EMPLOYING CRITICAL REFLECTION IN A FLUID MECHANICS COURSE TO IMPROVE AND DOCUMENT ETHICS LEARNING BY UNDERGRADUATE ENGINEERING STUDENTS

Critical reflection can be a powerful tool for instructors to guide, enhance, and document student learning, especially from experiential learning activities.[1] Few published studies on student reflection in engineering education exist despite the prevalence of applied learning in engineering programs. The potential for critical reflection to promote learning in engineering prompted us to scaffold reflection-based engineering ethics assignments across the undergraduate curriculum. Herein, we describe our approach to implementing such an assignment in a fluid mechanics course. This work was partially supported by the National Science Foundation Division of Social and Economic Sciences, under award number 1737157.

The DEAL Model is a three-step critical reflection process, first described by Ash and Clayton in 2009.[1] First, the DEAL Model prompts the reflection writer to *Describe* their experience objectively. Next, the writer will *Examine* the experience through lenses related to the learning goals. Finally, the writer will *Articulate Learning*, documenting what they learned, how they learned it, and why it matters. Although the DEAL Model does not specifically target ethics instruction, its focus on experiential learning and civic engagement make it a valuable critical reflection tool for our ethics assignments.

As part of a broader effort to integrate ethical reflection across our engineering curriculum, we developed an experience for a junior-level Biofluid Mechanics course that included a guest lecture, classroom discussion, and written reflection assignment. The entire exercise counted as one homework grade for the course, requiring lecture attendance and a submitted reflection to earn full points. The guest lecture, delivered by the owner of an engineering consulting company that addresses environmental challenges in Indiana, focused on the pharmaceutical pollution of drinking water and engaged students in a question-and-answer session. Instructor-moderated discussions in subsequent class sessions connected fluid mechanics principles — as they relate to both the human body and wastewater treatment — to the ethical issues around pharmaceutical pollution.

As homework, students reflected on their experiences in two-page responses to provided prompts that were motivated by the DEAL Model and program-level ethics learning outcomes. The outcomes assessed included (1) "students will demonstrate awareness of ethical and professional responsibilities in global, economic, environmental, and societal contexts" and (2) "students will reflect on contemporary ethical issues in engineering design for biological and medical applications."[2] The prompts included:

- *Describe:* Describe what you took away from the presentation. What did you learn or observe? What individuals or groups are relevant players and/or stakeholders? How are they being affected? What do you think are the best interests of the relevant groups? In your initial reaction to the presentation, what ethical issue(s) has been presented?
- *Examine:* What options do the relevant groups have for action? Which option best respects the rights of all who have a stake, or would treat people equally, or serves the whole community? How would you act as the person you want to be, as an engineer?
- *Articulate Learning:* In light of what you learned, what do you propose as a course of action that would produce the most good and the least harm to the maximum number of people? Discuss your understanding of contemporary ethical issues in engineering design and applications for biological and medical purposes.

The critical reflection assignments inserted in this course convey several benefits to our students and faculty. First and foremost, repeated critical reflection deepens student learning and contributes to professional identity formation.[3] Second, the assignments generate documented examples of student learning that support our assessment and reaccreditation efforts. In Spring 2021, all students demonstrated abilities to identify appropriate stakeholders and to identify a global, environmental, economic, or societal ethical issue. Finally, the students' reflections represent a rich and longitudinal data set for education research. We continue to study student learning and experiences through these artifacts to inform our ethics curriculum development and revisions.

REFERENCES

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