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RIEF: Introducing a Mixed-Methods Approach to Engineering Students through Human-Centered Design

Dr. Jason J Saleem, University of Louisville

Jason J. Saleem is an Associate Professor with the Department of Industrial Engineering at the J.B. Speed School of Engineering at the University of Louisville. Dr. Saleem received his Ph.D. from the Department of Industrial and Systems Engineering at Virginia Tech in 2003, specializing in human factors engineering and ergonomics. Dr. Saleem's research interests focus on the integration of human factors engineering with the development of health information technology (HIT). His research also focuses on provider-patient interaction with respect to exam room computing, as well as virtual care tools and applications. Dr. Saleem also maintains an engineering education research portfolio and in 2024 was awarded a grant by the National Science Foundation (NSF) entitled, 'Introducing a Mixed-Methods Approach to Engineering Students through Human-Centered Design'.

Edward James Isoghie, University of Louisville

Edward J. Isoghie is a PhD candidate with a research focus on human factors and engineering education leveraging emerging technologies such as AI, digital twin, and virtual reality. He obtained his bachelor's and master's degrees in Industrial and Production Engineering from the University of Ibadan, Nigeria, and a masters in Operations Management at the University of Alabama, Tuscaloosa.

Dr. Jeffrey Lloyd Hieb, University of Louisville

Jeffrey L. Hieb is an Associate Professor in the Department of Engineering Fundamentals at the University of Louisville. He graduated from Furman University in 1992 with degrees in Computer Science and Philosophy. After 10 years working in industry, he r

Dr. Thomas Tretter, University of Louisville

Thomas Tretter is professor of science education and director of the Center for Research in Mathematics & Science Teacher Development (CRIMSTED) at the University of Louisville. His scholarship includes collaborative efforts with science and engineering faculty targeting retention of first-year engineering students as well as other engineering education efforts.

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Introduction

Although the benefit of qualitative research and design methods is clear in social sciences and other fields, little is known about the need and impact of adding qualitative methods training for engineering students and professionals. The curriculum for undergraduate engineering students is heavily focused on developing quantitative skills that are inherent to the engineering discipline. The increasingly multidisciplinary nature of engineers' work points to a need for engineering students to be trained to work effectively with other disciplines [1]. The lack of a deep understanding of human needs, abilities, and limitations, is an integral part of many engineering design failures [2]. Qualitative research methods are equipped to reveal unique insights for engineering design by better illuminating processes, cultures, relationships, and motivations relevant to what is being designed [3]. Therefore, engineering professionals may need to expand their expertise and training to also include qualitative methods based on the interdisciplinary and evolving workplace. This project introduces qualitative methods training into an existing engineering curriculum so that students acquire both quantitative and qualitative skills (i.e., "mixed methods"). We expect this research will help enable future engineers to more systematically craft designs to better meet the needs of their clients and communities. This project investigates the potential benefit of a mixed-methods approach (quantitative and qualitative methods) to engineering design within the realm of human-centered design (HCD). This research is guided by three questions: (RQ1) What are current mixed methods scenarios that are used in the practicing engineering community? (RQ2) What is the impact of introducing qualitative methods training for engineering students using the HCD example? (RQ3) What mixed-methods models can be developed using an HCD process? Investigating these questions has the potential to substantially advance our knowledge for preparing engineers as interdisciplinary professionals.

Methods

Our study used a sequential mixed-methods design based on a framework for designing and conducting mixed methods research (Figure 1). We have completed data collection for this study and are working through analysis and interpretation of results. Our data collection methods to investigate the first research question (RQ1) included an industry survey to assess the familiarity, frequency, and use of qualitative and mixed-methods among practicing industrial engineers, and interview data from a subset of the survey respondents to capture more context from a diversity of experiences. The interviews were semi-structured in nature and designed to deepen understanding of industrial engineers' real-world use of qualitative and mixed-methods and to explore organizational factors influencing these practices.

To examine the second research question (RQ2), we created a classroom experiment to compare instructional approaches. Students in a mixed methods group who received both quantitative and qualitative instruction (cohort 2, Fall 2025), along with a comparison group of students who received standard quantitative-only methods training (cohort 1, Fall 2024), were asked to work through an HCD problem (Table 1) that included both quantitative and qualitative data.

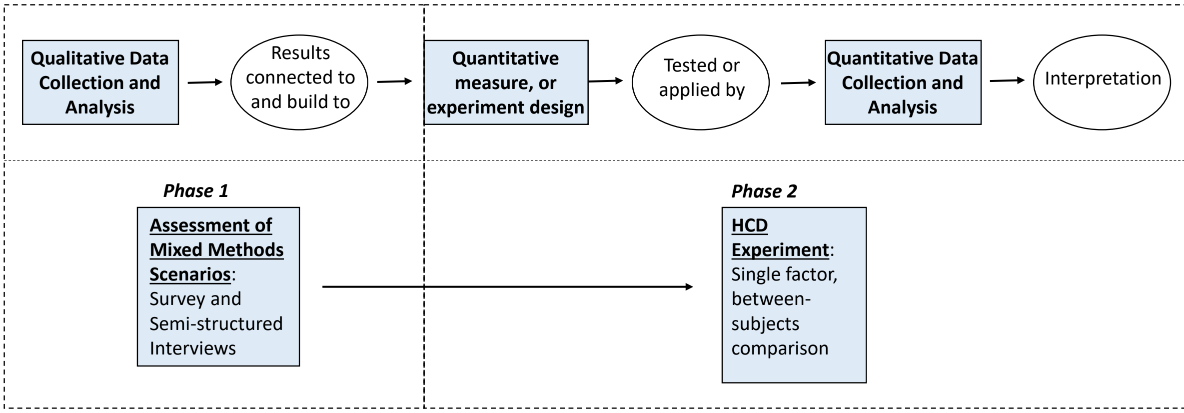

Figure 1: Exploratory Sequential Design Research Framework; adapted from [4]; with corresponding research methods for this study.

Table 1: Human-centered Design (HCD) Problem (adapted from [5])

<table>
<tr>
<td><u>Workstation Design</u>: You have been asked to design the workstations that will be constructed in each faculty and staff private office for a brand-new Industrial Engineering building at the university. Each private office will have a window. This is a workstation meant for a sitting individual while working with a desktop computer. There are about the same number of male and females that will be using these workstations. There is no strict budget limit for this design problem, but you should aim to make it cost effective when considering your design decisions. Account for the relevant anthropometric dimensions for your workstation design and any other human-centered design (HCD) considerations to produce a high-quality workstation design. Available for informing your design are handouts that include:

• anthropometric data tables
• detailed transcripts of end-user interviews and observations of workstations in use</td>
<td><u>The workstation, at a minimum, should account for</u>:
University assigned desktop computer and monitor(s), placement of the computer tower / central processing unit (CPU); The height of the center of the monitor(s) in relation to eye level; Placement of the monitor(s) to reduce likelihood of glare from the window on the screen; Chair; Desk dimensions
Placement and arrangement of the following items: Keyboard and mouse for the university assigned desktop computer; Printed course materials and textbooks; Research folders and documents; Personal items (smart phone, charger); Personal laptop; Fan; Water bottle</td>
</tr>
<tr>
<td colspan="2">The workstation may also include other items or elements that you decide are important to include. Consider component arrangement principles (e.g., frequency of use, importance, functional grouping). The desk may be designed as you wish (any shape, with storage, etc.). You can make any assumptions you wish for this design problem, as long as you document and justify your assumptions.

<u>Deliverables consisting of two main products detailed below</u>: (1) schematic, and (2) justification.

1. A complete schematic diagram or drawing with dimensions for the desk, chair, computer components, and placement of all other workstation items. The diagram does not need to be drawn precisely. However, it should be clearly labelled with relevant dimensions. You must use engineering anthropometric data and any other human-centered design (HCD) considerations to show how the workstation is designed to accommodate the person using it.
2. A summary <u>and justification</u> of each of your decisions, including:
o Anthropometric dimensions used to inform your design
o Any other human-centered design (HCD) considerations used to inform your design
o Placement and arrangement of workstation items
o Why certain items or elements or positions are included for your workstation design</td>
</tr>
</table>

Both groups of students received the same amount of instruction. We removed additional exercises and practice on quantitative methods for the mixed-methods group and instead administered instruction on systematic analysis of qualitative interview transcripts. Specifically, the qualitative instruction included guidance on (1) reviewing interview transcripts for relevant terms or phrases, (2) aggregating terms or phrases into potential codes, (3) developing and using a code book, (4) organizing the coded data by recurrent themes, and (5) translating the findings to design improvements.

Because of the relative sparseness of qualitative methods training for HCD problem-solving in engineering, studying the impact of this additional training required the development of a valid, context-informed, highly discriminant measurement tool sensitive enough to capture potential differences in student thinking that may emerge. We developed and used a context-informed research measurement tool – an HCD depth of thinking rubric to score and compare workstation design submissions from each group [5]. The third research question (RQ3) is explored by analyzing the different approaches engineering students who received qualitative methods training used, as well as existing mixed-methods literature, to propose effective means of using mixed-methods for HCD problems.

Results

RQ1: What are current mixed methods scenarios that are used in the practicing engineering community?

We received completed surveys from 31 practicing industrial engineering professionals across several industries. A subset of 12 survey respondents agreed to and completed virtual follow-up interviews. The industry survey and follow-up interviews revealed that industrial engineering professionals frequently rely on quantitative data as a primary decision foundation, while qualitative methods are often employed to contextualize, interpret, or explain quantitative outcomes. The results also revealed that mixed methods are most commonly applied in problem diagnosis, process improvement, workforce-related analysis, and technology implementation contexts. Despite recognizing the value of mixed methods for improving insight quality and decision confidence, participants reported notable challenges, including limited formal training in qualitative techniques, uncertainty about methodological rigor, and difficulties integrating heterogeneous data sources. The survey and interview results seem to highlight a gap between the recognized value of mixed-methods and the depth of their execution in practice. Quantitative traditions remain strong, but several participants acknowledged and advocated for the added value of qualitative evidence. Many interview participants agreed a greater emphasis for mixed-methods in the undergraduate engineering curriculum may help students be better prepared for contemporary engineering practice and enhanced interdisciplinary collaboration as professionals entering the workforce. As one participant noted:

> "*I think it would be beneficial to address qualitative information first and kind of apply it throughout because I think engineers go through a bunch of classes - it's differential equations and chemistry classes where everything is there's one solution. And then, later on, we kind of talk about different scenarios to think about and different ways to do investigations, observations. So, I think leading with more of an abstract knowledge would be helpful to kind of pull the focus away from quantitative, I think that's generally how a lot of people [engineers] think about solutions and problem solving is quantitative methods. So, I think focusing on a qualitative first would be*

great because in the back of their minds they may already be thinking about how could we think about this quantitatively, because that's what they're taught."

RQ2: What is the impact of introducing qualitative methods training for engineering students using the HCD example?

We have completed scoring the workstation design submissions from the comparison group (cohort 1, Fall 2024) who received standard quantitative-only methods training (n=25) as well as workstation design submissions from a second cohort (cohort 2, Fall 2025) of sophomore industrial engineering students (n=27) who received mixed-methods training. Comparisons between the two groups show that the mixed-methods group produced higher quality solutions to the HCD workstation design problem using a mixed-methods approach (quantitative + qualitative methods) than students in the comparison group, who receive the same amount of classroom instruction with emphasis on quantitative methods alone. "Quality" is determined by our HCD depth of thinking rubric to score and compare workstation design submissions from each group [5].

The first category indicators for the rubric are based on the quantitative application of anthropometric data. This permits comparison of students based on standard quantitative techniques – potentially to be used as a covariate in subsequent analyses. These include (1) placement of the computer tower; (2) height of the center of the monitor(s) in relation to eye level; (3) placement of the monitor(s) to reduce likelihood of glare from the window on the screen; (4) chair; (5) desk. For each primary indicator, points are applied to each workstation design as follows:

- design principle indicated (extremes, adjustable range, or average) (+1)
- relevant body feature(s) indicated (+1)
- corresponding data table values are correct (+1)
- anthropometric data values reasonably justified (+1)

For placement of the monitor(s), an additional point is given for: monitor is placed perpendicular to the window, or the design reduces the likelihood of glare in another way. (+1)

The second category of indicators correspond to recurrent design seeds intentionally planted in the qualitative interview transcripts by the research team (e.g., the desire for dual monitors, the need for adequate lumbar support). These interview transcripts were provided to the students as part of the workstation design problem. Each design seed included in the workstation design can receive up to two points based on the follow three level scoring system:

- level 0 = absent / not considered at all (0)
- level 1 = minimally considered, but not fully fleshed out or well justified (+1)
- level 2 = adequately considered / reasonable justification (+2)

The complete student depth of thinking scoring instrument is available in [5].

The mixed-methods group (cohort 2) had significantly greater success in extracting and applying design seeds from the interview transcripts (qualitative analysis) than cohort 1: 51.9% possible design seeds vs. 39.5%, $t(48) = -2.41$, $p = 0.02$ (while also successfully applying the quantitative training to the workstation design). With a Cohen's d = 0.68 the effect size is considered large [6]. That is, we were able to shift the performance of an entire class of students by 2/3 of a standard deviation with a relatively short and focused instructional intervention on qualitative analysis. There was no significant difference between the two cohorts for the primary indicators, which demonstrates that there was no drop in quality of ability for the mixed methods group (cohort 2) to perform the quantitative analysis, despite not having the extra examples and practice that cohort 1 received.

Discussion and Future Work

The findings from the industry survey and follow-up interviews highlight a gap between the acknowledged value of mixed methods and the depth of their execution in practice. This suggests that industrial engineering professionals may benefit from professional development opportunities in the form of mixed-methods training. We plan to work directly with industry partners to establish the amount of interest in a relevant professional development opportunity and then use the findings from this project to develop a mixed methods workshop for engineering professionals. We also plan to reach out to engineering educators at other institutions to establish if there is interest in a similar workshop specifically geared toward the engineering education community.

The results from the classroom experiment suggest that industrial engineering students may benefit from mixed-methods training at the undergraduate level. Students who received training on how to systematically analyze qualitative interview transcripts for recurrent design seeds are successfully translating that knowledge into their workstation design submissions to a higher degree than students who did not receive that training, but were able to produce equally strong quantitative-based designs as the first cohort. We plan to extend this research in a follow-on grant proposal by: (1) broadening mixed-methods instruction beyond HCD to additional design contexts; (2) embedding mixed-methods instruction within existing senior-level courses to support scalable and sustainable curricular change; and (3) implementing a longitudinal research design that follows students into early professional practice to examine real-world impacts of mixed-methods instruction.

A final research question for the study was to investigate effective mixed-methods models for analyzing HCD problems. Although we will propose these models after analysis is complete, a preliminary observation is that the mixed-methods group seemed to place equal emphasis on the use of quantitative and qualitative data for their workstations designs, while the comparison group placed greater emphasis on their quantitative analysis using engineering anthropometry, which was not unexpected. A shift toward a more equal emphasis on quantitative and qualitative data for engineering students may enable students to more systematically craft designs to better meet the needs of their clients and the community in their professional career. Ultimately, we are developing plans to weave qualitative methods training into the existing engineering curriculum, initially, within our university's Department of Industrial & Systems Engineering. This work will engender future research that will formalize qualitative methods training for engineering students to equip them as mixed-methods professionals to engage in interdisciplinary endeavors.

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References

[1] L. Oehlberg, I. Leighton, A. Agogino, and B. Hartmann. “Teaching human-centered design innovation across engineering, humanities and social sciences,” *International Journal of Engineering Education,* 28(2). p. 484. 2012.

[2] W. P. Neumann, J. Village, M. Bristow, and F. A. Salustri. “Developing a model for innovation in undergraduate engineering education–the systematic integration of human-centered design,” *Proceedings of the Canadian Engineering Education Association (CEEA)*. 2015.

[3] S. Daly, A. McGowan, and P. Papalambros. “Using qualitative research methods in engineering design research,” Paper presented at the DS 75-2: *Proceedings of the 19th International Conference on Engineering Design (ICED13), Design for Harmonies*, vol. 2: Design Theory and Research Methodology, Seoul, Korea, 19-22.08. 2013.

[4] J. W. Creswell, and V. L. P. Clark *Designing and conducting mixed methods research*. Sage publications, 2017.

[5] J. J. Saleem, E. J. Isoghie, J. L. Hieb, and T. Tretter. “Systematic development of a rubric for assessing a human-centered design problem using a tiered framing of depth for student thinking,” *2025 ASEE Annual Conference & Exposition*. 2025.

[6] A. Lovakov, and E. R. Agadullina. Empirically derived guidelines for effect size interpretation in social psychology. *European Journal of Social Psychology,* vol. 51, pp. 485-504. 2021.