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Systematic Development of a Rubric for Assessing a Human-Centered Design Problem using a Tiered Framing of Depth for Student Thinking

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Introduction

This evidence-based practice work in progress paper presents a systematic approach to design a high-quality context-informed research measurement tool – a human-centered design *(HCD) depth of thinking rubric* that gauges undergraduate engineering students' use of qualitative and quantitative data in a HCD task. The development of this rubric is part of a larger study that will introduce qualitative methods training into an existing engineering curriculum so that students acquire both quantitative and qualitative skills (i.e., "mixed methods"). This mixed methods approach may better prepare engineering professionals for interdisciplinary work. There is a broad understanding that qualitative and mixed-methods approaches may be beneficial for engineering; however, there is a clear bias for favoring quantitative methods in the engineering teaching curriculum [1] and little is known about the impact of adding qualitative and mixed-methods training for engineering students and professionals. Qualitative research methods are less familiar to engineers as the curriculum for undergraduate engineering students is heavily focused on developing quantitative skills. 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 [2]. Therefore, engineering professionals may want or need to expand their skill set to also include qualitative methods based on these inherent advantages and the interdisciplinary and evolving workplace. To that end, this research project introduces and studies qualitative methods training included in an existing industrial engineering course. Students in this mixed methods group, along with a comparison group of students who received standard quantitative-only methods training, are asked to work through an HCD problem that includes both quantitative and qualitative data (Table 1). Because of the relative sparseness of qualitative methods training for HCD problem-solving in engineering, studying the impact of this additional training requires the development of a valid, context-informed, highly discriminant measurement tool sensitive enough to capture potential differences in student thinking that may emerge.

Approach

For the given design problem, students are provided with 10 qualitative interview summaries in addition to standard quantitative anthropometric data tables to support their work on a design problem focused on workstation design. We used generative AI (i.e., ChatGPT) to produce 10 fictitious interview transcripts as a starting point, adjusting the prompts as needed to construct realistic looking interviews. After editing the transcripts to introduce more variability and distinction across the 10 interview transcripts, intentional "design seeds" were planted within the interview texts for students to potentially discover during their qualitative analysis. Our goal was to have recurrent design seeds (e.g. comments about the absence of adequate lumbar support for the desk chair), appearing across multiple interview transcripts in a variety of conversational ways, that students could discover during their analysis of the interviews and include in their workstation designs.

Table 1: Human-centered Design (HCD) Problem

<table>
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<td>Workstation Design: 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 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>The workstation, at a minimum, should account for:
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>
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<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.

Deliverables consisting of two main products detailed below: (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 and justification 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>
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We then developed a *HCD depth of thinking rubric* to include a tiered framing of depth of student thinking, that mapped to the design seeds we planted in the transcripts. Each interview transcript did not have the same design seeds; that is, placement of the design seeds was purposefully varied. Design seeds mapped to the following tiers: (1) explicit, (2) implicit, and (3) external (Table 2). Explicit design seeds are ones that were directly tied to the workstation problem statement and implicit design seeds were indirectly mentioned. A third category of external design seeds was not mentioned directly or indirectly in the problem statement. This tiered framing allows us to assess the depth of student thinking in their approach to the design problem, and how their analysis of the qualitative interview transcripts supported their design thinking. The *HCD depth of thinking rubric* also includes a class of "primary" quality indicators based on quantitative data that students work with (anthropometric data to design chair height, desk dimensions, reach envelope, etc.). "Secondary" quality indicators are those based on the

qualitative data. This structure, built into the measurement tool, permits sub-score analyses as well as the tiered analyses and will be tested, and refined, on the comparison group first.

Table 2: Discoverable Design Seeds from the Qualitative Interview Transcripts

Tier	Design Seed	Example	Recurrence across transcripts
Explicit	Fan placement	*…sometimes the fan will blow their papers off the desk and they find themselves having to use paper weights and move loose papers out of range of the fan's air flow.*	6
Explicit	Account for condensation	*The warm temperature also seems to produce some condensation on the desk, perhaps their relatively cold water bottle.*	6
Implicit	Lumbar support	*The chair lacks sufficient lumbar support, causing lower back pain after a few hours of sitting.*	7
Implicit	Dual monitors	*…the desk has enough room for their dual-monitor setup, which they say is the one thing that keeps their productivity up.*	7
External	Adequate electrical outlets	*They state that the desk also has more than enough electrical outlets that are integrated in the desk itself and easy to access*.	6
External	Stool or footrest	*They also mention a stool for their feet would be useful for their relatively short legs.*	6

HCD Depth of Thinking Rubric

The primary 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)

For other items that were to be accounted for in the workstation design, but do not necessarily need application of anthropometric data, a point is given for each item included in the design, and another point if the placement of the item is reasonably justified. Placement and arrangement of the additional items: keyboard and mouse; printed course materials and textbooks; research folders and documents; personal items (smart phone, charger); personal laptop; fan; water bottle.

- Accounted for in the workstation design (+1)
- Placement/arrangement reasonable justification (+1)

Secondary indicators correspond to the recurrent design seeds in the qualitative interview transcripts (Table 2). 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)

Additional points are given in cases where students use the qualitative data to inform design decisions for the workstation in other ways. For example, Chat GPT created design seeds in the interview transcripts that were not planted by the research team (e.g., the desire for a lamp for controlled lighting). Each instance of using the qualitative data to inform design decisions, outside of what the research team designed in Table 2, is award a point (+1).

Discussion

Students in the mixed methods group will receive the design problem (Table 1) in Fall 2025 after receiving additional training on analyzing qualitative interview transcripts (i.e., basic thematic analysis). A comparison group of 25 students received standard quantitative-only methods training and completed the same design problem in Fall 2024. Although the comparison group was given the qualitative interview transcripts, the students did not receive qualitative training for analyzing the transcripts. To evaluate the designs of students, we will use the rubric which identifies characteristics that reflect the use of quantitative methods (engineering anthropometry) and characteristics of the design that reflect the use of qualitative methods (interviews). These two sets of quantitative and qualitative characteristics represent subscores in the rubric that can be analyzed separately. We are currently applying the rubric to a subset of the workstation design solutions of the comparison group and will refine it as needed before scoring both the comparison group and mixed methods group completed designs with the finalized rubric. We will use heat maps or other ways to cluster design features from the students' submissions to inform the refinement of the rubric.

The rubric is intended to be robust such that we can understand the depth to which the qualitative interviews were considered and applied to produce a human-centered workstation design beyond what would be expected from only applying quantitative engineering anthropometry. The rubric, including subscore analyses offering stronger possibilities for discrimination, emphasizes relevant contextual factors that can be abstracted from qualitative interview data, especially those that are recurrent across multiple interviews, to enhance a design that should be human-centered.

References

[1] M. Borrego, E. P. Douglas, and C. T. Amelink, (2009). "Quantitative, qualitative, and mixed research methods in engineering education," *Journal of Engineering Education,* vol. 98(1), pp. 53-66, Jan. 2009.

[2] S. Daly, A. McGowan, and P. Papalambros, "Using qualitative research methods in engineering design research," in *DS 75-2: Proceedings of the 19th International Conference on Engineering Design*, Design for Harmonies, vol. 2: Design Theory and Research Methodology, Seoul, Korea, 19-22.08. 2013. pp. 203-212.