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WIP: Integrating Human-Centered AI Algorithm Design into an Undergraduate Biomedical Imaging Course

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Introduction

Artificial intelligence (AI) is increasingly embedded across engineering domains such as design, manufacturing, energy, healthcare, and cybersecurity [1]–[7]. In this study, AI refers broadly to data-driven approaches such as machine learning and computer vision commonly used in engineering practice, rather than generative AI tools alone. This distinction is important because students' reasoning may differ depending on whether AI is used for predictive decision support versus open-ended content generation. As AI expands engineers' capabilities, it also raises questions about responsibility and societal impact [8]. Despite these shifts, undergraduate engineering education has been slow to adapt, and many students encounter AI as a technical tool with limited opportunities to examine its human and ethical dimensions [9], [10].

At the same time, professional formation has become a central concern in engineering education. Professional formation refers to how students develop ways of thinking, acting, and being as engineers, including ethical reasoning and responsibility to diverse stakeholders [11]. However, there remains a limited empirical understanding of how engagement with AI influences students' emerging professional identities. Human-Centered AI Algorithm Design (HCAD) offers a framework for connecting AI learning with professional formation. More specifically, HCAD integrates principles of human-centered design into algorithm development by highlighting human values, social context, and ethical implications alongside technical performance [12]. Prior research has shown that AI systems developed without such considerations can reinforce harmful biases or produce unintended social consequences [13], [14]. Educational studies further suggest that students require explicit support to attend to fairness and equity in AI design and that open-ended, project-based activities are particularly effective for engaging students in reflection about professional practice [15], [16].

This study examines the use of HCAD within an undergraduate biomedical engineering course as a means of supporting students' professional formation. Supported by the National Science Foundation (NSF), the study investigates how students reason about human-centered considerations in AI, how they envision their future professional roles, and which HCAD principles they prioritize in design work. As a work in progress, this paper presents the study design and early observations to inform future analyses of professional formation in AI engineering education.

Methods

This study uses a design-based research approach to examine how Human-Centered AI Algorithm Design (HCAD) can support professional formation in undergraduate engineering education. Design-based research is well suited for studying instructional innovations in authentic classroom settings, where interventions are refined iteratively as data are collected and analyzed [17], [18]. The project is being conducted across two academic years and is currently in an early stage of implementation, with preliminary classroom activities completed and initial observations informing ongoing protocol development.

Research Questions

The study is guided by three research questions aligned with core dimensions of professional formation:

- RQ1: How do students conceptualize the humanistic aspects of AI use in engineering after participating in HCAD-focused modules?
- RQ2: How do students envision the role of AI in their future professional practice as engineers?
- RQ3: Which aspects of HCAD do students prioritize in their engineering design work?

Together, these questions examine students' ways of thinking, being, and doing as they engage with AI-enabled engineering tasks.

Research Context

Data are being collected in two engineering courses within an undergraduate-only engineering program. The primary research context is an upper-level biomedical engineering elective focused on medical imaging, where several weeks are devoted to AI-enabled image analysis, explainability, and design activities situated in healthcare contexts. A shorter introductory HCAD module is being implemented in a required first-year engineering course to examine how students at different stages of the curriculum engage with human-centered AI concepts. Across both courses, students complete hands-on technical activities paired with structured reflection. These activities include examining cases of biased AI systems, experimenting with simple classification models, and completing design tasks that require attention to user needs, ethical considerations, and contextual constraints. In this study, HCAD is implemented as an instructional approach that explicitly connects algorithmic performance with human stakeholders, including considerations of fairness, transparency, usability, and contextual deployment. In the first-year course, students engage with introductory activities such as using browser-based tools to build simple classification models and intentionally introduce biased training data to observe how model outputs change. These activities are paired with guided discussions about sources of bias, including dataset imbalance, proxy variables, and historical inequities. In the upper-level biomedical imaging course, HCAD is integrated into technical AI modules through case analyses of biased clinical imaging algorithms, hands-on experimentation with explainability tools, and a culminating design project in which students will research and justify algorithmic decisions in relation to real-world clinical workflows and constraints. At the time of writing, only curricular approaches have been finalized, and the instructional materials and research instruments are continuing to be refined. In the upper-level course, HCAD was integrated by restructuring an existing unit on image analysis and AI-based methods, while the first-year activity builds on pre-existing introductory instruction rather than adding new course content.

Data Collection and Analysis

A mixed-methods approach is being used to address the research questions. Planned and ongoing data sources include surveys, reflective writing, interviews, focus groups, and analysis of student project artifacts. To examine students' conceptions of the humanistic dimensions of AI (RQ1), students will complete the Attitudes Toward the Ethics of AI (AT-EAI) survey [19] before and after HCAD-focused instruction, along with short reflective writing prompts grounded in humanistic engineering frameworks [20], [21]. Qualitative analyses of reflections use thematic coding to characterize how students reason about fairness, responsibility, and societal impact. To explore how students imagine AI shaping their future professional practice (RQ2), a subset of students will participate in semi-structured interviews and small-group discussions before and after instruction. These data will be analyzed using narrative inquiry methods to examine how students describe their emerging professional identities and anticipated roles as engineers working with AI [22], [23]. To investigate which HCAD elements students prioritize in design practice (RQ3), student project artifacts and design documentation will be analyzed alongside classroom observations and focus group data. An intra-action analysis approach will be used to examine how students, technologies, and learning contexts jointly shape design decisions, grounded in the HCAD framework [12] and the social construction of technology perspective [24]–[26].

Work-in-Progress Status

At the time of writing, the project is in its early stages, instructional approaches have been finalized, and data collection and analysis procedures are being refined. No full implementation cycle has been completed. Ongoing data collection and iterative refinement of instructional activities and research instruments will continue over the next academic year.

Preliminary Observations and Lessons Learned

Although full data collection and analysis are ongoing, several early observations have emerged from prior classroom implementations. Students readily engage with technical aspects of AI-enabled image analysis but often require explicit prompts to articulate human-centered and ethical considerations. Reflection activities have helped emphasize these perspectives, particularly in early iterations of the modules. In addition, we have found that students generally frame fairness and bias primarily in terms of data quality rather than broader societal context.

Conclusion

This work-in-progress paper presents the study design and early implementation of HCAD to support professional formation. As research activities continue, future analyses will more fully examine how students reason about ethics, responsibility, and identity in AI-enabled design contexts. The long-term goal is to inform instructional approaches that integrate human-centered and responsible AI into engineering curricula. This work contributes early implementation insights for educators seeking to integrate human-centered AI into biomedical engineering curricula.

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