Work in Progress: Embedded Ethical Inquiry and Reflection in a Biomedical Engineering Curriculum

Dr. Sharon Miller, Indiana University Purdue University Indianapolis

Dr. Miller is the Undergraduate Program Director and Clinical Associate Professor of Biomedical Engineering at Indiana University Purdue University Indianapolis (IUPUI). After earning her BS in Materials Science and Engineering from Purdue University (West Lafayette), she earned her MS and PhD degrees at the University of Michigan (Ann Arbor). Her current roles include teaching, assisting in program assessment, student advising, and helping oversee undergraduate curriculum development and enhancement.

Dr. Steven Higbee , Indiana University Purdue University, Indianapolis

Steve is a Clinical Assistant Professor of Biomedical Engineering at Indiana University-Purdue University Indianapolis. He received his PhD in Bioengineering from Rice University (Houston, TX) in 2013, after earning his BS and MS degrees from Purdue University (West Lafayette, IN). His current position focuses on teaching, advising, and promotion of undergraduate research.

Prof. Joseph M Wallace, Indiana University (IUPUI)
Dr. John H. Schild, Indiana University Purdue University, Indianapolis
Dr. Julie Y. Ji

Work in Progress: Embedded Ethical Inquiry and Reflection in a Biomedical Engineering Curriculum

Introduction

The field of biomedical engineering (BME) aims to improve medicine through design. Ample curricular resources guide instructors when helping students practice application of theory toward design; however, few content-rich, teaching resources exist for faculty to incorporate engineering ethics throughout a student's BME undergraduate experience. BME programs continue to refine the implementation and assessment of ethics assignments, as the recent 2018 ABET changes identify the ability to recognize ethical responsibilities as a necessary student outcome in the preparation of engineers that can make informed judgements [1]. Despite this, challenges of implementing engineering ethics in BME curricula still exist and can include difficulty in emulating ethical situations [2], ill-prepared or tentative instructors [2]-[3], peripheral or isolated ethics coursework [4]-[5], and varied engineering ethics education expectations. Prior to engaging in this work, our program used varied approaches on teaching ethics or ethical reasoning. After a curricular gap analysis, we decided that additional touchpoints covering BME-relevant ethical topics throughout our curriculum were warranted. This work in progress shares: 1) a method used by a biomedical engineering department to develop embedded ethical reflection throughout its curriculum and 2) thematic analysis results from embedded student reflection in an Introductory Biomechanics course.

Curriculum Development and Research Methods

Building Ethics Reflection in Biomedical Engineering: Using backward instructional design [6]-[7], a programmatic student outcome on ethics guided development of student learning objectives (mapped to knowledge and cognitive learning dimensions). During a yearlong faculty learning community, five BME faculty that teach at different levels in our undergraduate curriculum collectively developed a programmatic outcome: *Students will recognize their professional responsibilities and apply ethical inquiry when developing, refining, and communicating the solution to a biomedical engineering situation.* This aided development of student learning objectives (Table 1), embedded assignments and reflections to assess.

Table I: Mapping Ethics with Backward Instructional Design (LO = Learning Objective)

Important for Students to Know or Do	**Topics Worth Being Familiar**
LO1: Recognize own values and morals **LO2: Demonstrate** ability to engage in discussion **LO3: Demonstrate** awareness of ethical and professional responsibilities in global, economic, environmental, and societal contexts **LO4: Describe, apply, and document** ethical inquiry **LO5: Reflect** on contemporary ethical issues in engineering design for biological and medical applications	• Professional organizations and their codes of ethics • FDA regulations and medical device classifications • Specifics of confidentiality (e.g., HIPAA) • Animal research, living systems consequences • Human research/IRB/informed consent • Life cycle of medical devices • Stem cells, genetic modification, CRISP-R • Industrial decisions regarding drug discovery • Intercultural awareness

A one-page curricular overview that outlines the Markkula Center for Applied Ethics framework for ethical reasoning was developed and presented to students in all courses (200-level to 400-

level courses) in fall 2019. This framework emphasizes the following steps: Recognize the Ethical Issue, Get the Facts, Evaluate Alternatives, Action, and Reflection [8]. Each ethics assignment was implemented in the class per the instructor's assignment design. BME core courses chosen to include an ethics assignment included 200-level courses (Biomechanics and Biomeasurements), 300-level courses (Implantable Materials and Cell and Tissue Mechanics), and 400-level courses (Biofluid Mechanics and BME Capstone). Chosen courses added two or more student learning objectives. All courses included the student learning objective: *Reflect on contemporary ethical issues in engineering design for biological and medical applications*. Since many of our BME courses include active learning, the DEAL model for critical reflection helped instructors design a reflection strategy for each ethics assignment. The DEAL model involves **D**escribing the experience objectively, **E**xamining learning, and **A**rticulating one's own **L**earning [9]. The goal of integrating the DEAL model for critical reflection is to help students use reflection during the learning instead of only after learning.

Ethics Reflection in an Introductory Biomechanics Course: Biomedical Engineering is a multidisciplinary field, but a focus on human health and disease is at the heart of the discipline. Connecting animal use in biomedical research to an Introductory Biomechanics course, a newly developed assignment specifically prompts students to participate in cognizant recognition of ethical knowledge and to use intentional reflection to improve their ethical reasoning. Within this course, BME students harvest animal tissue, learn proper tissue storage techniques, and mechanically test various tissues throughout the semester. Students (n = 37) enrolled in a 200-level Introductory Biomechanics lecture and lab course participated in six assignment touchpoints (Figure 1).

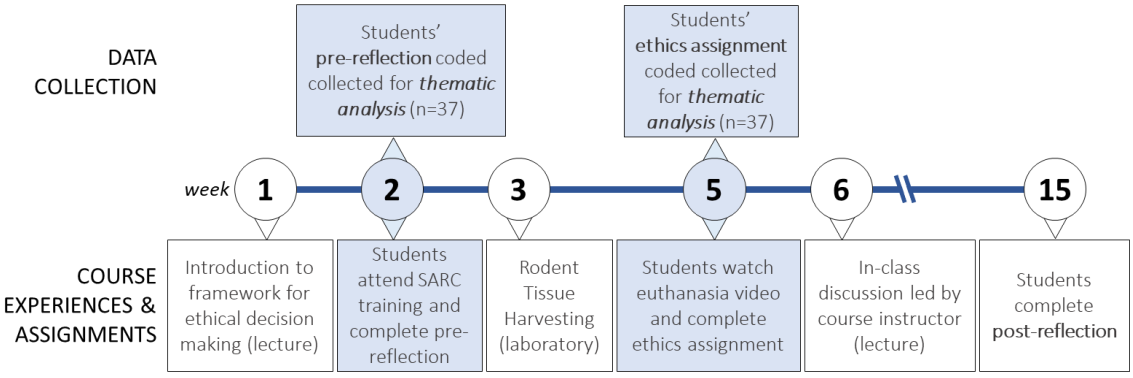

Figure 1: 200-level Introductory Biomechanics timeline showing course experiences and assignments (bottom) and points of data collection for thematic analysis (top).

(1) The first touchpoint was a brief introduction to the ethics resources provided on the first day of class. (2) During the second week, students were required to submit pre-reflection questions (**pre-reflection**) and attend the annual user's meeting for the Science Animal Resource Center (SARC). (3) Students participated in a tissue harvesting lab that was unchanged in comparison to past years. (4) After attending the SARC meeting and completing the laboratory, students watched an animal euthanasia video to complete ethics discussion prompts (**ethics assignment**). (5) An in-class discussion was facilitated by the course instructor for 40 minutes. (6) Finally, a short post-reflection question (**post-reflection**) was required. Completion points were awarded for each reflection. We applied thematic analysis on two artifacts: (1) the pre-reflection and (2) the ethics assignment. We inductively generated codes via a close review of student responses.

Two authors collaborated to refine codes after reading the pre-reflections. Then, they independently coded data from student pre-reflections (week 2) and student ethics assignments (week 5). Thematic codes were iteratively compared to achieve agreement.

Results and Discussion

Generally, students were and remained engaged in the Introductory Biomechanics ethics assignment. The course instructor noted that 40 minutes of discussion time for this topic was not enough and is determining how to best accommodate a longer discussion on this topic as a class for the future. Five themes emerged from student reflections as defined in Figure 2. When considering ethical issues surrounding animal research, students identified examples in research design, animal treatment, human benefit, worth, and emotion. Before attending the SARC user meeting, watching the euthanasia video, and performing the tissue harvesting lab, student reflections included many comments on practical reflection themes (research design, treatment of animals, and benefit to humans); however, after the activities, student reflections identified more examples of worth and emotion (Figure 2) and less on practical reflection themes.

Theme	Example Codes
Research Design	Researchers exhausted all alternatives, necessity in research design, appropriate sample sizes
Treatment of Animals	Pain management oversight, animals are treated humanely, researchers are educated in animal care and use, varied euthanasia methods explored
Benefit to Humans	Generally provides value to humans, is important to advance knowledge, is necessary to advance science
Worth	Existing species hierarchy, agency considerations by all species, justification of using animals
Emotion	Raw response (e.g., sadness), inner conflict between own values and STEM perspective, respect for life

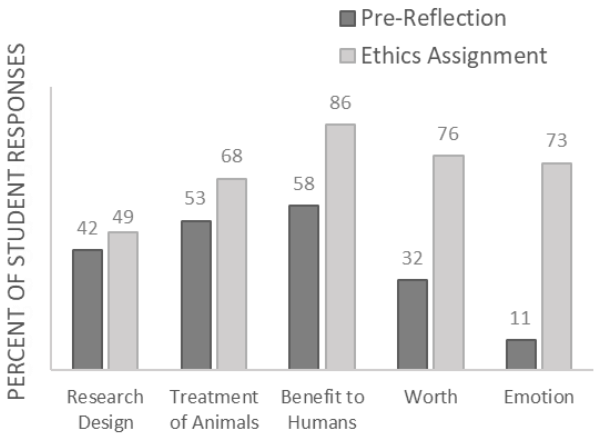

Figure 2: (Left) Reflection themes and example codes (Right) Percentages of BME students using coded themes in ethical reflections from Introductory Biomechanics

Integrating ethics in engineering curricula is a challenge. By providing content-connected ethics assignments in BME fundamental courses, we aim to better equip our students with reflection methods that will help them recognize ethical issues related to the BME profession. Providing students with opportunities to critically reflect on topics linked in courses can also help faculty add context within a course as a program aims to develop professional biomedical engineers. As a student matriculates through our program, our goal is to monitor their ability to reason and reflect when presented with an ethical situation. The preliminary data presented for Introductory Biomechanics is the first step in this data collection; nonetheless, the data are encouraging and responses from students and the instructor have been positive.

Acknowledgments

The authors thank the STEM Education and Innovation Research Institute (SEIRI) and the leaders on the NSF CCE-STEM Award #1737157.

References

[1] ABET Engineering Accreditation Commission. 2020. Criteria for accrediting engineering programs: Effective for evaluation during the 2019-20 accreditation cycle. Baltimore, MD: Accreditation Board for Engineering and Technology.

[2] A. Colby and W. M. Sullivan, "Ethics Teaching in Undergraduate Engineering Education," *Journal of Engineering Education*, pp. 327-338, Jul. 2008.

[3] B. Newberry, "The dilemma of ethics in engineering education." *Science and Engineering Ethics*. vol. 10, pp. 343-51, 2004, DOI: 10.1007/s11948-004-0030-8.

[4] C.J. Finelli, M.A. Holsapple, E. Ra, R.M. Bielby, B.A. Burt, D.D. Carpenter, T.S. Harding, and J.A. Sutkus, "An Assessment of Engineering Students' Curricular and Co-Curricular Experiences and Their Ethical Development," *Journal of Engineering Education*, vol. 101, no. 3, pp. 469-494, Jul 2012.

[5] K.A. Reyer, M.B. Cantwell, P.C. Lam, and R.M. Rafferty, "Improving Ethics Education in Engineering," *Worcester Polytechnic Institute Digital WPI*, May 2014, Retrieved from https://digitalcommons.wpi.edu/iqp-all/345

[6] R.A. Reiser and W. Dick "Instructional planning: a guide for teachers," Boston: Allyn and Bacon. 1996. 2nd ed.

[7] G. Wiggins and J. McTighe, Understanding By Design, Published by Association for Supervision & Curriculum Development, 2005, 2nd Expanded Edition.

[8] Markkula Center for Applied Ethics at Santa Clara University, www.scu.edu/ethics/ethics-resources/

[9] S. L. Ash, and P.H. Clayton, "Generating, deepening, and documenting learning: The power of critical reflection in applied learning." *Journal of Applied Learning in Higher Education*, vol. 1, no 1, pp. 25-48, 2009.