculty members to clarify their expectations with learners early and explicitly to ensure that others are (1) knowledgeable about expectations and (2) prepared and comfortable if/when facing ethical conundrums.

2. **Ethical Mindsets**: This category depicts strategies for building ethical mindsets to encourage understandings of ethics that are more holistic. An example heuristic is to *consider ethical outcomes*, which prompts learners to consider the impacts of research beyond a lab, e.g., discerning the direct and indirect effects of research findings to others.
3. **Ethical Lab Culture**: This category depicts strategies for cultivating and immersing learners in environments that promote ethical engineering research. One strategy is to *create a safe space* by encouraging learners to share their mistakes and showing them how to rectify mishaps, including the positive outcomes of doing so (and negative outcomes of not doing so).

The next steps involve ensuring theoretical alignment between the heuristics, the data, and participants' contexts, and refining heuristics and categories based on external input. In addition to potentially generating new heuristics and refining current heuristics, we will continue to explore framing and organizing heuristics in text, graphical, and interactive forms to support their usage.

Community of Practice (CoP)

The final component of our study involves engaging biomedical engineering faculty members who aspire to promote better training for ethical engineering research. This community of faculty practitioners have interrogated research results and advised on educational applications at semi-annual summits. As we conclude the final year of this project in 2025, the CoP will help to *translate* key findings into pedagogical heuristics for dissemination back into the broader BME research community. **Table 1** provides example feedback from the CoP in response to study findings. In addition to the project-specific CoP, we are also engaging a broader CoP through the NSF-supported Online Ethics Center (OEC) for Engineering and Science. This OEC CoP community includes faculty, staff, and students at universities and in professional and research organizations who are involved with or interested in teaching, research, and professional activities related to ethics of biomedical engineering, particularly the research and design, development, and deployment of biological and medical technologies. The OEC CoP will serve as an additional validation check of emergent findings and provide a broader dissemination and testing pool for strategies and related efforts at cultivating cultures of ethical research beyond the project.

Conclusion

By focusing on the actual experiences with ethical engineering research among biomedical engineering faculty members throughout the US, this study aims to guide current educational efforts and future research directed at cultivating cultures of ethical STEM research. In this paper, we have provided emergent results highlighting our current understanding of how biomedical engineering faculty experience ethical engineering research; critical factors that influence ways of experiencing ethical engineering research; and educational heuristics grounded in the lived experiences of biomedical engineering faculty. Findings will help promulgate evidence-based approaches to improving ethical engineering research in biomedical engineering, as well as other fields of science and engineering research, and will support a better understanding of the overlap between *engineering ethics* and *research ethics* as experienced in industry versus academia.

Table 1: Formative Feedback from Lead Faculty Consultants

Prompt	RQ1: Phenomenography	RQ2: CIT	RQ3: Education Heuristics
Reflecting	Regarding *Challenging Systems*, I think it is a hard category for clarity because if you read each of these four bubbles, I think we could all find a different tab they could belong on. Thinking about whether the phrasing can really distinguish the system-level thinking and/or institutional-level thinking that is behind some of these.	Engineering research sometimes includes the design, development, and testing of prototypes that might later be commercialized. As a consequence, many engineering researchers encounter ethical issues that involve industrial partners or potential patents.	Ethics is not just this checkmark that you tick, but it actually pervades all the different things that you do. That's one of the things that I think makes ethical education so difficult because you're in a course, and they're telling you, no, here's an example. You do this thing, but it's really, it's really everywhere.
Identifying	None of the categories really capture the educational goals in training future scientists; it's within the lens of research lab training but not training undergrads or graduate students in the classroom in general.	These critical inciden[t]s, can we turn those into cases, case studies that can go out to the community as a way of showing what are the various ethical traps, if you will, that you can find yourself in?	I really like encouraging the idea that the trainees are an important output of the lab, not just papers.
Translating	I think a one-pager would be beneficial here too. I like to think of what one page would I want someone to print out and have hanging on their bulletin board to remind them of a strategy or approach or collection of ideas?	Are you implying that people should have one of these negative incidents in order to sculpt them? What doesn't kill you makes you stronger kind of thing?	I look forward to seeing suggestions on incorporating heuristics. My thinking gets stuck in case studies because I think you can frame discussion questions at the end of a case study to hit multiple heuristics.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant Nos. 2124953 and 2124907. 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 or Purdue University.

References

[1] M. Davis and A. Feinerman, "Assessing graduate student progress in engineering ethics," *Science and Engineering Ethics,* vol. 18, no. 2, pp. 1-17, 2012.

[2] T. Phillips, F. Nestor, G. Beach, and E. Heitman, "America COMPETES at 5 years: An analysis of research-intensive universities' RCR training plans," *Science and Engineering Ethics,* vol. 24, pp. 227-249, 2018.

[3] N. D. Fila, J. L. Hess, and A. O. Brightman, "What do Biomedical Engineering Faculty Talk About When They Talk About Ethics?," in *2023 IEEE Frontiers in Education Conference (FIE)*, 2023: IEEE, pp. 1-7.

[4] N. Suppiger, N. Tabassum, S. Miller, and S. Higbee, "A study of biomedical engineering student critical reflection and ethical discussion around contemporary medical devices," *International Journal of Ethics Education,* vol. 9, no. 1, pp. 29-56, 2024.

[5] C. B. Zoltowski, N. D. Fila, J. L. Hess, A. J. Kerr, D. Kim, M. C. Loui, and A. O. Brightman, "Ways of experiencing ethics in engineering practice: Variation and factors of change," presented at the ASEE Annual Conference, Virtual, 2020.

[6] J. A. Bowden and P. Green, *Doing developmental phenomenography* (Qualitative Research Methods Series). RMIT University Press, Melbourne, Australia, 2005.

[7] F. Marton and S. Booth, *Learning and awareness*. Lawrence Erlbaum Associates, NJ, 1997.

[8] J. C. Flanagan, "The critical incident technique," *Psychological Bulletin,* vol. 51, no. 4, pp. 327-358, 1954.

[9] L. D. Butterfield, W. A. Borgen, N. E. Amundson, and A.-S. T. Maglio, "Fifty years of the critical incident technique: 1954-2004 and beyond," *Qualitative Research,* vol. 5, no. 4, pp. 475-497, 2005.

[10] S. Yilmaz, S. R. Daly, C. M. Seifert, and R. Gonzalez, "Evidence-based design heuristics for idea generation," *Design Studies,* vol. 46, pp. 95-124, 2016.

[11] N. D. Fila, J. L. Hess, and S. e. Purzer, "Instilling new ways of understanding the innovation process: Evidence-based heuristics from student innovation experiences," *International Journal of Engineering Education,* vol. 36, no. 2, pp. 633-649, 2020.