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Driving the conversation of social and educational influences in human-centered design biases among first-year engineering students

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Abstract

This complete evidence-based practice paper focuses on how to introduce the concept of social, cultural, and educational biases in a first-year engineering course through the lens of human-centered design. Consideration of the user can be a challenging concept to capture and effectively communicate to engineering students, but engineers are critical in the design and experience of everyday life. Therefore, it is crucial for engineering students to be exposed to the social and cultural differences of the user. Engineering curriculum can produce heightened levels of social responsibility and concern about public welfare, but to effectively do so, social issues, diversity, and social responsibility need to be consistently and effectively presented within the engineering curriculum.

This work is motivated by the Engineering Accreditation Commission's (EAC) desire to promote the understanding of professional and ethical responsibility and the understanding of engineering global, economic, environmental, and societal solutions. The insistence by the EAC that students be educated on the impact engineering and design have on the general public has led our research team to facilitate the first conversations of deconstructing assumptions around social and ethical dimensions of design, specifically, the interaction between the human, machine, and environment.

In an effort to introduce diversity in design and to troubleshoot the concept of the universal user, we adapted the display compatibility questionnaire from Smith's study of display-control stereotype designs, and presented the ambiguous design questions to first-year engineering students, non-engineering students, and non-engineering professionals. First-year engineering students completed the survey, after being introduced to principles of design methodologies and human factors, and then were required to provide the questionnaire to two other non-engineering students or professionals. The first-year engineering students collected the completed surveys of their non-engineering peers and responded to three open-ended questions related to commonalities and differences in understanding the ambiguous interfaces.

In three cohorts' reflections (99), nearly half attributed the variation of responses to differences in experiences and shared understandings. Other explanations for the observed variation in responses were disciplinary differences (23), difference of interpretation of instruction (30), and common sense (20). The series of ambiguous design questions facilitates the conversation for the unique insights of first-year engineering students to naturally identify the complexity and impact of the design process. While students demonstrate a base level understanding of diversity or difference in user approach, it is the responsibility of educators to extract how these recognized differences are the scaffolding to begin to design for inclusivity.

The compatibility questionnaire within the human-centered design unit provides a strong pedagogical tool to have students analyze and critique survey design, cultural trends, diversity in users and populations, and the overarching concept of the universal user. The students were surprised by the differences they found, especially when they assumed similar characteristics would be found amongst peers. The assignment serves as an evidence-based practice to expose first-year engineering students to the challenges of designing for a universal user, creating an interactive unit to understand the variations of user interpretations in an active way.

Introduction

In 2018, the U.S. Bureau of Labor Statistics reported that engineering professionals are working within all major industry workforces [1]. The perception of engineers only contributing to the manufacturing and technical service fields is historical knowledge, not contemporary reality. Today, engineers are applying technical knowledge in government, retail, entertainment, and transportation industries. Mann & Tan [2] highlight that the diversification of engineering professions presents a clear need for students who seek degrees in engineering to be equipped to meet the expectations of a multi-disciplinary workplace. Graduates of engineering programs across the country are no longer solving discipline specific problems, now they are collaborating and entering the workforce to solve society's complex problems.

The Engineering Accreditation Commission's (EAC) desire to promote the understanding of professional and ethical responsibility and the understanding of engineering global, economic, environmental, and societal solutions aligns with this adapting workforce [3]. However, our undergraduate engineering curriculum needs to adapt as well [2]. A problem we face at the University of Indianapolis in our first-year engineering design course is the lack of recognition that design can be a practice of Diversity, Equity, and Inclusion (DEI). Students should be educated on the impact engineering and design have on the general public, and provided a dialog about social and educational biases that can dilute design.

How can students come to the realization that design has social and ethical dimensions? How can we, educators, improve the instruction of design and motivate them to look beyond technical knowhow toward social impact? Our team has adapted the display compatibility questionnaire from Smith's 1981 study of display-control stereotype designs [4], presenting ambiguous design questions to first-year engineering students, non-engineering students, and non-engineering professionals [5]. Our first-year engineering students are using the results of the survey as a tool to compare and contrast how different users (i.e. differences in age, gender, education, etc.) interpret displays and controls. These comparisons are composed in short reflections by the engineering students to facilitate discussions of social, cultural, and educational design biases.

Introducing the discussion of inclusivity in design can be accomplished in many ways. We are proposing the use of a compatibility survey and reflection to drive unit discussions. Some other approaches to this quandary include course development, gamification, and design projects. The Picker Engineering Program at Smith College has created the TOYtech project. Through the TOYtech project, students are designing educational children's toys with universal gender appeal, which simultaneously applies technical knowhow and inclusive consumer consideration [6]. An adaptation of the Delta Design game is used in a sophomore solid mechanics course at Stanford University to open the conversation to inclusive design [7]. As students participated in the game they found that final designs are the combination of team members' expertise, views, and values. The Designing Technology for Girls and Women course at the University of California at Berkeley incorporated questionnaires, interviews, and a design process assignment to capture student perceptions of how the design process worked [8]. The results identified the necessity of representation and inclusion of underrepresented users within the design process.

We will be presenting the results of our analysis of first-year engineering student perceptions of social and educational influences on user understanding of displays and controls. The development of a pedagogical tool and curriculum unit on human-centered design and its biases is in its infancy. Through our analysis of the survey reflection assignment, you will read how students have acknowledged diversity among users. The current curriculum unit is exposing first-year engineering students to the challenges of designing for a universal user and the understanding that many user interpretations can exist.

Literature Review

Social Competency in Engineering Education Requirements

The role of engineers is to construct systems, structures, and interfaces, oversee how they are built and implemented, and ultimately, utilized by people in society. Educational institutions are increasingly aware of the need to diversify and build equity into their curriculum, student experience and support, and hiring practices. This push has social and ethical implications for the discipline of engineering as well as practical implications. Exposing engineering students to social and cultural differences fosters their ability to reflect on the impact their designs can leave on society [5]. Building social competencies into the curriculum serves two significant purposes: 1) It produces engineering classrooms and programs that are better prepared to support students from diverse backgrounds, and 2) It produces an engineering graduate who is better equipped to engage in their future careers.

As noted, the EAC believes it is important to promote the understanding of professional and ethical responsibility and the understanding of engineering global, economic, environmental, and societal solutions. However, some question if engineering education packages social concerns as outside of the realm of engineering and fosters disengagement from the social world along three key ideological pillars: depoliticization, the technical/social dualism, and meritocracy [9]. In order for there to be genuine engagement with social considerations, curriculum must move past the technical/social dualism. Social concerns cannot be presented as secondary to engineering education or as an addition to squeeze in when there is a second of free time. In a review editorial, Berdanier [10] acknowledges that there is precedent to integrate the humanities and social sciences into engineering education and was called for by founders like Charles Mann (1918) and William Wickenden (1920's). Despite 100 years of various calls to do so, the integration has not gone well as engineering is perceived as a hard/applied discipline versus a soft/pure field such as communication or sociology [10]. Sticking to this distinction allows for the lessons that pertain to "dealing with people" to sit at the margins of the engineering curriculum. Arguably, these need to be folded in to better enhance the educational experience and as a route for promoting inclusivity and equity within the field.

Even when there is a will to better integrate social concerns into the engineering curriculum there are institutional and structural barriers toward doing so, such as lack of time and access for curriculum development of courses or workshops, lack of structural support in implementing equitable or inclusive practices, and lack of knowledge of how to engage in interdisciplinary pedagogy [11]. There are models in which engineering programs can challenge their students to think critically about the relationship between public welfare and technological systems [9]. Engineering educators are pivotal figures to translate the best practices of curriculum development which include social awareness, diversity, equity training, and questioning social justice into the classroom [5].

Promoting DEI in the Engineering Classroom

Engineering pedagogical approaches have increasingly begun to adopt qualitative components which are utilized to push students and professors alike to question which forms of knowledge production are valid, how people in society and in classrooms learn, and what knowledge "counts" in the classroom and the profession at large. These practices have the ability to promote avenues for inclusion and equity and allow for students and educators to engage with diversity in meaningful ways. To genuinely achieve a curriculum that encompasses DEI considerations then it is necessary to implement curriculum changes [12]. This is challenging for any discipline to thoroughly incorporate, and all the more challenging for engineering programs which have so many technical components that are necessary for accreditation. Arguably, the best way to approach this is to reconsider how the standard engineering curriculum can be taught alongside implementing or highlighting the cultural competencies that naturally go hand-in-hand with various units. This could range from teaching a brief history of marginalized voices that are left out of the conversation, bringing in guest speakers from various community backgrounds, and getting students to learn via diverse, real world experiences.

This implementation aligns with the push for engineering education to be culturally competent and we can see various approaches to implement these skills utilized in the engineering classroom. In pre-college classrooms for example there has been a push to bring in Evidence-Based Reasoning (EBR) which is necessary for argumentation and the ability to describe decisions in a professional setting, to people on an engineering team as well as people outside of the team [13]. Another way to implement DEI practices is to broaden what is considered legitimate knowledge. One way to do this is to take a "funds of knowledge" lens [14] that draws on the lived experiences of students and specifically recognizes that households are a site where student learning occurs. This approach has been utilized in work with adolescents who are engaged with engineering specific curriculum as well as with first-generation college students in engineering with success [15]. First-year students are academically under-trained and come in with a wide range of previous knowledge and skill that is greatly influenced by their class background, social capital, race, gender, etc. Connecting their knowledge and experience to capital [16] within the classroom setting broadens inclusivity and promotes acceptance of a wide range of backgrounds within the institutional setting.

Producing engineering students who are career ready and socially competent is a desired outcome for all programs. It is crucial for programs to set the tone that learning how to engage with diverse groups via apprehending the social dimensions and implications of design is just as important as understanding how a mechanism works or being able to pitch an idea. This work aims to begin to build this skill for students by providing them with active engagement with user approaches via the proposed compatibility survey.

Methodology

In our first-year engineering course, "Introduction to Engineering", the human-centered design unit culminates with a compatibility survey [4] and reflection assignment (see Appendix A2). Students are instructed to complete the display-control compatibility survey and recruit two other non-engineering students or professionals to take the survey as well [5]. The students then review the three survey responses before composing a comparative reflection focusing on the similarity and differences in the responses. The assignment was designed with user variation in mind to challenge the students' notion of universal users and universal design. To encourage reflection about student responses in comparison to their chosen participants' responses, students were prompted to respond to the following open-ended questions:

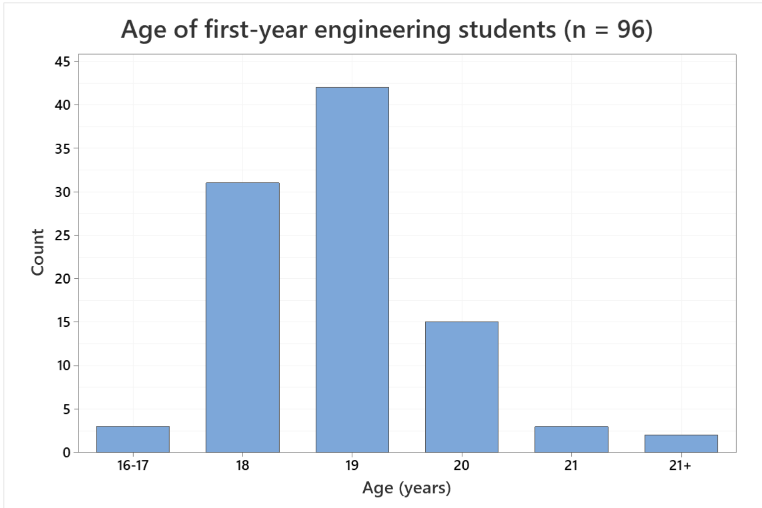
- What designs shared common understandings?
- What designs differed in the responses?
- What else did you notice?

For purposes of analysis, the reflective responses from each first-year engineering cohort (Fall 2019, Fall 2020, and Fall 2021) were combined, resulting in a sample size of 99 students. Data were coded and analyzed utilizing inductive qualitative content analysis [17] that served as the method of reducing, categorizing, and interpreting the data. Researchers read through the open-ended responses and applied an initial set of codes. After initial coding, researchers collaborated on emerging themes and set a standardized coding schema [18]. As coding progressed, specific themes and patterns emerged with regard to student explanations for the similarities and differences they saw between their responses and those of their subjects'. While patterns uncovered in data analysis indicate consistent explanation of similarity and variation, any attempt to generalize these patterns requires continued study and application of the assignment.

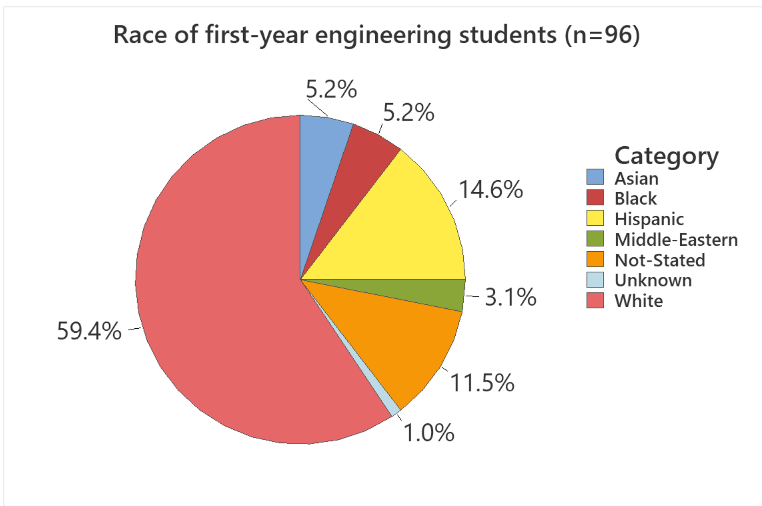
In the summer of 2021 we adapted the survey to an online interface. In the online adaptation we added an opportunity for people to explain their responses to each question that was adapted from the original compatibility survey. After selecting their response to each design question they were asked "Do you want to explain why you chose that answer for the question?" People could elect to do so or skip ahead to the next item. This version of the survey was only offered in Fall 2021. Both engineering students and non-engineering students did offer question level feedback. For this paper, only the responses from engineering students to a select handful of questions were analyzed along the method indicated above. This information affords us the ability to trace how explanations and understandings of engineering students develop while comparing their responses to those of their subjects. We searched for themes that were similar and held consistent between both phases of explanation as well as themes that were different or expansive.

Results

In our sample of 99 students, 81 students identified as male, 14 identified as female, there was one transgender female, and 3 students did not report. Figures 1a and 1b summarize the age and race of our students, respectively.



(a) Age of first-year engineering students when taking the survey



(b) Self-reported race of first-year engineering students

Figure 1. Demographic information of first-year engineering students taking the survey

Student responses (99) of the three open-ended questions from the reflection assignment were collected and analyzed. Following an inductive qualitative content analysis [17], student reflections were reduced, categorized, and interpreted by the researchers. Coding of the reflections resulted in five overarching themes (see Table 1) that indicate a serious consideration of the similarities and differences in the survey responses.

Table 1. Coded Themes of Student Reflections

Theme	Education	Experience	Common Sense / Logic	Interpretation	Demographic
Frequency	23	47	20	30	26

The following three themes will be examined further in this discussion section: experience, education, and demographic variability.

Explanation #1: Experience

The experience of the user was noted in some capacity in 47 out of the 99 reflections collected by students in their attempts to explain differences and commonalities in responses among themselves and their surveyed peers. Some references to experiences alluded to demographic differences, such as age, gender, and culture which will be discussed further in the demographic section below. The explanation of experience was invoked in different ways by the students. Some referred to very specific examples when speculating as to why people provided certain answers, such as, "Other questions would be answered according to what car someone drove or how they were taught certain subjects in school [male student]," or, "A lot of the responses dealing with handles, levers, or faucets differed because everyone has different handles at their homes. Everyone is used to different things, so the questionnaire is all about perception [female student]." Students would reference what they had in their houses growing up, or what their car was like, to explain why their answers might have differed or were similar to other people. Another student also referred to experience as being related to reality, noting, "It seems that our first reaction to these questions is to relate them to our world as much as possible which leads to answers grounded in reality. When asked which way you turn a door handle, most people turn it down in the real world so that's the answer people gave…This leads us to habits that may seem odd or illogical to an outsider but to us [it] is what we've done our entire lives so we apply it here [male student]." Notions such as the "real world" provide ample ground to engage students further, and broach how subjective the "real world" is.

Sometimes experience was invoked to explain similarities and differences, with students drawing on specific references. One student noted, "[related participants] had the same answers on almost every question which points to how an understanding of design can be influenced by the environments people grow up within." In another example, one male student reflected:

> However, we did differ on a lot of things because I believe it has to do with what **we are used to using.** For example, the door handle. I open door handles up because I'm used to that. However, the other two open them down. I didn't ask why they did this, but I will assume that it's just subconscious and they don't even know why…I infer that these answers are **based on previous usage** of other similar items. Due to previous usage, we have gotten used to the action that it almost seems natural for us, say, to turn the knob clockwise to make a counter go up. It's logical for us. For other things like the door handle, it really **varies on personal experience**.

Interestingly, we can see the student utilize experience in very specific and nuanced ways. There is the nod to “previous usage” which they account for similarities and how actions become to be considered “natural” by people, however, they also nod to experience when they are talking about differences they saw in responses. There is a wealth of opportunity to unpack how a concept can be used in a multitude of ways.

Other examples where a previous experience with a product or interface influenced response were seen in the question-level feedback given by students during the survey. A survey question asked students to label keys using numbers from 0 to 9 (see Appendix A1); twelve (12) first-year engineering students from our Fall 2021 cohort provided their rationale on their selected answers, with nine (9) citing their experience with the standard US keyboard layout as the main driver for their response. Furthermore, another survey question showed the students a portable music player with a rotating scroll wheel and prompted the students about the correct rotation [clockwise or counterclockwise] for advancing to the next song. Out of the eight students (8) providing question-level feedback, seven (7) used a multi-level association of words such as clockwise → right → forward/next to describe their experience-learned mapping.

Similarly, students relied heavily on common sense in relation to experience and drew on the concept of common sense in various ways leading us to interrogate, how do they justify what is common sense and how can that be utilized in the classroom setting to enable them to question stereotypes, knowledge construct, and ideally, the notion of the universal user. Students made conjectures about how the answers to the ambiguous interface questions related to common sense understanding (20) of the scenario. In one of the survey questions, students were presented with an opened refrigerator (see Question 7 in Appendix A2) and were prompted to answer if this was a right-opening or left-opening refrigerator. Eleven (11) students from our Fall 2021 cohort provided question-level feedback to give rationale as to why they have selected their response. Eight (8) of the students relied on the position of the hinges and/or location of the door once opened to attribute the refrigerator to be right-opening, while the remaining three (3) students focused on the location of the opening of the refrigerator to describe it as left-opening. Another example as to why the use of “common sense” to describe a design choice can be detrimental to the spirit of inclusivity in human-centered design.

When speaking to how personal experiences impacted results, students also linked common sense or logic (11) within these explanations. Multiple students noted how similarities in user responses were because of common sense, where differences in responses were explained by their differing experiences. Similar objects or prior uses were also referenced to explain how responses were logical or common based on experiences. A male student wrote, “In my findings I found several things to be very common. The most common was an understanding that turning things right, moves things right, and moving things left moves things left. This feels like it would be a common thread and makes a very large amount of sense since it feels logical." For this student, what they refer to as sense is connected to what they conceptualize as logic and experience, which are two very different things. Other students invoked notions of commonality, for example, a male student wrote, "Color was the most interesting because it created a debate between us on using common sense or following directions," and another male student wrote, "I think we had different answers for some of them because we both think differently about how we do things. Also, I noticed that some of the answers were not even close because the way they think and the way I think is so different. This is because their brain does things differently and thinks differently than others. The common-sense questions, we had the same answers because we all think the same way on those." What is fascinating as educators is at the very same time they are reflecting on differences there is still an invocation of common sense.

Explanation #2: Education

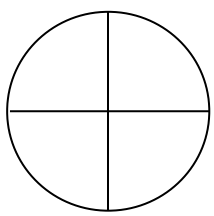
Twenty-three students, out of the 99 who submitted reflections, referenced how the education of the user attributed to either the differences and/or similarities in survey responses. Students commented on education by referring to level of education and disciplinary differences. Comments such as, "I found a lot of the responses to the questions to be different than my responses. I believe that this is due to the fact that people who are in different majors or who have different lifestyles than me weren't always taught to think the same as myself [male student]," and "This [differences in responses] shows that most people do think similarly when they are in the same age group and same education level. Those who are wiser and more educated make different choices [female student]." While many comments were primarily descriptive in nature, some students did attach assumptions of value to the educational differences they were speculating about as indicated by words such as "wiser," "smarter," or "right/correct". For example, a male student commented, "What I have discovered is that we have similar responses. I see that similar acting people have similar responses. And smarter people have to make sure they have the right answer to the questionnaire." This is particularly noteworthy since there is no "right" answer to these questions. One male student went into considerable depth about disciplinary differences:

> By analyzing the response of all the three-test subject, I would say that engineers, nurse and finance have different opinions and have **different critical thinking skills.** The engineering major students try to think more **practically** than nursing major. As a result, you will find more user-friendly result if asked to engineer than to nurses. The finance major students don't think more practically rather than think **analytically**. Their thinking is more based on the results of analysis. They try to consider all the possible ways of doing it and then they decide which will be the most suitable. The engineers try to understand the requirements of the project before they jump to number of possible solutions that satisfy the requirements. So basically, an engineer's solution is founded on the data they analyzed from the past

experiments, then the improvements needed to fulfill the requirements and then they come up with the solution. Generally, an engineering major's solution is **more reliable** than finance.

This student attached thinking style, critical thinking skills, and what kind of knowledge and analysis is valued to different disciplines.

One of the most common questions where educational and disciplinary influences (i.e. math courses) were referenced was in a question where students had to label quadrants in a circle (see Figure 2). Thirteen (13) first-year engineering students from our Fall 2021 cohort provided question-level feedback during the survey giving their rationale on their selected answers; seven (7) of these students cited the math, calculus and trigonometry knowledge acquired during their program as to the main reason for their choice, whereas five (5) of these students cited the reading order (left to right, top to bottom) as the basis of their response. This indicates that while education does play a role in how students responded to some of these questions, other students create other associations even if exposed to the same educational background (e.g., math, calculus).



In what order would you label the four quadrants of the circle?

Write in the values 1, 2, 3, and 4, assigning one number to each quadrant.

Figure 2. Labeling quadrants of a circle question from the compatibility survey

Explanation #3: Demographic Differences

Often, students invoked demographic reasons for the responses they saw. These sometimes were in relation to the experience and educational differences noted above. Students would invoke differences in age, gender, background, location, and lifestyle. One male student noted, "I also noticed how things such as the directional options were different as the one candidate was right-handed who I know also does things left-handed and came from a different part of the world where the standards might be different and may have influenced his decisions," and another male student wrote, "My friend and I are very close in age and we had more answers that were identical than my Moms'." Some students also invoked gender with one male noting, "Lastly, one big thing I noticed was the two males that did the survey were relatively the same, whereas the female participant thought a lot more differently." Below are two incredibly rich excerpts from two students who dove into analyzing why they saw the responses that they did. This first excerpt discusses differences in experience and common sense and is rooted in what they consider to be geographic/location differences. As the student notes, they deliberately picked their participants based on where they were raised:

> I tested two **different geographics** to see if there was a difference between two individuals born and raised in the **midwest** and an individual born in and raised **outside of the continental United States**, in Puerto Rico. All individuals shared a **common sense** with handles, levers, and dials and which way to rotate them to turn them on or off and to adjust something. Something that is interesting though is all three individuals had separate responses for labeling quadrants in a circular graph. I am unsure if this is based on **different levels and treatment of education**, especially in **math** where quadrants are heavily reinforced in geometry and trigonometry but not might be somewhere else in the country. Something I did realize and using data I knew outside of the survey, is the two individuals in the survey that **do not have a drivers' license** and do not commonly drive both had different shifter orders for an automatic transmission than what is standardized. I think this might just come from a lack of driving and they are **unfamiliar** with that system so they are not used to how it is supposed to and **lack the daily life experience** to be able to sufficiently answer the order of shifting. [male student]

By rooting their response in the deliberate decision to have geographic differences the student adds a variable to the explanations related to common sense and experience that we note above. The following student goes into educational and professional backgrounds to account for the responses they saw:

> Aside from my own results, I gathered the survey answers from my mom and dad. A **person's background** is important to the perspective they provide on certain matters, so it should make sense that their point of views should be brought to light. My mother is a **top-of-her-class college graduate** working as an **accountant** and my father is a **sergeant detective** for the IMPD. Both have been working in their respective line of work for as long as I've known them, with changes in employer and promotions every so often. My mom solved problems in the most **logical** way, my dad solved problems as **simply** as possible, and their answers to the survey reflect that as much as possible. **Despite this, they both shared a majority of answers to the questions posed**. When the phrase "left side down" is said, they both interpreted that as bringing the left side of the painting down. However, the biggest difference I've noticed between their answers and mine was that when it came to turning knobs and pulling levers, our answers varied. While I said shower knobs should turn away from each other, my parents said they should turn towards each other. After asking them about it, they told me it was because that's **how they were growing up,** and that things were different from what I grew up with. And

> after hearing that, the reasoning behind different answers made much more sense. **Education and profession aren't** as big of determining factors behind people's reasoning as **familiarity and experiences** are. If given the choice between a more efficient mode of operation and a mode one is familiar with, the individual will almost certainly choose the mode of **operation they know the best.** People don't like change, so unless designs need overhauled entirely in certain aspects, those aspects should be left as untouched as possible to make the product more appealing to the consumer. [male student]

This student went quite deep in their analysis, speculating as to what could cause variation (i.e., education, profession, experience, age, etc.) and then went to the next step to speculate as to efficiency versus familiarity. Drawing on a wide range of demographic explanations illustrates that some students are aware that there is going to be variation when it comes to the universal user and that interfaces are not going to be approached in a universal or unilateral way.

Discussion

The results presented above show the efficacy of the use of the compatibility survey to have students look beyond technical reasoning and explore how societal influences can impact design. Encouraged by the EAC to promote understanding of professional and ethical responsibilities, this work has provided evidence that students, even in their first-year, have the ability to recognize diversity among peers and their interaction with design. However, the survey/reflection assignment also indicated an openness to consider more than technical reasoning when reviewing survey responses. Students recognized and took note of response differences, especially, when the differing responses were from peers of which they thought to be "like" themselves. For example, students were surprised when siblings or friends didn't answer similarly. Comments of shock and surprise highlights the efficacy of the assignment to encourage students to think outside their specific orientations and view design from differing perspectives, even when they least expect it. This assignment poses the opportunity for students to consider global, economic, environmental, and societal influences as encouraged by the EAC.

It is noteworthy that without specifically prompting students to be cognizant of demographic, educational, or other differences students organically invoked those themes as explanations for the responses they analyzed. This indicates that they already have a foundation of what would cause variation and similarity in the responses. It follows that there are "funds of knowledge" [14] that educators can tap into and bring into the classroom. This is helpful because it means that students have real life examples to begin to build on as opposed to relying solely on abstract concepts when introducing social considerations. This foundation that students bring with them is important to connecting with each other and learning from each other. Using their own responses as a starting point for reflection enables genuine engagement with the preconceived notions or stereotypes that they have about other groups in societies, their own communities, and the language that they use.

Presented in the results sections above, the majority of our students made a connection between life experiences and instinctual responses to the survey questions. Many referenced prior use or experienced with similar/same products. If this connection holds true, that the understanding of the interface between product action and control interface relies on personal experiences, then the individuals in the room hold great responsibility to cultivate a diverse experience directory. Stereotypes and biases within the design will stem from the designers. The students have cracked the conversation that users have different experiences and knowledge, but now we need to expose them to how designing incorporates societal considerations as well.

Pilot Conversations: Social Dimension of Design Future/Next Steps

A curriculum is being developed by a joint collaboration between the School of Engineering and Department of Sociology at our institution to drive the conversation of social and educational influences in human-centered design biases. Our plan is to create a pedagogical tool to be implemented across a wide range of courses both within and outside the School of Engineering. We aim to promote the understanding of professional and ethical responsibility and the incorporation of global, economic, environmental, and societal factors in design solutions [3]. The survey has been a first step by our team to introduce the concept of social, cultural, and educational design biases in a first-year engineering design course.

In the Fall of 2021, we arranged a follow-up discussion session with the students after they submitted their surveys and their reflections on peer survey responses. With our digitized survey results, faculty presented key survey results in the following categories: (1) Overwhelming Compatibility in Responses among All Groups, (2) Overwhelming Compatibility in Responses among Engineering Students, and (3) Split Compatibility in Responses among All Groups. We reviewed the responses as a class, and provided a space for open discussion. We wanted the students to hear the thoughts of their peers and explain their reasons for the different categories of survey results. We broke the students up in their teams to conduct a think, pair, share exercise [19]. After the students had time with their teams to think and pair, we had each team share their thoughts on the collected results.

The next activity in the follow-up session was an iterative design activity. We took a question from the survey that presented split compatibility in responses across all users (see Figure 3). We then asked the students to brainstorm and sketch possible changes to create a more “compatible design” to address some of the varied responses presented earlier. The teams brought in concepts from the human-centered design module and began applying principles learned through the course. Teams updated the design by including features such as labels, colors, and symbols to enhance product usability. When presenting their iterated designs, teams often referenced elements of faucets they have previously used to enhance the original design (see Figure 3).

Figure 3. Which direction would you turn the hot water knob to turn the water on?

This follow-up session was our first iteration in the development of pedagogical tools to implement social awareness and interdisciplinary thought into engineering design. Using an evidence-based approach, we are continuously improving and expanding lessons for this unit with the data collected from the survey/reflection responses. We are planning to consult with different departments and colleges at the university to conceptualize and implement enhancements to the online survey and lessons to produce a pedagogical unit that can be utilized by a wide range of disciplines.

Conclusion

A compatibility survey provides a strong evidence-based pedagogical tool to engage first-year engineering students to conversations about cultural trends, diversity in users and populations, and the overarching concept of the universal user. Accrediting bodies and influential stakeholders have called for the inclusion of ethics and social considerations within engineering design instruction. This work explored how to effectively introduce conversations of social, cultural, and educational design biases in a first-year engineering design course.

Reflections of survey responses were drivers of the conversation on how bias in design can come from social and educational influences. One such example was the shock students expressed by the differences they found, especially when they assumed similar characteristics would be found amongst peers. The students' explanations of peer responses resulted in the overarching themes of user experience, education, and demographic makeup. An assignment that necessitated students to review peer responses and engage with open-ended prompts for reflection provided a channel to process and interpret display/control data. Students presented thoughtful justifications outside of their engineering knowledge base, leaning into their perceived understanding of people over process. The assignment provided first-hand exposure to a wide range of differences, with hopes of developing an understanding of difference and diversity in an active way.

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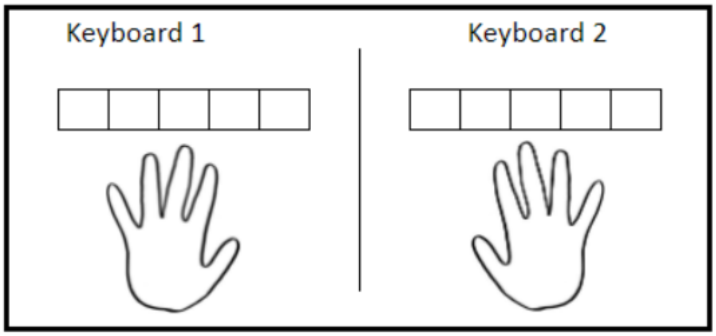
Appendix

A1- Number the Keys



- Which numbers would you use to label the "Keyboard 1" from right key to left key? (Please select from numbers 0-9)
- Which numbers would you use to label the "Keyboard 2" from left key to right key? (Please select from numbers 0-9)

A2 - Compatibility Survey and Reflections Assignment (Fall 2019)

Practical consideration of equipment design sometimes leads to ambiguity in choosing appropriate human interfaces. An equipment designer must consider many design standards that reflect customer usage and it is wise to test prototypes.

Questionnaires are an alternative to prototype testing to provide convenient and effective compatibility reports on effective matches between environment (interface) and user response. Attached is an example of a questionnaire that can aid the design process and evaluate effective user interaction of a design.

TASK:
Print (in color) 3 questionnaires.
Fill out one yourself.
Find two additional subjects to fill out the remaining copies. These subjects must **NOT** be engineering majors and cannot have taken the questionnaire previously (don't share subjects).

Review the responses from yourself and your two subjects. List three observations from the results; what designs shared common understandings, what designs differed in the responses, what else did you notice?

SUBMISSION:
Scan and submit the three questionnaires and the one paragraph report on your findings. You should be uploading 4 things: 1. Your completed questionnaire, 2. Subject one's completed questionnaire, 3. Subject two's completed questionnaire, and 4. Your observation on the collected responses.

COMPATIBILITY QUESTIONNAIRE

Adapted from Smith, Sidney L. "Exploring Compatibility with Words and Pictures." *Human Factors: The Journal of Human Factors and Ergonomics Society* 23.3 (1981): 305-15.

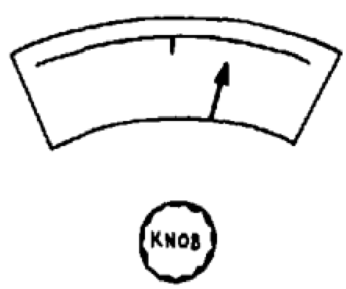
INSTRUCTIONS: Please respond to the following questions in order. Space is provided for any explanation of response, but no explanations are necessary. Enjoy.

Age: ____________________

Gender: ____________________

Major/Occupation: ____________________

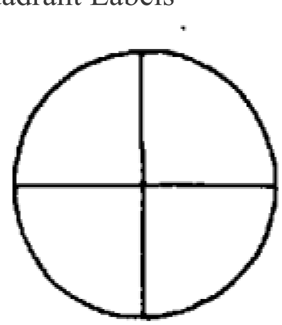
1. Knob Turn



To move the arrow-indicator to the center of the display, how would you turn the knob?

A. Clockwise
B. Counter-Clockwise

2. Quadrant Labels



In what order would you label the four quadrants of the circle?

Write in the values 1, 2, 3, and 4, assigning one number to each quadrant.

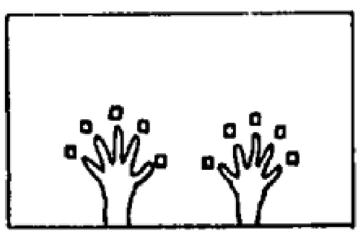
3. Left Wing Down

Flying in an aircraft cockpit, the co-pilot says “left wing down”.

How should the pilot act to change his roll position?

A. Lower the left wing
B. Raise the left wing

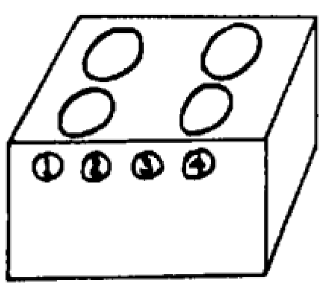
4. Numbered Keys



A worker is required to duplicate numbers as they appear on a screen, by pressing 10 keys, one for each finger.

Label the diagram to show how you would assign the 10 numerals to the 10 fingers.

5. Stove Burners



Here is a stove, with four burners on top, and four controls on the front.

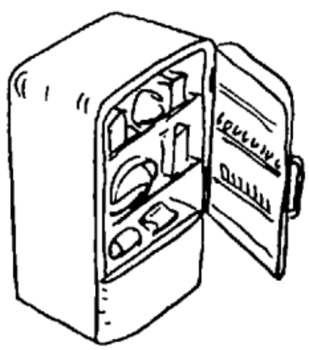
Put a number on each burner to show which control should operate it.

6. Cross Faucets

Here are two knobs on a bathroom sink, looking down at them.

Put an arrow on each dotted line, to show how you would operate these knobs to turn the water on.

7. Refrigerator Door

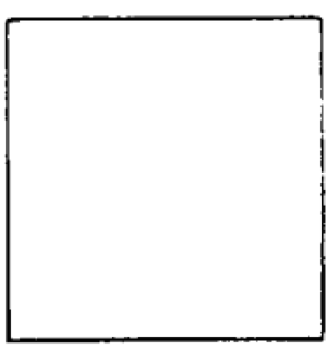


Here is a refrigerator.

Is its door

A. Left-opening?
B. right-opening?

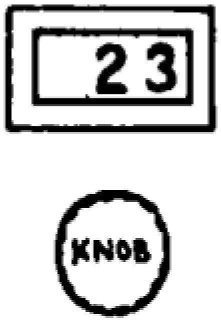
8. Auto Transmission



Some automobiles have push-buttons to control the automatic transmission.

On the panel at the left, draw in how you consider the buttons should be positioned for Neutral (N), Drive (D), Low (L), and Reverse (R).

9. Digital Counter



To increase the number displayed in the window, how would you turn the knob?

A. Clockwise
B. Counter-clockwise

10. Pressure High

Working with a fire crew, the hoseman yells “pressure high”.

What should be done to the water pressure?

A. Lower the pressure
B. Raise the pressure

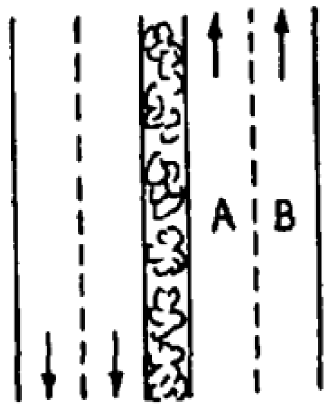
11. River Bank

Here is a river, flowing from East to West.

Is the church on the

A. Left bank?
B. Right bank?

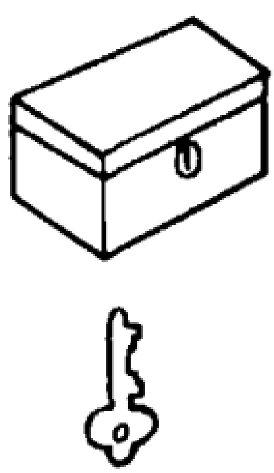
12. Highway Lanes



On the 4-lane divided highway pictured here, which is the outside lane?

A. Lane A
B. Lane B

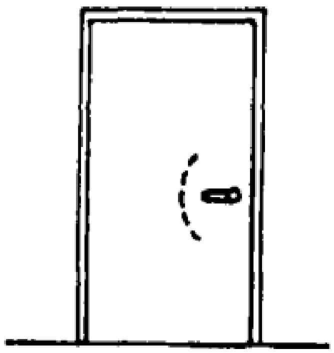
13. Locked Box



To open this locked bos, how would you insert its key?

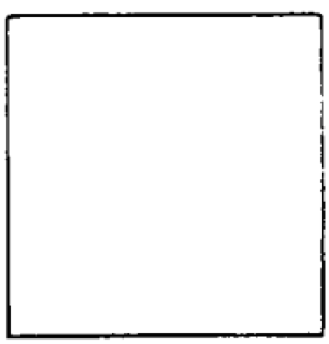
A. Teeth up
B. Teeth down

14. Door Handle



Put an arrow on the dotted line, to show how you would operate the handle to open this door.

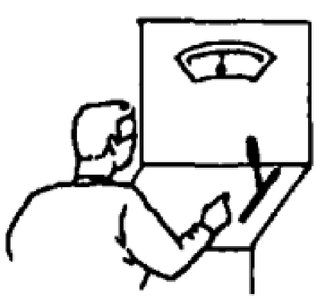
15. Adding Machine



An adding machine is designed to be operated with one hand.

On the panel at the left, draw in how you consider its keys should be positioned for the 10 numerals.

16. Lever Control



To move the arrow-indicator to the right of the display, how would you move the lever?

A. Push
B. Pull

17. Lever Faucets

Here are two knobs on a bathroom sink, looking down at them.

Put an arrow on each dotted line to show how you would operate these knobs to turn the water on.

18. What is this color?

GREEN

A. Red
B. Green