# Teaching Inclusive Design Skills with the CIDER Assumption Elicitation Technique

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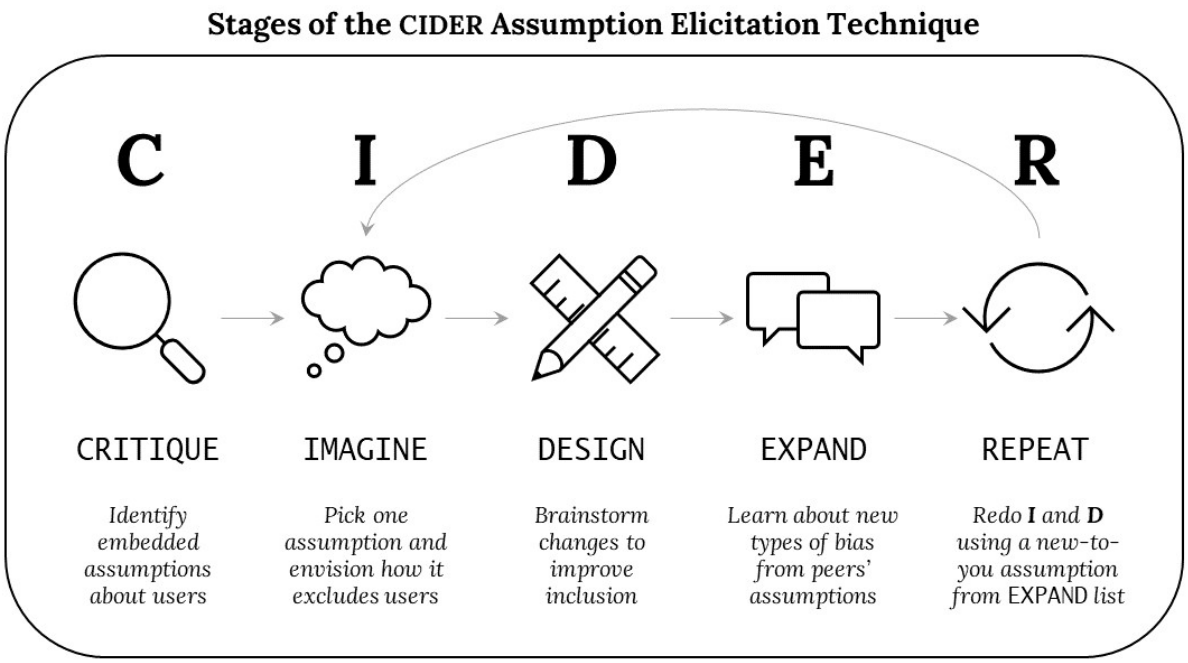


Fig. 1. The five stages of the CIDER assumption elicitation technique for helping early designers learn to recognize and respond to design bias. For each CIDER-based activity, the educator chooses an artifact for the whole class to analyze. Then, students use the five CIDER stages to identify assumptions about users present within the design, understand how those assumptions might lead to exclusion, practice brainstorming inclusive redesigns, and broaden their knowledge bases of design bias by engaging with peers' CIDER responses.

Technology should be accessible and inclusive, so designers should learn to consider the needs of different users. Toward this end, we created the theoretically-grounded CIDER assumption elicitation technique, an educational analytical design

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evaluation method to teach inclusive design skills. CIDER (*Critique*, *Imagine*, *Design*, *Expand*, *Repeat*) helps designers recognize and respond to bias using the critical lens of *assumptions about users*. Through an eleven-week mixed-method case study in an interaction design course with 40 undergraduate students and follow-up interviews, we found that activities based on the CIDER technique may have helped students identify increasingly many types of design bias over time and reflect on their unconscious biases about users. The activities also had lasting impacts, encouraging some students to adopt more inclusive approaches in subsequent design work. We discuss the implications of these findings, namely that educational techniques like CIDER can help designers learn to create equitable technology designs.

CCS Concepts: • **Social and professional topics → Computing education**; • **Human-centered computing → HCI design and evaluation methods**; *Interaction design process and methods.*

Additional Key Words and Phrases: HCI education, interface design education, inclusive design, design methods, assumption elicitation

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## 1 INTRODUCTION

In today's connected world, everyone should be able to effectively and equitably interact with technology so they can access the benefits it provides. Unfortunately, software and hardware interface designs often fail to support different kinds of users well. Prior work in the human-computer interaction (HCI) and user experience (UX) design spaces documents a plethora of cases in which a technology's design might discriminate against users of varying physical or mental capabilities [74, 82, 95], races or ethnicities [65, 72, 75], cultures [1], genders [18, 33, 56], and socioeconomic statuses [55], among other facets of diversity. These kinds of design exclusion often arise due to biases held by designers, who embed their values into the artifacts they create [28].

One prevalent type of design bias follows from the implicit or explicit assumptions designers make about their users. Reliance on some sort of assumptions is inevitable when designing because a single designer or design team cannot predict everything about how their design might be used [7, 48, 85], even if they leverage participatory or community-based design methods. However, exclusion often arises when the assumptions a design rests on involve users' capabilities, contexts, identities, or environments. Prior work describes how technology is often created with an imaginary "average user" in mind, and that this hypothetical user is usually of a socially or culturally dominant race, gender, age, culture, and class, who is heterosexual, affluent, comfortable with technology, and not disabled [21]. Designs made for "average" users tend to work well only for users from who fit all these categories. When design decisions are predicated on assumptions that users possess particular characteristics or have access to particular resources, the design of the resulting artifact often disproportionately disadvantages users from already-marginalized groups [92].

To counteract the harmful effects of design bias and contribute to more inclusive designs, those who design technology should be equipped with the skills to recognize and respond to harmful assumptions about users. Unfortunately, prior work from the area of HCI education documents a number of unresolved challenges people might face when learning or practicing inclusive design skills. Persistent problems reported include difficulties getting learners to recognize that they are making assumptions about users in the first place [49] and to consider diverse perspectives when designing [66]. Students may also lack the experience, knowledge, or perspective-taking skills to understand how their design choices can exclude different groups of users, or experience confusion about how seemingly abstract notions like inclusion manifest in actual design features [67]. Finally, students


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might actively trivialize inclusive design work, showing resistance to learning about such topics [66] or not taking the material seriously [67]. Because the way practitioners learn to design can impact their future practice [52, 53], successfully addressing these challenges in educational contexts may encourage more inclusive design approaches when current students transition into professional technology design practice.

Toward this end, we created the CIDER assumption elicitation technique, an educational analytical design evaluation method. CIDER, which stands for *Critique, Imagine, Design, Expand, Repeat*, aims to help designers recognize and respond to interface and interaction design bias in technological artifacts as a means of teaching inclusive design skills. In the following sections, we describe the theoretical grounding of CIDER, which draws on prior work from the areas of design rationale, perspective taking, and inclusive design education to help learners build concrete understandings of how inaccurate assumptions about users lead to design bias and exclusion. The novelty of this technique is twofold: To our knowledge, CIDER is the one of the first educational design techniques to explicitly use *assumptions about users* as its basis, tying together design features, design decisions, and the impacts designers' conceptions of users have on the inclusiveness of an artifact. In addition, the stages of the CIDER technique support learners in building concrete understandings of design bias and inclusion in actionable ways that they can apply to future design practice. This directly addresses unresolved challenges raised by recent HCI/UX design education work (e.g. [67]).

To evaluate the efficacy of the technique, we conducted a concurrent embedded mixed-method [22] case study in an post-secondary interaction design course where we explored the impact of CIDER on students' understandings of inclusion (n=40 students, with data collection spanning eleven weeks of instruction plus follow-up interviews one month later). This study investigated four research questions:

(1) How might CIDER-based activities impact students' self-efficacy as a designer?
(2) How might the CIDER technique help students recognize different types of exclusionary design biases?
(3) How might conducting CIDER-based activities collaboratively, rather than individually, impact students' experiences?
(4) What kinds of lasting impacts might the CIDER technique have on students' design approaches?

Finally, we discuss considerations for using the CIDER technique to teach inclusive design, as well as implications for our findings for future research on inclusive design pedagogy and educational practice. Our contributions are:

(1) The theoretically-grounded CIDER assumption elicitation technique for teaching inclusive design skills;
(2) An example of how the CIDER technique could be used in post-secondary introductory design courses to promote inclusive technology design; and
(3) Insights into how CIDER-based educational activities might promote better understandings of inclusion over time, with potential for lasting positive impacts on early designers' design approaches and attitudes toward inclusive design.

## 2 BACKGROUND AND RELATED WORK

The goal of this paper is to motivate and describe the CIDER assumption elicitation technique, as well as to explore its effectiveness in helping design students recognize and respond to bias. Our working definition of HCI/UX design in this paper draws on Park and McKilligan's model [68] and includes design practices related to interface, interaction, and UX design for HCI artifacts. We use the term *HCI artifact* inclusively to refer to both software and hardware with computational or computing-related components. For the purposes of this paper, we define an *assumption* within a design to be a way in which a design's features and affordances rely on the user to have particular capabilities, resources, means, or knowledge, without which they might find it difficult to interact with the artifact as intended by the designers[1]. We then define *design bias* to be the ways in which assumptions

[1]For instance, two assumptions which might be embedded in the design of a QWERTY desktop computer keyboard are that the user has enough fine motor control to press small keys in a particular sequence, or that they can recognize Latin/Roman alphabet characters.

might make it disproportionately difficult for particular (groups of) users to interact as intended with an HCI artifact, and *inclusive design* broadly to be an approach to or action of design work that recognizes and attempts to mitigate design biases.

In the following subsections, we motivate the need for a technique to teach inclusive design skills, drawing on work from HCI and UX education to illustrate challenges to learning and teaching inclusive design that arise in educational contexts. We also describe some of the ways in which students might struggle with designing inclusively for diverse user groups, highlighting the need for design methods to help students resist stereotyping behavior. We then draw on literature from software design and engineering to describe the role of assumptions in design through the lens of design rationale, illustrating how making assumptions visible can lead to higher quality designs. Finally, we describe how existing design evaluation methods may be used to surface assumptions (though assumptions themselves are rarely an explicit focus of existing methods), situating CIDER in the existing gap of evaluation methods designed for educational contexts that help students build concrete and actionable inclusive design skills.

## 2.1 Teaching and Learning Inclusive Technology Design

Though HCI education is a relatively young discipline [17, 88], there is a quickly growing focus on teaching computing students to critically consider the implications of the technologies they design. Fiesler et al. give an overview of the kinds of topics that are taught as "tech ethics," noting that much of this work has been published only within the past few years [27]. Some strategies for teaching the broader impacts of technology design focus on critiquing algorithmic design biases [73]. Others focus on teaching accessibility principles in standalone design courses [51], embedded in programming courses [41], or integrated throughout computing curricula [84]. Still others propose to help designers better understand the (sometimes conflicting) perspectives and values of various stakeholders, sometimes through techniques like Wong and Nguyen's *Timelines* value advocacy activities [93] or Cooney's notion of *micro-exposures* [20].

Nonetheless, prior work often reveals challenges that arise when teaching and learning design skills in computing-centric contexts. In general, teaching design principles to computing students can be difficult due to the ways that best practices for design pedagogy (c.f. studio approaches [6, 54]; "correctness" on wicked problems [25, 79]) conflict with the kinds of well-defined problems students tackle under traditional computing pedagogy [67]. Educators may not feel they have the expertise [77], time [42], or organizational supports [42] they need to properly teach accessible or inclusive design.

Students might also hold misconceptions about what design is or what it entails, leading them to devalue its importance. For instance, students can erroneously believe that design is strictly about aesthetics [67], that design work lacks rigor [16, 32], or that good design is just common sense [16]. These beliefs may be more prevalent among students with more technical backgrounds [50, 67], such as those in post-secondary HCI courses within computer science or information science programs. If these ideas are left unchallenged, students may have difficulty motivating themselves to address issues of inclusive design, implicitly assuming that these issues do not actually exist in in real-world designs or, at least, that they are not as critical as they are portrayed to be.

Sometimes, students may already value inclusion and inclusive design in an abstract sense, but they do not know how to translate those values into actual design decisions and actions, whether due to a lack of mechanical design knowledge [23] or of what inclusion means in terms of design [67]. Further, students with technical backgrounds can struggle with creativity when designing [24, 88] and fixate on what they consider to be design "standards" [63, 67], regardless of whether these designs actually fit users' needs. Prior work also suggests that the contexts in which early designers learn and practice design skills can influence their design values: If they are not supported, they might lose existing desires to prioritize inclusion in their designs [31, 86]. To ensure that learners who already value inclusion can translate their values into design practice, they need explicit support and scaffolding [15]. Otherwise, they may give up on designing inclusively due to confusion or a perceived lack of return on their efforts.

Students may also fail to recognize the connection between a designer's implicit biases and the way that these biases manifest in exclusionary designs. Designers, being human, inherently embed their biases and values into the artifacts they create [28], as well as their assumptions about users' capabilities, resources, and interaction styles [10, 21]. However, students do not always see the connection between the features of a design and the (implicit or explicit) beliefs of its designer. One reason for this is because software and other technical artifacts often carry perceptions of objectivity [2], making it difficult for early designers to understand the ways in which subjective choices manifest in design features. Another difficulty arises in moving students from considering only the features of a design to considering the broader contexts and systems of power that impact design decisions, especially if these contexts are never explicitly discussed or interrogated [79]. Either way, this challenge can lead to students misconstruing design bias as only a feature of an artifact itself, rather than a product of how the artifact's designer conceived of users or of the world during its creation.

Here, it is worth distinguishing the harmful design biases discussed in this paper from the standpoints and subjectivities of designers themselves. No early designer approaches a design problem as a completely blank slate. They are informed by their prior understandings of the world and their lived experiences. In the realm of engineering design eduction, Svihla et al. recently explored how enabling students to draw up on their personal *funds of knowledge* might help first-year students engage more deeply with design problem framing [81]. First-year students who engaged with design problems that allowed them to draw upon their community, family, or recreation-based prior knowledge succeeding in framing problems in expert-like ways, even more so than senior design students who were given more traditional design problems. Funds of knowledge-based approaches like these allow students to integrate their expertise in areas other than design into design learning—a particularly notable benefit when considering the broader power structures at play within formal education and how traditional academic contexts can de-legitimize knowledge of people from various, often intersectionally minoritized groups [90, 91]. Designers' subjective perspectives are not the problem when it comes to teaching and learning inclusive design: Instead, issues of inclusion arise when students do not *recognize* the ways in which their perspectives and experiences differ from others', and thus make inaccurate assumptions about how their users move through the world, which can result in biased designs. The technique presented in this paper aims to help students learn how designers' conceptions of their users concretely impact the inclusiveness of existing designs, so that students might later be more aware of their own biases during design processes.

A final challenge around teaching and learning inclusive design is that students can struggle to understand the perspectives of users different than themselves without resorting to stereotyping. Attempts to address this challenge often take the form of strategies, design methods, or tools that help students perspective-take or empathize with different kinds of users, such as through participatory/co-design methods [3, 51, 89, 94], use and co-creation of personas that focus on different aspects of users' identities [1, 5, 62], or variations of standard design evaluation methods such as cognitive walkthroughs [30, 55, 66]. Developing students' empathy skills is often seen as an important goal among HCI and UX design educators [88], though educators may find it difficult to support empathy development "amongst [the] young cognitively and physically high-performing students" that tend to dominate many computing and information science departments [49]. Early designers might also believe that they "just know" what different kinds of users want without having to do user research [79]. Students often may lack the prior experience or knowledge base needed to be aware of the ways that users with different capabilities, identities, and contexts might interact with designs, especially if they are part of one or more privileged groups [67, 71]. In the worst cases, this line of thinking can lead to stereotyping of marginalized groups during the design process: empathy-based methods may privilege the perspectives of the designer over those of actual users, leading to designs that embed biases and harmful stereotypes [3, 4, 8]. A successful method for teaching inclusive design skills should help early designers navigate these tensions, supporting productive empathizing while minimizing stereotyping behavior.

## 2.2 Design Rationale and the Role of Assumptions

Designers make decisions during their design processes that involve consideration of multiple variables, such as their understandings of the design space, its constraints, any given requirements, and user needs and preferences, among others. The reasoning behind these decisions is known as *design rationale*, and serves as justification for a designer's choices. Prior work from the area of software design suggests that documenting rationale during the design process can lead to higher quality final designs [9, 47] because it allows for designers to better account for artificial limitations they unintentionally placed on the design space [76]. Making design rationale explicit can also provide guidance for future design re-use efforts and concentrate organizational knowledge that might otherwise be diffuse or implicit in single, more easily accessible locations [46].

Because a single designer (or even a team of designers) can never have perfect information about the world, their users, or unanticipated interactions of either of these with their proposed design, they tend to rely on assumptions to make design decisions [48, 85]. Assumptions made during the design process are not always explicitly documented or even consciously recognized on the part of designers [7, 70]. As a result, these assumptions can be vectors for design bias, especially when designers assume certain things about potential users' ability levels, social or cultural contexts, or access to resources. Unless particular traits or characteristics about users are specified, technology designers tend to fall back on designing for users of socially dominant or majority races, genders, ages, cultures, and/or classes—even if the designer themself is from a historically marginalized group [21]. Explicitly surfacing and documenting assumptions made during the design process provides one way to catch potentially harmful biases and, ideally, to minimize their impacts on design decisions. This notion is supported by prior work on the role of assumptions within software rationale documentation, which suggests that augmenting rationale with explicit assumptions can help identify intervention points for improving a design, because it enables detection of parts of a system that rest on incorrect assumptions [9].

If assumptions are not caught during the early stages of the design process, they might also be identified and addressed using various design evaluation methods. Designers might turn to empirical methods such as usability studies, technology probes [37], or experience sampling techniques [19] to better understand how potential users might interact with their designs in more authentic contexts. The information gained through these methods can reveal hidden assumptions that were made during the design process which break down upon exposure to different interaction styles or preferences. Empirical design evaluation techniques can be used to test the efficacy or utility of a design, but they generally frame these findings around the designer's conceptions of their users. As a result, though empirical evaluation methods can reveal information that signals the existence of inaccurate user assumptions in a design, they do not support students in explicitly identifying the assumptions themselves or in drawing connections between embedded assumptions, design bias, and design decisions.

Alternately, designers might also employ analytical design evaluation methods to surface assumptions that are embedded within their designs. For instance, the claims analysis aspect of scenario-based design [13, 14] provides a causal mechanism for tying design features to design rationale. Claims analysis can help designers articulate ways in which different aspects of their design afford (or preclude) various outcomes and reactions on the part of users, and might serve to reveal embedded assumptions about users' environments, contexts, or preferences, though the core method does not explicitly reference inclusion as a design goal. Analytical methods like heuristic evaluations [64] and cognitive walkthroughs [87] might also help reveal erroneous assumptions designers made about a user's prior knowledge or preferred interaction styles.

Another analytical method designers might use to understand their users is the empathy map [40]. Several variations of empathy mapping techniques exist, but the key goal of empathy maps is to make users' underlying traits apparent by cataloguing what a user might see, think, feel, or otherwise experience [78]. Fernández and Martínez explored the effectiveness of empathy maps in helping undergraduate students understand the nuances of marketing consumer research, finding that students saw value and utility in the technique's practicality, but that teacher guidance and prior research methodology expertise were required for students to use them most effectively [26]. Empathy maps may help reveal gaps in design rationale, especially if they are informed by primary user research or co-developed with users, and can certainly illustrate alternate perspectives that designers may not have considered previously, which may positively impact inclusion. However, the empathy map method does not explicitly foreground the role of assumptions in the design process, which may not support early designers in making critical connections between designers' conceptions of users and their final design's features.

When targeting inclusive design in particular, designers might use modified analytical evaluation methods which specifically aim to evaluate gender [80], socioeconomic status [55], or cultural [1] inclusiveness. There is a small yet growing body of work that investigates how educators might use single-facet inclusiveness-focused analytical evaluation methods in the classroom, such as Oleson et al.'s GenderMag-Teach effort [66], or Anvari et al.'s investigation of cross-cultural persona use in a large user-centered design class [1]. However, in general, the analytical design evaluation methods described above were not originally designed for education purposes. Existing inclusiveness-focused analytical evaluation methods are not well-suited to address the particular problems students face when learning inclusive design skills (described in the previous section), nor are they targeted at early designers who are just learning the basics of the discipline. Further, similar to empirical design evaluation methods, these methods rarely frame their insights in terms of assumptions about users or provide the scaffolding learners need to tie assumptions, design bias, and inclusion together. In contrast, our proposed technique was created to be used in educational contexts, directly addressing several challenges and misconceptions students face when learning identify assumptions and design inclusively.

## 3 CIDER: CRITIQUE, IMAGINE, DESIGN, EXPAND, REPEAT

To help students learn to design more inclusively, we created the CIDER assumption elicitation technique (Figure 1), which stands for *Critique, Imagine, Design, Expand, Repeat*. This technique leverages guided critique, brainstorming, and feedback to help students understand how biased assumptions can manifest in design features and exclude people from interacting with a design as intended.

The goal of CIDER is to help students identify the ways that designers' implicit or explicit assumptions about user ability, capacity, environment, or resources concretely manifest in and contribute to exclusionary interface designs. The technique we describe here was originally intended for use in post-secondary design contexts that emphasize technology design and development, such as a HCI or UX design class, but the underlying principles may transfer to other contexts like K-12 computing education as well. A complete CIDER-based activity consists of the educator choosing an artifact of analysis, and then five major stages students progress through (see Figure 1). If time constraints require, educator might only conduct a single CIDER activity in their course—according to our case study, even a single CIDER activity may still contribute to better understandings of inclusive design. However, we found the best results to occur over time with reinforcement and repetition, conducting a series of CIDER activities over a span of several weeks and using a different artifact of analysis each time. This multiple-use approach enabled consideration of a broader range of assumptions, because different artifacts' interaction styles can make different types of assumptions more or less salient to students[2].

[2]For instance, we found that our participants only surfaced assumptions related to users' potential hearing ability when the artifact under analysis had a strong audio-based component to its interactions (Zoom video calling software, Google Home voice assistant). However, students identified assumptions related to users' potential visual ability across all activities.

As described in Section 2.1, students may face a number of difficulties when learning and practicing inclusive design skills. The CIDER technique was designed to target five of these challenges in particular:

(1) **Motivating inclusion:** Students may devalue design work or believe inclusion issues do not really exist in "real-world" designs, lacking motivation to learn and practice inclusive design [16, 32, 50, 66, 67].
(2) **Connecting features to assumptions:** Students, especially those with little design experience, may not recognize the connection between exclusionary design features and a designer's assumptions about users' capabilities and contexts [2, 20, 21, 28, 79, 92, 93].
(3) **Designing for diversity:** Students may implicitly design for users as a homogeneous population, failing to recognize and account for diversity, especially if they do not have extensive knowledge bases of user experiences to draw upon [1, 21, 49, 63, 66, 79, 80].
(4) **Acting on inclusion goals:** Even if they value it already, students may struggle to move from abstract appreciations of inclusion as a goal to concrete design actions they can take to reduce or mitigate design biases [15, 31, 66, 67, 86].
(5) **Avoiding stereotyping:** Students may struggle to understand the perspectives and experiences of users who are unlike themselves without resorting to stereotyping [4, 49, 67, 71, 79, 88].

Below, we describe how the CIDER technique addresses each of these challenges, beginning with the educator's choice of artifact and progressing through the five stages students engage in as they progress through the activity (Figure 1). For clarity, we provide a running example throughout the following section, using a common QWERTY desktop keyboard as a basis and providing illustrative quotes from participants in our case study. For the purposes of this paper, when referring to the five named stages of CIDER, the stage names appear capitalized and in monospace font (e.g. `CRITIQUE`).

### 3.1 Set-up: Educator selects a real-world HCI artifact for students to analyze

In preparation for conducting one of these activities, the educator first chooses some existing, real-world HCI artifact for students to critique using the CIDER technique process. This artifact could be any piece of software or hardware that has an interface and/or affords user interactions, but ideally should be a piece of technology that students are aware of, and possibly that they have interacted with before. For instance, some of the artifacts we used for CIDER activities in our case study included a Google Home digital voice assistant, the Zoom video calling desktop software interface, and an informational webpage from the university's website.

Once the educator chooses an artifact, they then find a way of conveying the design's features and interactivity to students in a way that fits the medium of instruction. For smaller, in-person courses, the educator might bring in an example of the artifact for students to interact with before the activity. In larger or remote learning courses, the educator might gather some images of the artifact or direct students to a electronic prototype. For the purposes of our case study, which was conducted during a period of exclusively remote learning necessitated by the COVID-19 pandemic, we found promising results using a combination of images of the artifact (one or more screenshots or pictures showcasing different functionality) along with a basic textual description of the device or interface's most salient features. For instance, our description of the desktop keyboard used as an example throughout this section highlighted the standard QWERTY layout of the board's English characters and symbols, its ten key number pad, the indicator lights in its upper right corner, and the board's USB wired connection which allows people to input text and command sequences to connected devices.

*3.1.1 Challenge addressed: Motivating inclusion (1).* Critiquing a real-world artifact and uncovering biases and assumptions present within its design helps students begin to understand that no design is infallible, and that inclusion issues truly do exist in the products around them. This can serve to motivate resistant learners [66] who may be skeptical of the existence or severity of design inclusion issues.

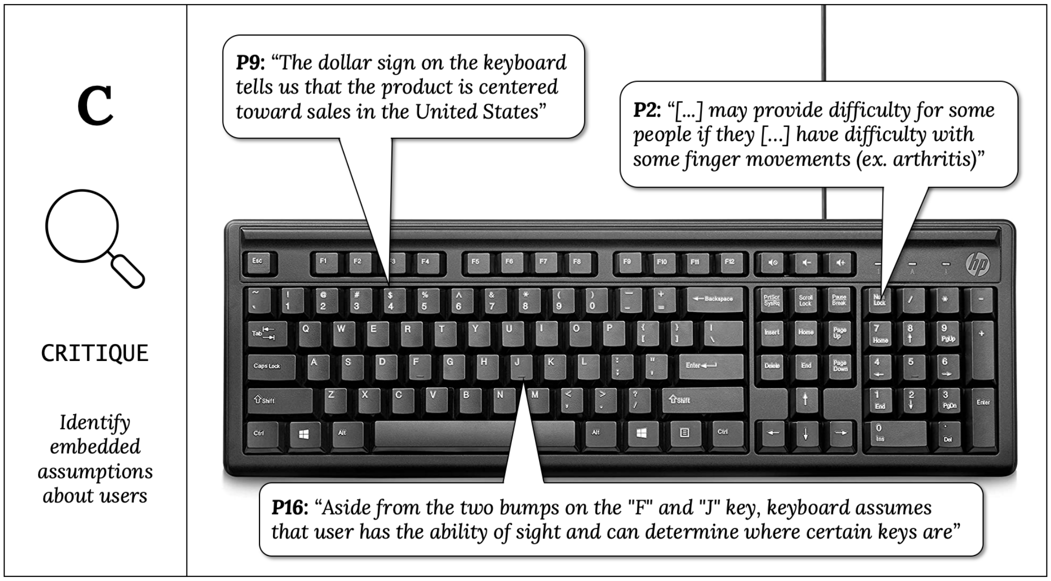


Fig. 2. Stage 1 of CIDER: CRITIQUE. Students draw on their prior knowledge and experiences to identify ways in which a design might rest on assumptions about users.

This also provides an opportunity for students to connect their own prior experiences and expertise to course content, which can increase engagement and motivation for learning inclusive design concepts [59, 61]. Using existing artifacts rather than students' own designs as the object of analysis also means that CIDER activities can be assigned and completed earlier in the course, conceivably as early as the first or second session of instruction, as there is no need to wait for students to gain enough design competence to create something of their own. When integrated into a course's early stages, the explicit focus on inclusion present in CIDER activities can even help to set a tone of considering human diversity when designing, contributing to foundations of inclusive design knowledge. Finally, because early designers may struggle to objectively and accurately critique their own designs, focusing CIDER activities on artifacts designed by others first can help circumvent blind spots obstructing recognition of biases.

### 3.2 C: Students CRITIQUE the artifact's design to identify embedded assumptions about users

Once the artifact of analysis for a CIDER activity is chosen, students can begin to identify its embedded assumptions. In the CRITIQUE stage, students list as many assumptions about users' potential capabilities, contexts, environments, and/or available resources as they can identify within the design. In our case study, for this stage, we used the prompt *"What assumptions do the designs make about users' potential interactions with the devices? List as many as you can think of in the next 3-5 minutes or so (bullet points encouraged)"*, along with an example assumption provided by the educator for clarity. Illustrative examples of students' responses can be found in Figure 2. In this stage, students should be encouraged to identify many different types of assumptions rather than focusing on in-depth descriptions of one or two assumptions. This helps resist fixation and encourages students to draw deeply upon their own experiences, observations of others, or other prior knowledge to identify how a design's features might present barriers to users.

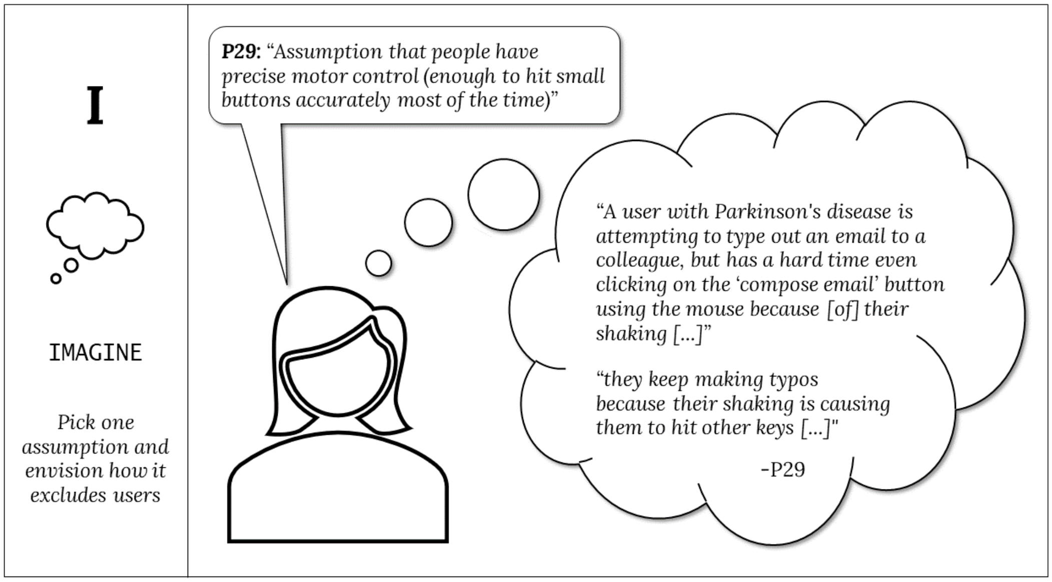


Fig. 3. Stage 2 of CIDER: IMAGINE. Students choose one assumption they identify and describe a scenario in which that assumption prevents a user from engaging with or using the design.

*3.2.1 Challenge addressed: Connecting features to assumptions (2).* Explicitly framing the shortfalls of a design in language like *assumptions* made by designers about users, *bias*, *inclusion*, and *exclusion* is key to addressing student learning challenges around how assumptions might manifest in design features. Using this frame helps to dispel notions of objectivity about design that early designers may hold [67], such as the belief that there is a "correct" design that will work for everyone. This emphasis on subjectivity highlights how designers' conceptions of their users influence their design decisions, making the connection between a designer's assumptions, design bias, and exclusion apparent. Using assumptions as a lens for critique helps students keep in mind that HCI artifacts are used in real-world contexts by a wide array of people, not by stereotypical "average" users or in "ideal" conditions. It also exemplifies the responsibility students might have as future designers to consider a wide range of user capabilities and contexts: If they are aware of the impacts their design decisions might have, they may be more inspired to value inclusion and interrogate their own assumptions within their own design processes.

## 3.3 I: Students IMAGINE how a particular assumption might lead to exclusion

Once students have identified some assumptions about users within a design, they can begin to consider how the design might be inaccessible to some users. In the IMAGINE stage, students choose an assumption from the list they created in the CRITIQUE stage. Then, they come up with a short scenario in which the artifact's design breaks down, describing how a user for which the chosen assumption is inaccurate might not be able to interact with the artifact as its designers intended. Our case study's CIDER activities used the prompts *"Select one of the above assumptions that you think is important to address"* and *"Write a 1-2 sentence scenario where a user could not use the [artifact] as expected because of the assumption you selected. This represents one way the design could*

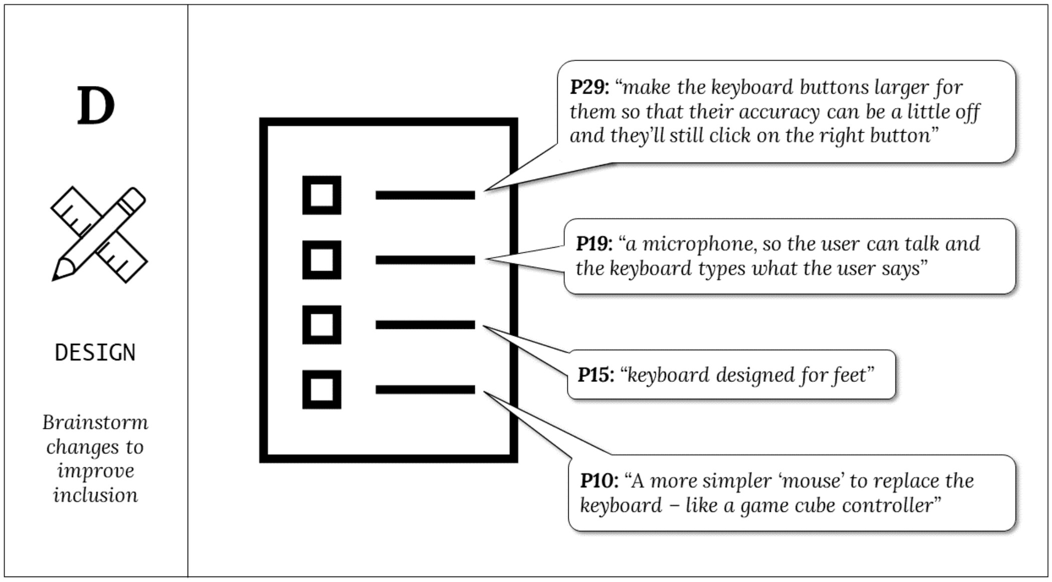


Fig. 4. Stage 3 of CIDER: DESIGN. Students brainstorm several changes to the design that would address the scenario they came up with in the IMAGINE stage, removing barriers to access. Students are encouraged to think of as many ways to improve the design's inclusion as they can, regardless of potential feasibility.

*exclude certain users."* One participant's chosen assumption and imagined scenario of exclusion for a QWERTY desktop keyboard can be found in Figure 3.

*3.3.1 Challenges addressed: Designing for diversity (3), Avoiding stereotyping (5).* Asking students to imagine a scenario where the design breaks down for a particular user helps refute the implicit misconception some students may have that users are a monolithic, homogeneous population, addressing challenges students might have around how to design for diversity. The scenario students imagine is a direct counterexample to the inaccurate notion that what works well for one user can or should work well for everyone. Further, framing design bias and exclusion as scenarios of usage centers the actual people affected by the artifact's design. As mentioned previously, it can also be difficult for students to properly empathize with users unlike themselves without stereotyping. To circumvent this, the IMAGINE stage asks students to focus on the concrete impacts that the design bias might have on a person that could prevent them from fully interacting with a design as intended. In this way, this stage of the technique provides some scaffolding for understanding the ways in which someone might not be able to interact with a design due to bias, while resisting students' potential unintentional reductions of minoritized populations to stereotypes.

## 3.4 D: Students practice DESIGN by brainstorming ways to address the assumption and make the artifact's design more inclusive

After envisioning a scenario of exclusion in the IMAGINE stage, students have a concrete starting point from which to begin thinking about improving a design's inclusion. In the DESIGN stage of the CIDER technique, students brainstorm ways to change or adapt the artifact's design which would circumvent the scenario they described, listing as many as they can. Our case study CIDER activities used the prompt *"Brainstorm ways to change the*

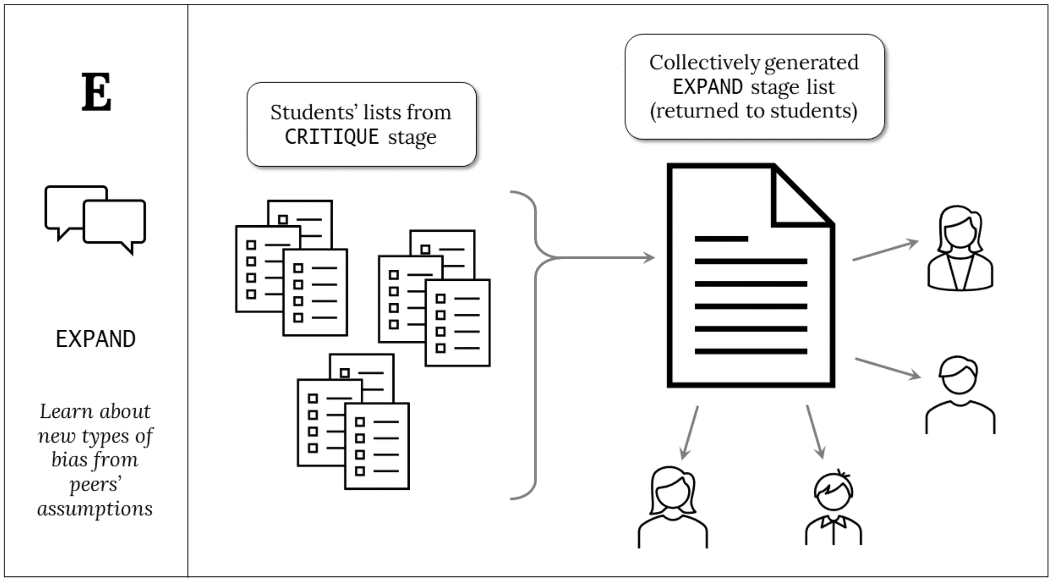


Fig. 5. Stage 4 of CIDER: EXPAND. The instructor collects the lists of assumptions students came up with during the CRITIQUE stage and uses them to create an overall list of assumptions embedded into the design, augmenting with their own expertise when necessary. The EXPAND list is made accessible to students and integrated into the next stage's activity.

*design of the [artifact] to avoid the scenario you wrote above. List as many different kinds of potential solutions you can think of over the next 3-5 minutes – aim for ten or more. Bullet points encouraged."* Several participants' responses to how one might modify or change a QWERTY desktop keyboard to avoid relying on the assumption that a user has fine motor control in their hands can be seen in Figure 4.

*3.4.1 Challenge addressed: Acting on inclusion goals (4).* By brainstorming with assumptions about users in mind, students practice coming up with actionable ways to address design bias and improve inclusion, helping them transition from abstract inclusion goals to concrete design actions. Targeting a specific assumption and a specific scenario of exclusion helps reduce uncertainty about what inclusion means or how to increase inclusiveness of a design. Further, asking students to come up with multiple different ways to address one assumption underscores that there is not necessarily a single "correct" answer to improve the artifact's inclusiveness. For simplicity's sake, the CIDER activity generally frames inclusion as reduced or mitigated barriers to use which in turn increases access for more user populations, similar to definitions used by Keates et al. [43, 44] and Goodman-Deane et al. [29], However, a design modification which increases access for one user does not necessarily lead to increased access for all users. Asking students to brainstorm several solutions encourages consideration of tradeoffs and constraints which might make some solutions more well-suited to addressing an inclusiveness issue than others.

### 3.5 E: Students EXPAND their understandings of inclusive design by engaging with peers' responses

While progressing through the previous stages of CIDER, students produce two lists—one of identified assumptions, one of brainstormed changes—and a scenario of potential design exclusion. In the EXPAND stage (Figure 5), the educator collects and combines students' lists of assumptions from the CRITIQUE stage to create a collective, more complete list of the assumptions embedded within the artifact's design. The goal of the EXPAND list is to be

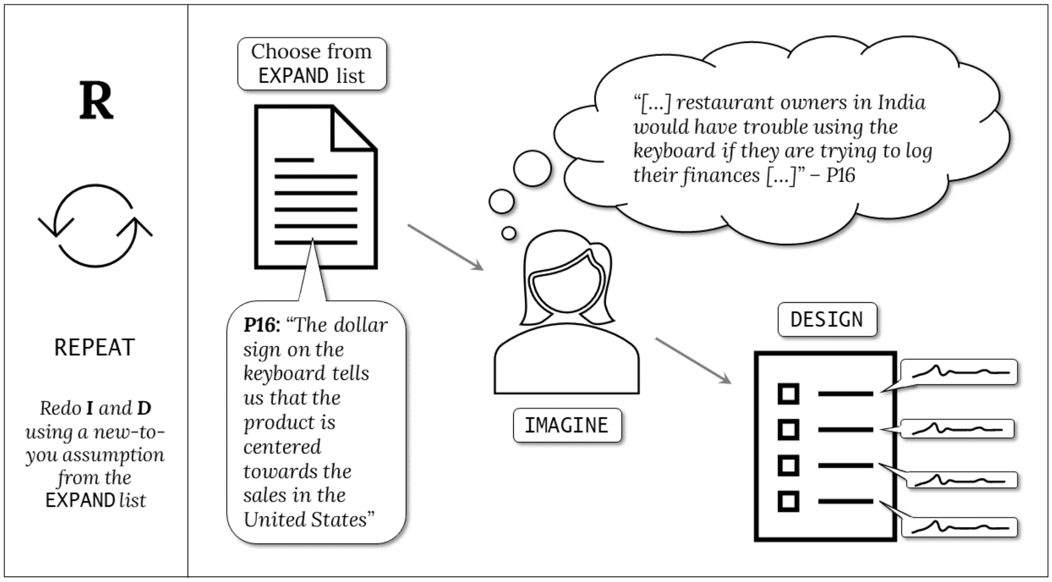


Fig. 6. Stage 5 of CIDER: REPEAT. Students review the EXPAND list and select an assumption which they had not identified during their own CRITIQUE activity. Students then go through the IMAGINE and DESIGN stages again using the new assumption.

a single, shared resource that details a wide breadth of assumption types, giving an overview of the *assumption space* for the artifact. In this way, the collectively-generated EXPAND list serves as a way for students to learn about new types of bias from their peers' responses and consider assumptions that they had not identified in their own work. Representative assumptions can be copy-pasted directly from students' submissions to build the list, or they can be paraphrased for clarity as needed. Once this list is made, the educator shares it back to the class and integrates it into the final part of the CIDER activity. In our case study, the educator accomplished this by collecting students' lists of assumptions, then manually reviewing and combining them into a single list, removing duplicates and augmenting the list's assumptions with their own expertise if there were any obvious gaps. The educator then posted the EXPAND list to the class's shared cloud storage space, encouraging students to review the list once it was available, and integrating it into the final part of the activity.

*3.5.1 Challenge addressed: Designing for diversity (3).* This stage serves as a key source of feedback for students, which is important for promoting learning [59]. The EXPAND list provides a means for students to compare the assumptions they identified on their own against the more complete list comprised of educator and peer-identified assumptions, revealing new perspectives they had missed and expanding their awareness of the assumption space for the artifact. Engaging with the breadth of assumptions covered in the EXPAND list helps students to build their knowledge bases of user experiences and design exclusion. By reflecting on the perspectives of their peers, students become aware of more ways users' capabilities and contexts can differ and how they might then design for different experiences.

### 3.6 R: Students REPEAT stages IMAGINE and DESIGN using a peer's assumption

To complete the CIDER technique, students draw upon their peers' knowledge bases and consider how a new type of design bias might lead to exclusion. In the REPEAT stage, students review the collectively-generated list of assumptions from the EXPAND stage and select one that they feel is important to address, but that they had not surfaced themselves during their own previous critique of the artifact. They then repeat the steps of the IMAGINE and DESIGN stages using this new assumption as a focus. Our case study's activity included the prompt *"Select another assumption from the list above that you think is important to address. Make sure to choose a different assumption than you used for [previous critique]. Choose one that you didn't even come up with during [previous critique], if possible"* for this stage, followed by similar prompts to those already described in the IMAGINE and DESIGN subsections. An example of a participant's chosen assumption from the EXPAND list and their accompanying scenario of exclusion can be found in Figure 6.

*3.6.1 Challenges addressed: Connecting features to assumptions (2), Designing for diversity (3), Acting on inclusion goals (4), Avoiding stereotyping (5).* Repeating the middle stages of the CIDER technique with a new assumption gives students more practice imagining scenarios of design and brainstorming concrete ways to address design bias. By using an assumption they had not identified themselves previously, students are also guaranteed to expand their knowledge of how design exclusion manifests by at least a single instance of bias. The repetition of these stages helps reinforce the connections between designers' assumptions and potential design bias, diversifying students' knowledge bases concepts and helping them generalize to broader understandings of inclusive design principles.

## 4 CASE STUDY: METHOD

To evaluate the efficacy of the CIDER assumption elicitation technique, we conducted a case study in an introductory design methods course which spanned eleven weeks of instruction and concluded with follow-up interviews a month after the course's conclusion. The technique was integrated into the course through five individual CIDER activities using different artifacts of analysis, and one team CIDER activity. We followed the concurrent embedded approach to mixed method research [22], collecting quantitative data to explore students' changes in design self-efficacy (RQ1) alongside qualitative data to understand students' experiences with both individual (RQ2) and collaborative (RQ3) CIDER activities, and supplementing these understandings with qualitative analyses of post-course interviews (RQ4). The study explored the following research questions:

(1) How might CIDER-based activities impact students' self-efficacy as a designer?
(2) How might the CIDER technique help students recognize different types of exclusionary design biases?
(3) How might conducting CIDER-based activities collaboratively, rather than individually, impact students' experiences?
(4) What kinds of lasting impacts might the CIDER technique have on students' design approaches?

### 4.1 Study Context

*4.1.1 Course context: Accessibility-heavy design culture; Remote learning.* The course we used for our case study was an undergraduate introductory design methods course in the information science department at the University of Washington, a large, public, United States-based university. The course focused on the design of user interfaces and interactive hardware and software-based systems. The instructor of record for this course was the first author, who had one prior term of teaching experience with the course. Based on their own background, the instructor taught from the perspective that designs are never value-neutral, and as a result that designers have a responsibility to carefully consider the interaction styles and preferences of many different types of users

| Week | Topics Covered | CIDER Activities |
|---|---|---|
| 1 | Class structure; What designers do | |
| 2 | Design process; Understanding problems (First mention of accessibility/inclusion) | QWERTY keyboard and mouse |
| 3 | Defining problems; Brainstorming | Zoom video calling software |
| 4 | Sketching; Prototyping; Interface design | University COVID-19 info site |
| 5 | Critique; Empirical evaluation | Google Home voice assistant |
| 6 | Analytical evaluation; Midterm | Revo R180 touchscreen toaster |
| 7 | Project: Research, Problem definition | |
| 8 | Project: Peer critique, Brainstorming, Low-fi prototyping | |
| 9 | Project: Peer critique, Feedback from users, Iteration | |
| 10 | Project: Evaluation, Limitations, High-fi prototyping | Collaborative activity on project prototype |
| 11 | Project: Design specification submission | |

Table 1. The schedule of the course, including topics covered each week. Students did five individual CIDER activities on different artifacts from Week 2 to Week 6 of the course, then a collaborative CIDER activity on their own prototypes in Week 10. Due to the nature of instruction, the concepts of accessibility and inclusion were introduced early on in the course and integrated throughout many of the topics.

throughout their design processes. Given this, the notion of accessibility and inclusion was introduced early on through course readings and integrated throughout many of the topics and design exercises that followed.

The particular university at which the study took place has a strong design culture in its computer and information science departments and tends to emphasize human-computer interaction (HCI) and accessibility in its research focus. While this creates a favorable environment to deploy and explore inclusive design learning techniques, it also means that the students at this university may be more aware of or open to inclusion-related topics than students elsewhere. It is possible that our case study would have produced different results if conducted at an institution whose technical departments were less favorable toward design and HCI. Future work should explore this possibility, evaluating the utility of the CIDER technique across a broad variety of learning contexts.

The course was taught during one of the first fully remote teaching terms necessitated by the COVID-19 pandemic. This required several changes to the typical course structure to ensure that students could engage with all the course elements entirely online. For instance, due to inherent inequities in requiring synchronous remote learning, the instructor allowed for students to participate in discussions either in synchronous small groups over video calling platforms like Zoom, or on asynchronous class discussion boards. It also required us to adapt the CIDER activities to a format that worked for remote learning. As we describe later on, we did still see strong evidence of inclusive design learning even in remote learning contexts, though future work should investigate potential benefits and tradeoffs of conducting CIDER activities in-person or online. The above factors may be considered limitations to the interpretations of our findings, but also additional context to better understand the backdrops against which our results arose.

*4.1.2 Course structure.* There were no prerequisites for the course, so we assumed no particular level of prior design knowledge or experience on students' parts. The course itself covered topics from the basics of what design entails and what roles designers play in making a product, to how to work through the various stages of the design process (using the Design Thinking framework [11] as foundation for instruction). A detailed schedule of topics can be found in Table 1 alongside a timeline of the course, which spanned eleven weeks (ten weeks of instruction plus one week of final exams).

The first part of the course (Weeks 1-6) followed a flipped classroom paradigm in which students read material about design foundations on their own and then participated in class discussions about the topics. As mentioned previously, many of these discussions took place on electronic peer discussion boards due to the nature of remote learning. To gain experience with design work, students also did *deliverables*, weekly activities where they practiced design techniques (ideating, brainstorming, critiquing, etc.) synchronously with a partner.

To give students experience designing alongside others, introductory design courses often include team projects as an aspect of instruction. Our course integrated a final project during the latter part of the class (Weeks 7-11). In teams of 2-3 members, students were tasked with coming up with an original design concept, moving through design stages from user research, to brainstorming and ideation, low and high-fidelity prototyping, and iterative critique over the course of four weeks (see Table 1 for details of timing). The theme of the projects for the course was to address an information gap that contributed to systemic inequality on campus or in the surrounding city. Students practiced communicating their design processes in the form of a design specification, where they wrote up the results of their user research, described their design concept and their design evaluation processes, and finally elaborated on any known limitations of their design concept.

*4.1.3 Participants.* There were 40 students enrolled in the course. Students could enroll at any undergraduate class standing and without necessarily needing to be in the information science major, though the course was required for students enrolled in the major. Thirty-two students self-reported computer or information science as their current or intended major field of study. Four students reported that computer or information science was their current or intended minor (with majors in other disciplines). Three students self-reported other major fields of study, and one student declined to report this information.

We also asked to students to describe any prior design experience they had. Nineteen students self-reported that the only design experience they had was from prior classes (one of the courses traditionally taken before this one was a survey course which included a small design project). Ten students reported that they had done design for their personal, non-class projects, such as creating an interface for a website or mobile application. Six students reporting having some professional experience with design such as an internship. Only five students reported having no design experience prior to the course. To get a sense of students' perceived design expertise, we additionally asked them to fill in the blank of the statement *"I consider myself to be a <blank> designer"* with one of five options. The majority of students considered themselves *novice* (14) or *between novice and intermediate* (18) designers. 4 students considered themselves *intermediate* designers, and 2 considered themselves *between intermediate and expert*. No students considered themselves *expert* designers.

*4.1.4 CIDER activity integration.* Throughout the course, students completed six CIDER activities: five individual and one collaborative. Due to the remote nature of the course, all the activities were electronic-based formats hosted on the Canvas learning management system, the details of which are described below. To mitigate potential response bias on students' parts, all CIDER activities were graded only on completion—As long as students filled out each question of the activity and submitted it by the deadline, they automatically received full credit. The instructor disclosed to students that their responses to CIDER activities would be analyzed as part of a research study through the syllabus, through a addendum on the activity description itself, and during the first optional synchronous class meeting as they gave an overview of the course structure. In all these cases, students were made aware that they could elect for their responses not to be analyzed for research purposes by notifying either the instructor or the TA (who was unaffiliated with the research project) at any point before the end of the term, and that this choice would not have any impact on their grades or other personal course outcomes. No students opted out of participation in the study.

**Individual CIDER activities.** From Weeks 2 to 6 of instruction, students completed CIDER activities individually (see Table 1). Figure 7 shows the timing and generalized structure of these CIDER activities, with the tags (`CRITIQUE`, `EXPAND`, etc.) referencing the corresponding stages described in Section 3. Part 1 of each activity

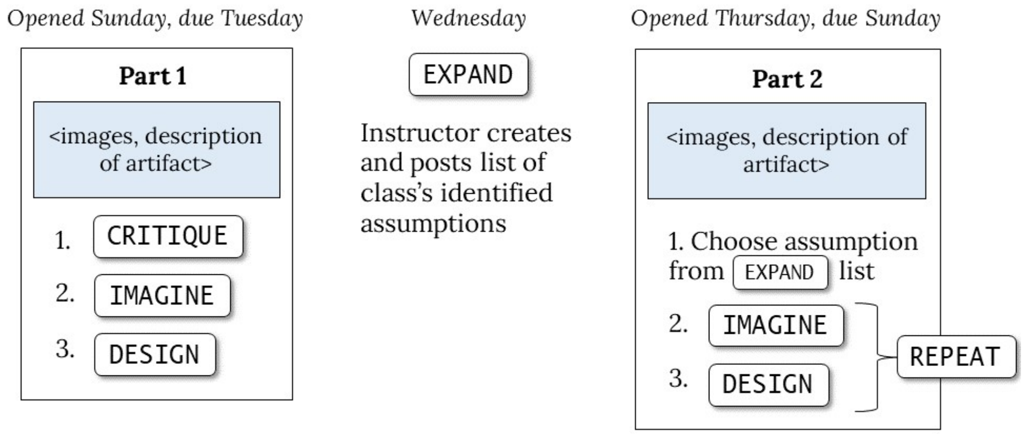


Fig. 7. The structure and timing of the individual CIDER activities used for the case study in Weeks 2-6 of instruction. The wording used for each stage's prompts can be found in the corresponding subsection of Section 3.

opened to students on Sunday afternoon, was due by the following Tuesday, and contained activity prompts for the `CRITIQUE`, `IMAGINE`, and `DESIGN` stages. The instructor compiled the week's `EXPAND` list of student-generated assumptions each Wednesday, posting the results in the class shared Google Drive and embedding the list into the Part 2 assignment for easy access. Part 2 of each CIDER activity opened on Thursday, was due the following Sunday morning, containing the prompts pertaining to the `EXPAND` list and the `REPEAT` stages of the technique.

Each CIDER activity used a different HCI artifact of analysis, chosen to represent a variety of interaction types, interface styles, and usage contexts.

- Week 2: A QWERTY desktop keyboard and mouse designed for use with a Windows computer, chosen as an example of physical hardware that required lots of fine motor interaction.
- Week 3: The Zoom video calling platform desktop interface, chosen as an example of a relatively resource-heavy software that students were familiar with and that required video and audio-based interactions.
- Week 4: An informational webpage published by the university about COVID-19 and related classroom policies, chosen as an example of a software. interface with a very information-dense structure
- Week 5: The Google Home digital voice assistant device, chosen as an example of an artifact that relied largely on audio-based interactions rather than visual components.
- Week 6: The Revo R180, a toaster with a digital touchscreen interface, chosen as an example of a non-standard touch-based interface intended for use in a context where HCI artifacts are generally less common.

These individual activities were implemented as timed quizzes on the Canvas learning management platform. We chose to enforce a time limit of 30 minutes on each CIDER activity to avoid students spending excessive amounts of time on it during remote instruction, because these activities were originally intended to take no more than 10-15 minutes when integrated into a more traditional in-person classroom setting.

**Collaborative CIDER activity.** To explore the impact that collaboration and teamwork might have on students' experiences using the CIDER technique to identify potential design bias, we created a version of a CIDER activity that could be done in teams. The collaborative CIDER activity might be considered more similar to a professional design context, in which designer teams critique and evaluate their own artifacts, considering the needs of different groups of stakeholders. Project teams completed this collaborative activity during the final week of instruction (Week 10, see Table 1). The collaborative activity was positioned within the class as one way for teams to identify limitations of their designs, which they were required to report on in their final design specification writeups. To mitigate potential response bias from teams, the instructor took the same measures as they did for the individual CIDER activities. Additionally, the instructor made clear to teams that they would not view teams' collaborative CIDER activity responses and feedback until after final grades had been submitted.

The collaborative CIDER activity was similar in concept to the previously described individual CIDER activities, though it had several notable differences in format which enabled us to investigate the CIDER technique's utility in this new context:

- It was performed in teams, rather than individually. Teams consisted of 2-3 students, save for three students who opted to complete their projects individually. (Data from the students who worked individually was excluded from analysis for the purposes of this research question, because we were interested in collaborative aspects.)
- Instead of performing the activity on an existing artifact which was designed by someone else, teams were asked to use the CIDER technique on their own high-fidelity prototypes.
- As teams were identifying assumptions in their own designs and each team's artifact of analysis was different, the instructor did not create collective assumptions lists (i.e. the CIDER `EXPAND` stage was not present). However, all previous lists from the previous `EXPAND` stages of the individual CIDER activities were available to students for reference, if they wished to use them as a resource (and, as described later, many did).
- As a result of the above bullet, when teams did the final stage of CIDER (`REPEAT`), they simply chose a second assumption from their own list to ideate on, rather than using someone else's assumption.
- Unlike the individual CIDER activities, we did not enforce a time limit on the collaborative CIDER activity, because we felt doing so might unfairly disadvantage students whose teams were spread across multiple time zones or who otherwise found it difficult to meet synchronously during a remote learning quarter.

These collaborative activities additionally contained five open-ended questions for teams about the role of collaboration in their process for the CIDER activity (see Section 4.2.3), as well as asking them to reflect on the experience they gained over the course of the term and some final thoughts on the activity's usefulness.

## 4.2 Data Collection and Analysis

Three researchers participated in data collection and analysis:

- The first author, a computing education researcher with six years of research experience in inclusive software interface design methods, including three years researching HCI education within that space and half a year of teaching experience in post-secondary computing contexts. The first author was also the instructor for the course in which the case study took place. They conducted the statistical analyses of students' self-efficacy for RQ1 in addition to participating in the collaborative qualitative analyses for RQ2, RQ3, and RQ4.
- The second author, a research assistant with two years of research experience in computing education and design methods as well as two years of UX design experience. The second author had expertise in qualitative methods and interviewing, conducting the post-class interviews for RQ4 as well as participating in the collaborative qualitative analyses for RQ2, RQ3, and RQ4.
- The third author, a research assistant with four years of experience in inclusive software interface design methods, including two years researching HCI education within that context. The third author had expertise in qualitative methods and participated in the collaborative qualitative analyses for RQ2 and RQ3.

*4.2.1 RQ1: How might CIDER-based activities impact students' self-efficacy as a designer?* At the end of each week of instruction during the quarter, students filled out a short weekly check-in survey. The purpose of these

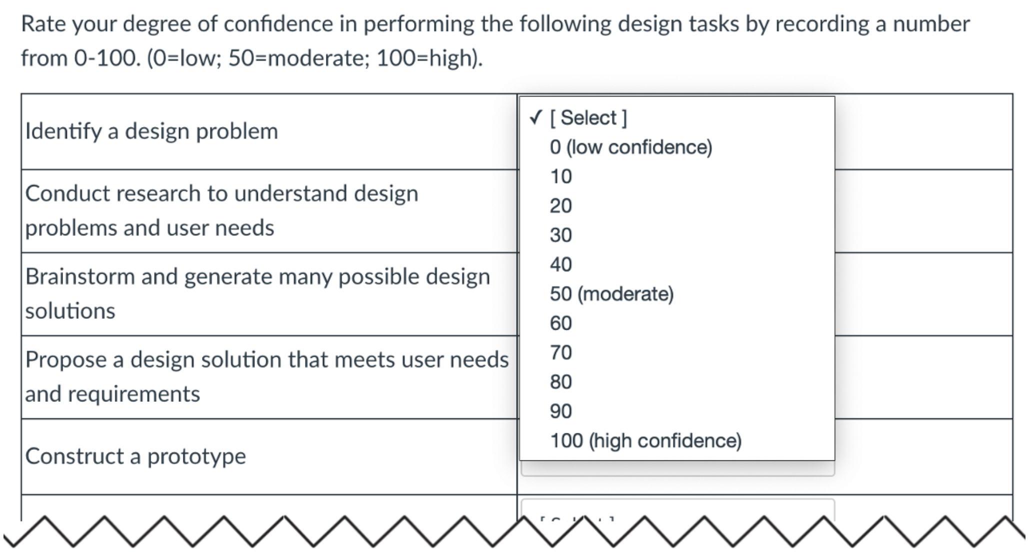


Fig. 8. The format of the self-efficacy items as students saw on their weekly check-in surveys.

surveys were twofold: First, to be a communication medium through which students could give feedback and raise concerns to the instructor during a period of semi-synchronous remote learning; and second, to capture changes in students' design self-efficacy over time. Within the context of the course, these surveys were graded based on completion (i.e., students received full participation points so long as they logged in and submitted a survey). To gather self-efficacy information, we asked students to rate their degree of confidence in performing nine general design tasks and four inclusive design tasks on a scale of 0 (low confidence) to 100 (high confidence) in intervals of 10. The general design items and the scale of measurement were adapted from Carberry et al.'s investigation of engineering design self-efficacy [12]. The inclusive design items were created by our research team to correspond to design tasks carried out when using the CIDER technique, with language and structure mirroring those of the general design items from Carberry et al.'s study. Figure 8 shows an example of how the survey presented the self-efficacy items to students, and Table 2 lists the text of all 13 self-efficacy items. The result of this was 10 sets of ordinal measures of students' self-reported design self-efficacy for 13 design tasks.

To understand at a high level how students' confidence in their abilities may have changed over time, we conducted nonparametric Wilcoxon U Signed-Rank tests to understand the changes in general and inclusive design self-efficacy between the beginning (week 1) and end (week 10) of the academic term[3]. We opted to conduct this analysis at the granularity of each skill due to our desire to understand if particular design skill self-efficacies were more or less impacted over the course of instruction. Consistent with the recommendations of the Transparent Statistics in HCI working group [38], we also calculated and report effect sizes of statistically significant results, including the Vargha and Delaney A effect size [83] which provides a means of making a common-language comparison between two groups.

To supplement these statistical analyses, for each weekly survey after the first, we asked students to self-report their perceptions of whether they were *more confident*, *about the same*, or *less confident* in their ability to do

[3]One student did not report self-efficacy scores for week 1, so we used their week 2 scores instead. Similarly, one other student did not report week 10 scores, so we used their week 9 scores instead.

| General Design Items (adapted from Carberry et al. [12]) | |
|---|---|
| *identify-problem* | Identify a design problem |
| *conduct-research* | Conduct research to understand design problems and user needs |
| *brainstorm-general* | Brainstorm and generate many possible design solutions |
| *propose-solution* | Propose a design solution that meets user needs and requirements |
| *construct-prototype* | Construct a prototype |
| *evaluate-test* | Evaluate and test a design |
| *critique-design* | Critique a design |
| *iterate-update* | Iteratively incorporate feedback and update a design |
| *communicate-design* | Communicate about a design |
| **Inclusive Design Items (corresponding to CIDER technique aspects)** | |
| *identify-assumptions* | Identify assumptions a design makes about users' abilities or contexts |
| *identify-exclusion* | Identify ways in which a design might exclude certain types of users |
| *exclusion-scenario* | Write a scenario in which a user might not be able to use a design due to an assumption |
| *brainstorm-inclusive* | Brainstorm changes to a design that might make it more inclusive |

Table 2. The thirteen self-efficacy items we asked students on each weekly check-in survey. Students self-reported a score for each item on a scale from 0 (no confidence in their ability to perform the task) to 100 (high confidence) in intervals of ten, as shown in Figure 8. Tags in the leftmost column are used to represent each item in the Results section.

general and inclusive design work compared to the previous week, and if they perceived a change, what they thought led to that change. This provided us with explanatory qualitative data to help us interpret any changes in students' reported self-efficacy scores. To analyze the qualitative feedback gathered on these open-ended items, one researcher (the second author) conducted a thematic analysis [69] with a sensitizing concept of *becoming more or less confident in design skills*. The results of this analysis were iteratively shared and discussed with the rest of the research team until collaborative agreement on the major themes was achieved.

Finally, on the Week 6 check-in survey, we also asked students to rank the contributions of different components of instruction to their personal design learning. Week 6 represented the "halfway" point of the course, where students pivoted from completing readings and discussions on their own to working on their final design projects (see Table 1). We opted to ask for students' ranking of course components in Week 6 rather than the end of the term in order to capture this information when it was more immediate in students' minds. The aspects of the course we asked students to rank included:

- *Required readings*, such as chapters from the course's textbook;
- *Optional readings*, which were supplemental to the required readings;
- *Reading quizzes*, single-question comprehension check quizzes based on the required readings;
- *Peer discussion boards*, where students asked and answered questions about readings;
- *Deliverables*, weekly activities where students practiced design skills with a partner;
- Optional *synchronous discussion sections*, where students could (virtually) discuss design topics with peers and the instructor;
- and the individual *CIDER activities*, which students completed weekly from Weeks 2-6.

We also included a "something else" response in the ranking options where students could fill in their own answer (such as an internship or hackathon they had participated in). We asked students to assign each of these options a rank from 1 to 8, with 1 indicating *"I learned the most from this"* and 8 indicating *"I learned the least from this"*, and to elaborate on their rankings as much as they wished in an open-ended response. To analyze these rankings, one researcher (the second author) examined students' responses for trends, noting for each course component how many students had ranked it as one of the most helpful to their design learning and what students mentioned about it in their open-ended responses. Given the nature of the study, the researcher focused in particular on any trends in students' rankings of and comments about the CIDER activities. These results were shared and discussed with the rest of the research team, who collaboratively came to agreement on the nature of the observed trends and their potential interactions with student self-efficacy.

#### 4.2.2 RQ2: How might the CIDER technique help students recognize different types of exclusionary design biases?

For each of the five individual CIDER activities performed by students in weeks 2-6 of the course, for each student, we collected a list of assumptions they identified during the technique's `CRITIQUE` stage; two scenarios of exclusion (one from the `IMAGINE` stage and one from the analogous part of the `REPEAT` stage); and two lists of proposed redesign ideas to make the design more inclusive (one from `DESIGN` and one from `REPEAT`).

To analyze how students' recognition of different types of design bias may have changed over time, we began by categorizing the types of assumptions students came up through iterative inductive coding. Across the five individual CIDER activities, we collected 1259 student-generated assumptions about users. Two researchers (the second and third authors) collaboratively affinity diagrammed a subset of the assumption data in order to generate initial themes for our coding efforts, memoizing their rationale as they developed a set of categories which fit the data well. Once they felt they had a stable set of themes, they shared and discussed the categories with the other member of the research team (the first author), adjusting the codeset as needed until all three researchers agreed on the categories and their descriptions. All researchers then divided and coded the remaining assumptions by type according to the agreed-upon codeset, recording rationale for their coding when appropriate. We allowed for multiple codes to be applied to each assumption item during this coding effort, because it was possible (though uncommon) for one assumption statement to identify multiple different types of embedded assumptions. After this process was finished, the research team met once more to review the results of the coding effort and discuss any discrepancies in the application of the codeset, collaboratively adjusting the coded data as needed after discussion of interpretations and reaching agreement on the major types of assumption present.

In addition to the above, we analyzed students' coverage of the major assumption types across their individual CIDER activities. We did this to better understand whether students really were able to surface new types of assumptions over time, or whether they simply repeated the same types of assumptions they had mentioned before. If students mentioned increasingly more types of assumptions over time, it could signify their gaining new perspectives on different ways designs could exclude potential users, thus building their knowledge bases of design bias examples for future design work. One researcher (the first author) wrote a script which operated on the assumptions lists students produced during their CIDER activities, which were coded by type as described in the previous paragraph. For each student, the script output their cumulative coverage of identified assumption types, broken down by week to give a sense of potential change over time. Combined with quotes from students' weekly check-in surveys, this enabled us to understand how students' abilities to recognize different types of design bias may have changed, as well as what may have led to those new understandings.

Though we collected 2,246 student-generated redesign proposals from the individual CIDER activities' `DESIGN` stages, we opted not to analyze these other than to note that every student was able to generate at least one redesign idea to make a design more inclusive for each CIDER activity they completed (minimum=1, maximum=13, median=5). Given the nature of this case study and its situatedness within the broader course, it would be difficult to disentangle the effect of the CIDER from the effects of general instruction and/or prior knowledge on the type or number of redesigns students were able to propose. Instead, we chose to focus on the more salient part of the intervention: students' abilities to identify different kinds of design bias, and how the CIDER activities may have improved that recognition over time. Future work around this technique should investigate the influence of the CIDER technique on the types and numbers of inclusive redesigns students come up with.

*4.2.3 RQ3: How might conducting CIDER-based activities collaboratively, rather than individually, impact students' experiences?* Fifteen teams completed a collaborative CIDER activity using their own designs as artifacts of analysis. Each team produced a single list of assumptions about users which they identified in their design during the `CRITIQUE` stage, chose two of those assumptions to focus on in sequence, and then provided a scenario of exclusion (`IMAGINE` stage) and a brainstormed list of redesign ideas (`DESIGN` stage) for each target assumption.

To understand teams' experiences during the collaborative CIDER activity, we asked them to respond to five open-ended reflection questions. These questions were included at the end of the activity and were answered after teams completed their collaborative CIDERs. The questions as presented to students were:

(1) *Previously, we did these activities alongside our textbook readings and discussions. Now, you've had a chance to practice and apply your design knowledge through project work. Did the experience you gained over the past few weeks change your approach or the kinds of responses you gave to this activity? Why and how, or why not?*
(2) *What was different about doing this activity on your own design rather than someone else's designed artifact?*
(3) *What was different about doing this activity with teammates rather than individually?*
(4) *Do you think this activity helped you uncover meaningful limitations of your design? Why or why not?*
(5) *If you were to continue working on this project beyond the end of the quarter, do you think it would be feasible to address all (or most of) the assumptions you uncovered? Would there be any unavoidable tradeoffs? Explain your thinking.*

To answer RQ3, two researchers (the first and second authors) conducted collaborative qualitative thematic analyses on teams' responses to each of the five reflection questions. The two researchers used initial sensitizing concepts of *differences between team and individual contexts*, *using CIDER on one's own design* and *perceptions of the activity's usefulness in team contexts* depending on the question. The two researchers shared and discussed the results of their analyses with the third author, and together the research team came to agreement on major trends which arose from students' responses related to collaboration, teamwork, and how these themes interacted with teams' usage of the CIDER technique.

*4.2.4 RQ4: What kinds of lasting impacts might the CIDER technique have on students' design approaches?* To better understand how the use of the CIDER technique might have influenced students' perspectives on design and inclusion, we conducted semi-structured interviews with students from the class after the term was over. To recruit for these interviews, on the final weekly check-in survey, we included an item that asked students to leave their email address if they were interested in participating in a short, compensated follow-up interview about their experiences in the course after the term had concluded. The item on the survey included a note to students that participation in these interviews was entirely optional and would have no impact on their grades or any other course outcomes, because the instructor (first author of this paper and lead researcher) would not see their responses until after final grades had been submitted. To ensure this held true, the instructor did not participate in analysis of the final week's survey data until after they submitted final grades and resolved any marking discrepancies.

17 students left their contact information on the final survey to indicate interest in participating in interviews. The instructor sent an initial recruitment email to these students three weeks after the conclusion of the quarter. This email contained more information about the goal of the interviews (i.e., to understand students' experiences in the course, specifically around the CIDER activities) and offered participants a $10 gift card to participate in a half-hour interview. To account for preferences and availability, we offered students the option of participating in the interviews over a remote video call or through email. In an attempt to avoid biasing participant responses, all communication after the initial email, including the interviews themselves, was carried out by the second author, a researcher who was not involved in or connected to the course itself. Six students responded to our recruitment email and agreed to participate in the post-class interviews.

| | Week 1 SE | | Week 10 SE | | Wilcoxon U Signed-Rank | | Effect Size | Vargha and Delaney A |
|---|---|---|---|---|---|---|---|---|
| **Design Skill** | **Median** | **IQR** | **Median** | **IQR** | **Z** | **p** | **r = Z/sqrt(N)** | **A** |
| *identify-problem* | 60 | 20 | 90 | 12.5 | 5.1255 | <.0001 | 0.8104 | 0.8700 (large) |
| *conduct-research* | 55 | 40 | 80 | 10 | 4.9255 | <.0001 | 0.7788 | 0.8191 (large) |
| *brainstorm-solutions* | 60 | 30 | 90 | 10 | 4.9043 | <.0001 | 0.7754 | 0.8144 (large) |
| *propose-solution* | 60 | 22.5 | 80 | 12.5 | 5.2605 | <.0001 | 0.8318 | 0.8469 (large) |
| *construct-prototype* | 50 | 30 | 85 | 12.5 | 5.214 | <.0001 | 0.8244 | 0.8988 (large) |
| *evaluate-test* | 55 | 22.5 | 80 | 10 | 5.3876 | <.0001 | 0.8519 | 0.8844 (large) |
| *critique-design* | 50 | 40 | 90 | 10 | 5.3535 | <.0001 | 0.8465 | 0.8616 (large) |
| *iterate-update* | 60 | 30 | 90 | 10 | 5.0855 | <.0001 | 0.8046 | 0.8441 (large) |
| *communicate-design* | 60 | 30 | 90 | 10 | 4.9819 | <.0001 | 0.7878 | 0.8453 (large) |
| *identify-assumptions* | 55 | 22.5 | 90 | 12.5 | 5.4449 | <.0001 | 0.8609 | 0.9147 (large) |
| *identify-excluded* | 60 | 22.5 | 90 | 10 | 4.9713 | <.0001 | 0.7860 | 0.8416 (large) |
| *write-scenario* | 60 | 20 | 85 | 10 | 5.4368 | <.0001 | 0.8596 | 0.8866 (large) |
| *brainstorm-inclusive* | 65 | 30 | 85 | 10 | 4.9089 | <.0001 | 0.7762 | 0.8172 (large) |

Table 3. Results of nonparametric statistical analyses of students' self-efficacy scores on thirteen design skills (nine general and four specifically related to designing inclusively with CIDER). Tags in the *Design Skill* column correspond to those listed in Table 2.

The interviews themselves were semi-structured and carried out by the second author. The content of the interviews focused on understanding students' experiences with design before, during, and after the class, with a particular focus on how their perspectives on design and inclusion had shifted during the course, if at all. We also asked students to tell us about their experiences with the course activities based on the CIDER technique, such as whether and how those activities had played a part in shaping any newfound perspectives on design and inclusion. Finally, we asked students to tell us their biggest takeaways from the course overall, and if they were comfortable sharing, to describe how those takeaways had impacted any design work they had done since the course concluded (e.g. if they were on an internship or working on personal portfolio projects). The interviews ended with a general open question *"Is there anything else you'd like to share with us?"* to enable participants to fully share their thoughts and experiences as much as they wanted.

Interviews were recorded and transcribed for analysis if they took place over video call. If the interviews were conducted over email, we used the text of the email responses as the source of data. To analyze these transcripts, one researcher (the second author) conducted a thematic analysis on the responses with sensitizing concepts of *shifts in perspectives on design* and *newfound understandings of inclusion*, noting in particular places where students mentioned impacts of the CIDER activities on their learning or design approaches. Then, the first and second authors discussed the results of this analysis, returning to the data when necessary to collaboratively converge on agreement about the major themes that arose from students' narratives.

## 5 CASE STUDY: RESULTS

### 5.1 RQ1: How might CIDER-based activities impact students' self-efficacy as a designer?

Overall, more than half the students in the class (22/40) ranked the CIDER activities as one of the top three aspects of the class that helped them learn the most, with almost a third of students (13/40) ranking it within the top two, and a fifth (8/40) as the most conducive to their overall design learning. For context, students only ranked two other aspects of the class consistently higher with regards to how much they learned: the required readings (36/40 top three, 31/40 top two, 19/40 most helpful), which formed the core of class instruction, and the weekly deliverables (26/40 top three, 24/40 top two, 11/40 most helpful), where they practiced and applied design skills.

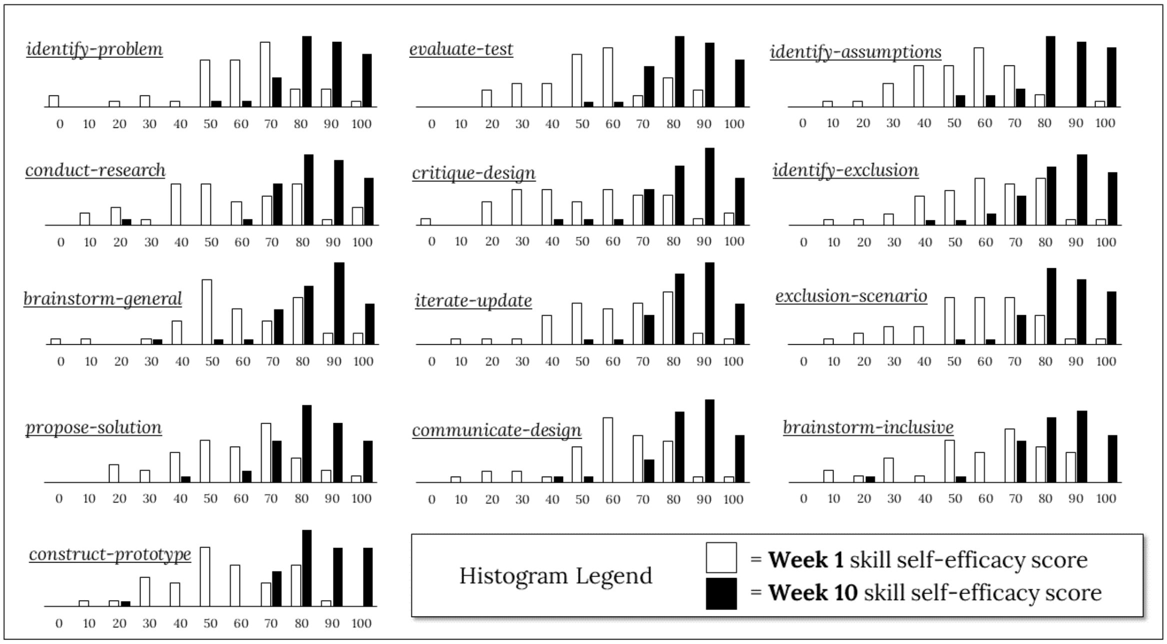


Fig. 9. Distributions of students' self-efficacy scores on 13 design skills, comparing students' beginning (Week 1) and ending (Week 10) self-efficacy ratings. Skill tags correspond to those listed in Table 2.

Figure 9 shows the histograms of students' self efficacy scores and Table 3 shows results of our nonparametric analyses for each of the 13 design skills we asked about in the weekly surveys. Differences between the median self-efficacy scores for all skills were statistically significant according to Wilcoxon U Signed-Rank tests. For each skill, we also calculated effect size according to the guidelines from the Transparent Statistics in HCI working group [38]. We identified a large effect size for all skills (Table 3, "Effect Size"). Finally, we calculated the Vargha and Delaney A effect size [83] for a common language comparison between the two groups, which can be interpreted as a probability. We interpret the large Vargha and Delaney A effect sizes for each skill to state that there is between an 81-91% chance that the self-efficacy score for a random student from week 10 will be higher than the self-efficacy score for a random student from week 1, depending on the skill in question (see rightmost column in Table 3).

A rise in design self-efficacy is to be expected given the introductory nature of the course: Students with little-to-no design experience *should* feel more confident after practicing design skills for several weeks. To understand how CIDER activities may have influenced students' self-efficacy gains, we turned to the qualitative data collected on weekly surveys. Several students with varying self-efficacy trajectories mentioned CIDER activities in their open responses. Some students began the course with very little confidence in their inclusive design skills, but showed large gains in confidence over the term. For instance, P10 started the course with the lowest self-reported inclusive design self-efficacy of the class, with a median score of 10 on four inclusive design skills in the Week 1 survey. They took a few weeks to report feeling more confident about inclusive design, citing a lack of familiarity with many of the skills they were practicing, but during Week 5, they were able to see their own improvement through their answers on the CIDER activity:

> P10, Week 5 survey: *"This week helped me put more principles into action ... the ability to visibly see my improvement through the exercises [CIDER activities] this week was awesome - really helped me feel more confident with my ability."*

The repeated CIDER activities seemed to give P10 a mechanism to reflect upon and see concrete gains in their ability to design inclusively, contributing to increased confidence. By the end of the course, P10 reported a median self-efficacy score of 85 on the four inclusive design skills. For students like P10 who came into the class with little confidence in their ability to design inclusively, the concrete examples and feedback provided by repeated CIDER activities may have helped them better understand and practice inclusive design.

Conversely, some students reported that initial engagement with CIDER activities had *decreased* their confidence in being able to do inclusive design, because they suddenly realized just how much they had previously been missing or overlooking. For instance, P13 reported a median self-efficacy score of 40 across the four inclusive design skills during Week 1, which dropped to a median of 35 in Week 2. They ascribed this drop to the CIDER activity in their survey response:

> P13, Week 2 survey: *"I feel slightly less confident in my inclusive design skills again because this week's activities showed me that I struggled a little more than I thought I would with identifying assumptions and generating viable solutions. This change in confidence is not a result of this class or its structure, it is the result of a reality check the inclusive design activities gave me"*

However, P13 quickly bounced back and gained confidence in their inclusive design skills over the next few weeks. By Week 6, the week of the final individual CIDER activity, they reported a median inclusive design self-efficacy score of 80, which further rose to a median of 90 by Week 10. They reported feeling more and more confident in their ability to do inclusive design over time, ascribing the gains to the practice they got from repeating the inclusive design activity on different artifacts, as well as the experience they gained from their final project work and having to consider inclusion from the perspective of a practicing designer rather than only as a critic. For these types of students, the CIDER activities may have played a part in showing them just how much they still had to learn about inclusion, dispelling the notion that good design is easy to achieve and making them more mindful of areas they could improve.

Students with prior design experience and high inclusive design self-efficacy at the beginning of the course rarely reported that CIDER activities influenced their self-efficacies, though they seemed to find the activities useful for reinforcing existing competencies. For instance, P28 self-reported an average inclusive design self-efficacy score of 97.5 across the four skills we measured in Week 1 of the course, attributing their confidence to past internships and design projects they had led or participated in, as well as a past project they had done specifically on inclusive design. P28's confidence in their inclusive design skills remained high throughout the course, though they did note a few ways that the CIDER activities helped them reflect upon challenges they faced in their own design processes:

> P28, Week 3 survey: *"If inclusive design is designing for as many users as possible and taking into account the needs and abilities of as many users as possible then I would think [I have] the same [level of confidence as last week] because in some cases it becomes hard for me to identify what to do unless I see their experiences."*

P28 did rank the CIDER activities as one of the parts of the class that was most helpful to their learning in Week 6, tied for first place with the weekly deliverable assignments, indicating they did receive some value from the activities. Their comments on later surveys ascribed this value largely to the repeated practice with the format, noting that they were getting quicker at listing assumptions. For students with existing in-depth inclusive design knowledge, CIDER activities may be better for practicing and reinforcing existing inclusive design skills rather than necessarily imparting new perspectives on design.

| Code | Description: Assumptions about a user's... |
|---|---|
| *Prior Knowledge (PK)* | Knowledge of affordances or familiarity with similar interfaces/interaction styles |
| *Vision (Vi)* | Level, extent, and/or type of visual ability |
| *Hearing (He)* | Level, extent, and/or type of hearing ability |
| *Motor (Mo)* | Level, extent, and/or type of motor ability |
| *Cognition (Co)* | Level, extent and/or type of cognitive ability |
| *User Context (UC)* | Physical, social, or cultural context of the user |
| *Access to Technology (AT)* | Access to technology and/or resources needed to engage with it (Internet, electricity) |
| *Device Specifications (DS)* | Device capabilities (speed, processing power) and/or hardware (inputs, outputs) |
| *Language and Literacy (LL)* | Fluency and/or literacy level with a particular language |

Table 4. The nine types of assumptions students identified throughout their individual CIDER activities, including assumptions about different kinds of user capabilities as well as assumptions about users' broader contexts.

## 5.2 RQ2: How might the CIDER technique help students recognize different types of exclusionary design biases?

*5.2.1 Students identified assumptions about users' prior knowledge, capabilities, and broader contexts.* Table 4 describes the nine types of assumptions about users students identified which emerged from our analysis of students' `CRITIQUE` lists on the individual CIDER activities. There were also three categories of responses from students which did not contain assumptions: statements about user preferences (e.g. *"The user might not like the color scheme"*), general critiques of the interface which did not contain assumptions (e.g. *"This looks more like a blog than a table of contents"*), and statements which were incomplete, incomprehensible, or otherwise did not fit into the assumption categories, which were marked with an "other" code. Students' non-assumption responses are not reported on in this paper.

For this analysis, we adhere to the perspective on qualitative coding proposed by Hammer and Berland [34], in which we treat the results of our coding effort as organizations of claims about data, rather than quantitative data in and of itself. As a result, we do not report exact code frequencies in the following subsection or calculate metrics such as inter-rater reliability, preferring instead to focus on characteristic descriptions of code instances we observed in the data. Below, we present examples of each assumption-related category and code below, supported by quotes from students' CIDER activities.

Some assumptions students identified revolved around concerns that are generally considered in traditional design processes, even if accessibility and inclusion is not a focus. When students identified these kinds of assumptions, they highlighted how the interfaces or interaction styles of the designs under scrutiny relied on some facet of a user's *Prior Knowledge (PK)* to work correctly. For instance, multiple students mentioned that several designs relied on the user to have prior experience with similar kinds of technology, especially when there were no easily evident indicators to help first-time users:

> P40, Week 6: *"Touchscreen-only interface assumes users have a basic understanding of how to use a touchscreen"*

Others specifically mentioned the reliance on the user's recognition of common affordances [35], especially after the fourth week of the term, when the course covered concepts such as gulfs of execution and evaluation [36]:

> P3, Week 4: *"Usage of blue links assumes that users are familiar with the understanding that hyperlinks are underlined and blue"*

*PK* codes were some of the most commonly identified types of assumptions, with at least two-thirds of the students listing one or more *PK* assumptions each time we conducted a CIDER activity (see Table 5).

When reflecting on the inclusiveness of a design, many students also identified assumptions about users which had to do with a their potential physical or mental capabilities. Assumptions related to a user's potential *Vision (Vi)* manifested when students identified potential bias around a design's sole reliance on visible cues to convey information:

> P16, Week 2: *"Aside from the two bumps on the 'F' and 'J' key, keyboard assumes that user has the ability of sight and can determine where certain keys are"*

A common *Vi*-coded assumption we observed was that of colorblindness, in which students often pointed out that not all users could distinguish all colors easily:

> P19, Week 3: *"The different color of the orange "New Meeting" icon compared to the blue icons assume the user is not color blind and call tell the difference"*

Students only identified assumptions related to a user's potential *Hearing (He)* ability in the Week 3 (Zoom) and Week 5 (Google Home) CIDER activities, likely due to the salience of audio-based interactions in these artifacts' designs. Students who surfaced *He*-coded assumptions listed different ways that a design might be biased against users who could not hear or process audible information in the particular way that the design conveyed it:

> P22, Week 3: *"Users are not deaf and are able to hear other users."*

> P29, Week 5: *"assumes that the user can hear or at least hear the frequency at which the Google Home talks"*

Sometimes, students identified *Motility (Mo)*-based assumptions that designs made about users. These were more prevalent when the physical interactions required to use a design were more salient, such as how a keyboard and mouse (Week 2) respond largely only to tactile input, or the toaster (Week 6) having only touchscreen-based interactions:

> P2, Week 2: *"There are a number of edge cases which may provide difficulty for some people if they are blind or have difficulty with some finger movements (ex. arthritis)."*

> P29, Week 6: *"assumes the user has enough motor control to accurately choose options on the small touch interface"*

Students occasionally surfaced assumptions embedded into designs which were related to a user's potential *Cognition (Co)* or cognitive abilties. Overall, relatively few students mentioned *Co*-coded assumptions each week (see Table 5). This is consistent with prior work reporting that neurodiversity is an often-overlooked facet of inclusion in the design of technology [21]. However, the handful of students who did surface *Co* assumptions noted a breadth of ways designs might be biased against neurodivergent individuals:

> P25, Week 4: *"is the font dyslexic friendly? (or other condition friendly)"*

> P28, Week 5: *"a person with color-taste synesthesia might feel a bad taste if one of the colors is associated with a taste for them"*

The *Vi*, *He*, *Mo*, and *Co* assumption types signify students' recognition of a number of ways that artifacts might perpetuate exclusion when their designs are built on assumptions about users' physical or mental capabilities. Accessibility and ability-related topics like these are often included in inclusive design resources (such as [39, 57]), though as discussed in the Related Works (Section 2), it can be difficult to get students to recognize and act upon them in their own design practice [49]. The fact that these kinds of ability-related assumptions were consistently identified by students across the five individual CIDER activities performed indicates promise for the technique's ability to help students surface different kinds of user diversity.

Sometimes students uncovered assumptions which went beyond a users' potential ability to their surrounding contexts and resources. When students identified embedded assumptions that had to do with a user's environment, we categorized these as *User Context (UC)* codes. For instance, some students highlighted how cultural or societal contexts might influence a user's ability to interact with a design:

> P9, Week 2: *"The dollar sign on the keyboard tells us that the product is centered towards the sales in the United States."*

Others identified ways in which designs made assumptions about the properties of a user's physical location:

> P29, Week 4: *"Doesn't give the time zone in which the page was updated so assumes that users are either using PST or assuming PST when visiting the page"*

> P3, Week 5: *"Primary mode of communication being voice assumes that users have a quiet enough space to place the Google Home where it can hear the user's voice"*

Students also identified instances in which designs assumed particular levels of *Access to Technology (AT)* that users might or might not have. Notably, *AT*-coded assumptions were often acute barriers that might have entirely prevented a user from interacting with the design as intended. Several touched on issues that might have been outside the designers' control, yet were important to consider in light of device use, such as the assumption that users would have reliable Internet or electricity:

> P23, Week 3: *"Users have access to reliable, high-speed internet to hear + see everything live-time"*

> P39, Week 6: *"It assumes that users have access to electricity in order to turn on the toaster"*

Assumptions coded as relating to *Device Specifications (DS)* were similar in some ways to the previously mentioned *UC* and *AT* codes, but they had to do in particular with the capabilities, inputs, and outputs of devices that supported the HCI artifact's use. As can be seen in Table 5, students surfaced these kinds of assumptions more often when the target artifact of analysis was a piece of software (e.g. Zoom) or a hardware device that connected to other devices (e.g. the keyboard and mouse), and rarely or never when the artifact was self-contained (e.g. the non-networked touchscreen toaster).

> P27, Week 2: *"Keyboard has a Windows symbol so it assumes it will be used with a machine running Windows, and with the specific Windows symbol it assumes Windows 8 or later"*

> P2, Week 4: *"Assumes the device has a large enough resolution to display everything on screen"*

A final category of assumptions students identified were those related to users' potential literacy levels and their fluency in various languages, which we coded as *Language and Literacy (LL)* assumptions. These sorts of assumptions arose more often when the design's interactions relied heavily on text, such as the COVID-19 information webpage or the touchscreen toaster's interface, or spoken audio, such as the Google Home voice assistant.

> P25, Week 4: *"users understands English very well (part of [university] is the [program for int'l. students] and I know for a fact that some of them doesn't have a fluent understanding of the language which is why they are here to learn and improve their English.)"*

> P11, Week 6: *"assumes the user can read English "Caution: Hot surface" and the "Face bagel inward" labels"*

Students' identification of *UC*, *AT*, *DS*, and *LL*-related assumptions indicate understandings of inclusion that can extend beyond a user's direct interaction with an interface and encompass their surrounding contexts. Cultural and social contexts, access to reliable technology and resources, and literacy and fluency levels can all substantially impact a person's ability to interact with a design, though these facets are not always considered in technology design processes [21]. Engaging with peers' assumptions about broader inclusion during the CIDER EXPAND stage may help students become more aware of the multiple ways users' contexts impact their interactions, leading to expanded understandings of how designers' assumptions can be fundamentally incompatible with users' realities.

| CIDER Activity | PK | Vi | He | Mo | Co | UC | AT | DS | LL |
|---|---|---|---|---|---|---|---|---|---|
| Week 2 (keyboard/mouse) | 28 (70%) | 28 (70%) | 0 (0%) | 29 (73%) | 1 (3%) | 12 (30%) | 4 (10%) | 17 (43%) | 10 (25%) |
| Week 3 (Zoom) | 28 (70%) | 18 (45%) | 13 (33%) | 8 (20%) | 3 (8%) | 14 (35%) | 30 (75%) | 26 (65%) | 17 (43%) |
| Week 4 (COVID info site) | 27 (68%) | 15 (38%) | 0 (0%) | 3 (8%) | 5 (13%) | 20 (50%) | 18 (45%) | 13 (33%) | 23 (58%) |
| Week 5 (Google Home) | 34 (85%) | 14 (35%) | 25 (62.5%) | 32 (80%) | 3 (8%) | 13 (33%) | 19 (48%) | 5 (13%) | 12 (30%) |
| Week 6 (Touchscreen toaster) | 36 (90%) | 29 (73%) | 0 (0%) | 23 (58%) | 1 (3%) | 20 (50%) | 10 (25%) | 0 (0%) | 23 (58%) |

Table 5. Count and proportion of how many students identified at least one assumption of a given type during the CRITIQUE stage of each CIDER activity. Percentages given are proportions out of 40 students, rounded to the nearest whole number. PK=Prior knowledge, Vi=Vision, He=Hearing, Mo=Motor, Co=Cognition, UC=User context, AT=Access to technology, DS=Device specifications, LL=Language and Literacy.

*5.2.2 Students tended to surface different types of assumptions when critiquing different artifacts.* To explore patterns and trends in the types of assumptions that students identified across the five individual CIDER activities, we counted the number of students who identified each type of assumption at least once in a given CIDER activity's CRITIQUE stage. Table 5 shows these results. Some types of assumptions were identified by most students across all activities—For instance, more than two-thirds of students identified at least one *Prior Knowledge (PK)*-coded assumptions in the CRITIQUE stage of every CIDER activity, and sometimes that proportion was as high as 90% (see Table 5, column 2). Other types of assumptions were less consistently surfaced. Students identified *Hearing (He)*-coded assumptions only in the CIDER activities corresponding to weeks 3 and 5, where the artifacts of analysis were Zoom and a Google Home digital assistant, respectively (Table 5, column 4). During week 6, when the artifact of analysis was the toaster with the touchscreen-based interface, no students noted assumptions having to do with users' *Device Specifications (DS)* (Table 5, column 9, last row).

These trends suggest that the choice of artifact for each CIDER activity, and specifically the salient interaction paradigm of the design under critique, influences the kinds of design bias students might notice. When the Week 3 (Zoom) and Week 5 (Google Home) CIDER activities made audio interactions salient due to the artifacts' reliance on speech and sound, students considered and successfully identified *Hearing (He)*-coded assumptions, but not otherwise. Similarly, when students were asked to consider a self-contained device with no obvious networked connections or outputs in the Week 6 touchscreen toaster activity, they did not consider assumptions about a user's *Device Specifications (DS)* might impact their experience with the design – likely making the assumption themselves that the designer of the toaster made it suitably powerful enough to do what it was meant to do. Certain types of assumptions might be surfaced more or less often depending on the object of critique during CIDER activities, which suggests that educators should take care to represent a diversity of interaction styles and device types when picking their artifacts of analysis for use with the technique.

*5.2.3 Students showed increasing awareness of different kinds of assumptions with each subsequent CIDER activity.* A key goal of the CIDER technique is that its use should help students expand their knowledge bases of design bias by providing concrete examples of exclusion, enabling them to recognize more types of design bias than they could before. If we consider the nine coded types of assumptions from the previous subsections to make up the possible "assumption space" within which students might identify specific manifestations of design bias, students then would signal broadening understandings of the assumption space when they identify a new type of assumption on their CIDER activities. To better understand how students demonstrated broader understandings of assumption spaces, we analyzed students' sets of assumptions they created during the CRITIQUE stages of the CIDER activities, and looked at how many students were identifying new types of assumptions each week (i.e. coded assumption types they had not yet mentioned on previous CIDERs). Table 6 shows the results of this analysis, including the final number of students who identified an assumption of each given type by the final individual CIDER activity.

| CIDER Activity | PK | Vi | He | Mo | Co | UC | AT | DS | LL |
|---|---|---|---|---|---|---|---|---|---|
| Week 2 (keyboard/mouse) | 28 | 28 | 0 | 29 | 1 | 12 | 4 | 17 | 10 |
| Week 3 (Zoom) | +9 | +8 | +13 | +1 | +3 | +10 | +28 | +14 | +13 |
| Week 4 (COVID info site) | +3 | *nc* | *nc* | *nc* | +4 | +11 | +2 | +1 | +8 |
| Week 5 (Google Home) | *nc* | +2 | +15 | +8 | +2 | +1 | +2 | +1 | +1 |
| Week 6 (Touchscreen toaster) | *nc* | *nc* | *nc* | *nc* | +1 | +4 | *nc* | *nc* | +3 |
| *Totals* | 40 (100%) | 38 (95%) | 28 (70%) | 38 (95%) | 11 (27%) | 38 (95%) | 36 (90%) | 33 (83%) | 35 (88%) |

Table 6. Cumulative count of how many students mentioned an assumption of that type for the first time during the assumption generation part of CIDER, using Week 2's initial count as a baseline. Cells with "nc" indicate there was no change since the previous week; i.e. no students mentioned that code for the first time during that week's activity. Percentages at the bottom are out of 40 students, rounded to the nearest whole number, and represent the proportion of students who had mentioned that type of assumption at least once by the final individual CIDER activity.

Over time, the CIDER activities seem to have helped students recognize and identify increasingly many different kinds of embedded assumptions which could lead to bias and exclusion. By the final CIDER activity, nearly all students (90%+) had successfully identified assumptions relating to users' potential *Prior Knowledge (PK)*, *Visual (Vi)* and *Motor (Mo)* ability, surrounding *User Context (UC)*, and their *Access to Technology (AT)*. Many students (70%+) also identified at least one assumption relating to users' potential *Hearing (He)* ability, their *Device Specifications (DS)*, or their *Language and Literacy (LL)* fluency. The least-identified type of assumption had to do with users' potential *Cognitive (Co)* abilities, but even then, slightly more than a quarter of the students in the class were able to identify at least one assumption of this type.

Compared to the baseline of the very first CIDER activity we conducted, more students showed recognition all of 9 coded types of assumptions after the final activity (Table 6, *Totals* row) than they did on the first activity (Table 6, Week 2). This is a strong indicator that students' understandings of the assumption space broadened over time. Indeed, by the final individual CIDER activity, all students had identified at least two more types of assumptions than they had on the very first activity. While some of this increase can likely be attributed to early designers learning more about design alongside the progression of the class, several students specifically mentioned the ways in which CIDER activities were the catalyst for their consideration of new perspectives. For instance, P29 reported that the CIDER activities helped open their eyes to new perspectives:

> P29, Week 6 Survey: *"The inclusive design activities are really helpful to help me push myself to understand inclusive design more and expand my perspective. They push me out of my comfort zone and getting me thinking in ways I wouldn't have otherwise."*

P8, who reported gaining more confidence in their inclusive design skills on the Week 4 survey, mentioned that the CIDER activities had enabled them to better consider diverse kinds of users:

> P8, Week 4 Survey: *"[I feel] More [confident] because I found the inclusive activities we have done so far to be helpful and to really get me thinking about the diverse range of users that exist and how they are put at a disadvantage."*

P36 reported being more confident on their Week 5 survey, specifically pointing to the socially-sourced list of assumptions created during the `EXPAND` stage as a mechanism for gaining new insights on inclusion:

> P36, Week 5 Survey: *"The [CIDER] inclusivity activity this week was beneficial because it was relevant and fellow classmates posted lots of good assumptions which I was able to get insight from."*

P18 highlighted the benefits of practice with respect to expanding their understanding of inclusion, specifically using the CIDER activity multiple weeks in a row:

> P18, Week 3 Survey: *"We consistently do the same [CIDER] exercise every week during which we are expected to think about how to include more people into the design. Doing this every week makes it easier each week."*

Given the nature of the case study and the integration of CIDER activities into the course under study, it is difficult to isolate the exact contributions of the CIDER technique to students' increased recognition of design bias. However, these quotes from students make it apparent that the CIDER activities played at least some part in helping some students consider perspectives that they would not have had the opportunity to otherwise, and thus did help students build their knowledge bases with new examples of design bias and exclusion.

Notably, we observed the largest increases in students' demonstrations of assumption space coverage during the first few CIDER activities, with diminishing returns in later activities. This is especially evident for the assumptions related to users' broader contexts in particular (see the comparatively larger numbers in the Week 3 row, columns *UC*, *AT*, *DS*, and *LL*, indicating that many students identified these kinds of codes for the first time in Week 3). The sharp increase in the number of students who were able to identify different kinds of assumptions after completing only one or two CIDER activities is promising, because it suggests that the CIDER technique may be beneficial even if only a single instance of it is integrated into a class. Exposure to the kinds of assumptions made visible to students by the CIDER technique's `CRITIQUE` and `EXPAND` stages, even if only experienced once, seems to be effective in helping students recognize more kinds of exclusionary design biases in existing artifacts.

## 5.3 RQ3: How might conducting CIDER-based activities in project teams, rather than individually, impact students' experiences?

As mentioned previously, students conducted a collaborative CIDER activity with their project teams in the tenth week of the course. For this activity, they analyzed their own prototypes and worked together to identify and address assumptions embedded in their designs, then answered a few reflection questions on how the team-based experience differed from doing CIDER activities on their own. We consider the collaborative CIDER activity to provide potential insights into how the technique might be used in a more authentic setting, such as if it were to be used in a design evaluation outside of a classroom context. Even though the majority of our students were early designers and the length of teams' design processes were artificially constrained due to the academic term, we still uncovered several interesting insights of how CIDER might support inclusive design work beyond classroom contexts.

*5.3.1 Collaborative CIDER activities enabled students to consider more perspectives and seemed more fun.* When asked to reflect on how doing the CIDER activity in teams was different than doing it individually, several teams reported it was easier to come up with a breadth of different assumption types during the activity's `CRITIQUE` stage when they had a chance to discuss with teammates:

> Team A: *"Doing this as a group definitely makes uncovering a lot of the design assumptions a lot easier because we pass our ideas around and build on each other. We also get to filter out a lot of ideas that may have been irrelevant."*

Many teams also mentioned the benefits of having multiple designers, each with their own perspectives and experiences, contribute to the same analysis. They often claimed that this allowed them to identify more kinds of assumptions or redesign ideas than they would have been able to individually:

> Team G: *"By having multiple people looking at the design from different perspectives, you end up with a wider range of assumptions. Working on the [assumptions] list as a group also opens your eyes to perspectives other than your own and lead you to notice things you wouldn't have before. "*

Team N: *"Having different lenses that we use to view the world and different backgrounds helped us [...] we were able to come up with different [redesign] solutions that we would not have come up with if we had been working on our own."*

A few teams found the collaborative CIDER activities more enjoyable than the individual activities, such as Team B, who simply stated:

Team B: *"This activity is more fun to do with a group!"*

The above insights suggest that collaboration with teammates may be an effective way to help students expand their personal knowledge bases of design bias. In the individual CIDER activities, the technique's `EXPAND` stage played this role by providing a means for students to see and engage with assumptions identified by their peers, who likely had different experiences and background knowledge. In the collaborative activities, coming up with an assumption list alongside teammates during the activity's `CRITIQUE` stage seems to have led to different kinds of discussion and consideration of diverse perspectives.

*5.3.2 Teams perceived limitations uncovered by CIDER as meaningful to address, but recognized feasibility tradeoffs.* We positioned the collaborative CIDER activities within the class as one way for teams to identify the limitations of their project prototypes, which they were required to address in a section of their final design specification writeups. Some teams found the CIDER activities very useful in identifying critical limitations, assumptions about users, and biases that they had previously overlooked:

Team I: *" [The CIDER activity] highlighted limitations in regards to accessibility and individual user abilities. It helped us find things that we didn't think of initially and going back and looking over our prototype helped us come up with a more inclusive version of our initial design."*

Some teams were more critical of the activity's usefulness, reporting that CIDER really only helped them find minor limitations:

Team C: *" [...] we didn't find them [the limitations] to be super significant or that would affect the entire design. They were minor changes that might help us remove some assumptions and make our design more inclusive."*

When asked whether they felt these uncovered limitations were actionable, teams recognized the tradeoffs and tensions inherent in trying to improve inclusiveness when certain design decisions had already been made. For instance, Team M's project involved a smartphone app which required Internet access to function:

Team M: *"[T]here would definitely be unavoidable tradeoffs. [...] While we could hopefully design around some of these problems and make it more accessible, basing our design online makes it inevitably hard for us to address some basic issues. Things like access to the internet, smart devices, electricity, the need to be able to read and function are all issues that ultimately can't be fixed with our current project."*

A handful of teams noted the particular constraints of analytical design evaluation methods like CIDER: It was difficult for them to really know how impactful the limitations they had uncovered might be without the input of actual users. One team suggested that the assumptions they identified with CIDER might even guide targeted recruitment for future empirical design evaluations and user studies:

Team L: *" [I]f we had more time we would definitely try to get more diverse individuals (based off of our list of assumptions) to interact with the prototype."*

*5.3.3 Critiquing teams' own artifacts was difficult, but prior CIDER experiences made it easier.* When asked to describe how their experiences differed when using CIDER on their own designs, almost all teams reported that they found it more difficult to critique their own designs. Sometimes, teams reported that this difficulty arose from being personally invested in the design decisions they had already made, which made unbiased critique difficult. Other times, teams noted that because they were so immersed in their projects, it could be difficult take a step back and interrogate their own assumptions:

> Team I: *"We think it is easier to critique someone else's design because when it is your own design it can be hard to find faults if you are set in your own perspective. When you spent so much time constructing the prototype, you've developed your own view on it and it can be hard to break free from that."*

This is somewhat similar to the *expert blind spot* phenomenon [58] which arises when expertise and experience prevent a person from perceiving difficulties which early designers might encounter. Finally, some teams noted that they had already tried to address the assumptions they could think of during their initial design process, which made it challenging to identify even more assumptions that they had not yet considered during their collaborative CIDER activity:

> Team A: *"I feel like with our own design, we already tried to address a lot of the assumptions when designing it. If we didn't already find assumption problems in the process of designing the prototype, it's harder to spot them out in this stage."*

In order to surpass these difficulties, teams often relied on experience they had gained from previous CIDER activities. Several teams noted the usefulness of having conducted prior CIDER activities in helping them identify a variety of different user attributes that they would otherwise not have considered when designing:

> Team B: *"It [the CIDER activity] helped us become more open-minded and consider more perspectives; for example, we learned to consider factors such as physical space, access to different resources, and mental capabilities of the users. Lastly, it helped us think about physical abilities that other users might not have that we take for granted."*

Other teams leveraged outputs of the previous CIDER activities to help surface more kinds of potential bias. For instance, Team E returned to the assumption lists they had created during the `CRITIQUE` stages of previous CIDER activities for inspiration:

> Team E: *"At the start of brainstorming our group really felt we had a practically perfect design. We had to go back to what we had written about other designs [on previous CIDERs] for ideas. In reviewing those answers we realized how our design was also challenged."*

Multiple teams also mentioned that the collectively-generated assumption lists from the individual CIDER activities served as a useful resource, especially when it came to identifying "common" assumptions that arose in multiple prior activities:

> Team K: *" Having practiced critiquing other design's has made us more critical and more aware of common design assumptions. Further, reading other people's responses to the [CIDER] Inclusive Design Activities were extremely beneficial in providing multiple perspectives and types of assumptions that we had previously not considered."*

When teams used the outputs of prior CIDER activities to help them better uncover assumptions in their own designs, they reported being better able to recognize potential design bias. Notably, the teams who used these strategies did so without any particular prompting from the instructor to reflect on prior CIDER results. Taken together, these results suggest that not only can the CIDER technique be useful in equipping students with skills to recognize design bias, but also that the outputs of CIDER-based activities might be beneficial in making future design processes more inclusive as long as they are readily accessible.

*5.3.4 Prior CIDER experience helped teams make their designs more inclusive from the outset.* Several teams mentioned in their reflections that their previous experiences with the individual CIDER activities helped them become aware of more types of assumptions:

Team N: *"All of our inclusive design activities [prior individual CIDERs] contributed a lot to how we approached our design assumptions this week [team CIDER]. From all of our practice with the past design activities, we were able to approach the assumptions from many perspectives: user goals/needs, a user's prior knowledge, and assumptions about their abilities. [...]"*

As a result, when they were working on their own design projects, many teams strove to avoid making these kinds of assumptions about users in the first place, recognizing the assumptions early on in their design processes (e.g. during low-fidelity prototyping) and addressing them by changing their designs to be more inclusive.

Some teams pointed out that even though they had benefited from the individual CIDER activities early on in their design processes, the team activity was even more helpful, because it gave them the prompting and scaffolding necessary to identify more nuanced kinds of assumptions that they might have otherwise overlooked. For instance, Team O identified a narrower range of assumption types in their collaborative CIDER activity's `CRITIQUE` stage than many other teams. However, they attributed this not to a lack of ability to recognize bias, but due to the fact that they had already identified and addressed some of their unconscious assumptions about users early on in their design process:

Team O: *"[W]e tried to identify these assumptions early on in this project and tackle as many as we could through our original design. Previous experience has helped us think of these assumptions in a wider scope, through not only target user feelings but also others who engage with this design. [... This week,] We tried to generate assumptions that could be tackled with a more solid solution that works with our prototype."*

Taken together, these results suggest that the CIDER technique may help students design more inclusively because it alerts them to common inclusion pitfalls. In a collaborative setting, CIDER-based activities might even provide teams a mechanism to talk about more often overlooked kinds of inclusion, even when teams consider their assumptions from the very beginning of the design process like Team O did. This especially promising given that having more experience with CIDER seems to contribute to more inclusive design processes overall, indicating that regular CIDER-based activities might build up early designers' knowledge base of design bias examples over time, and help them be better equipped to either avoid it in the first place, or respond to it when it does manifest.

### 5.4 RQ4: What kinds of lasting impacts might the CIDER technique have on students' design approaches?

To understand the ways in which CIDER activities might have had longer-term or broader impacts on students' understandings of inclusive design, we conducted post-class interviews about a month after the term concluded. These interviews asked students to reflect on how their own attitudes toward design and inclusion changed over the course of the term, as well as how the activities might have influenced their personal approach to design work or to other aspects of their lives.

*5.4.1 Students gained new understandings of design and the importance of inclusion.* Many students mentioned gaining a growing appreciation for design in general, which helped them check their stereotypes about the discipline. Prior work indicates that computing students often hold misconceptions about the discipline of design, such as that it is only about aesthetics or that it lacks rigor [67]. We saw this reflected in our interviews. Some students were initially intimidated by design due to these misconceptions, though they later grew to understand and appreciate the complexity of design:

P22, interview: *"[Originally] I felt like I was not born for this. [... like] I can't visualize where stuff should be and how it should actually look for an actual product. [...] I first thought that design was more about*

> *the look, the aesthetics. Well, after taking the class, I also know that the user experience is so important and that a navigable interface is more of what design kind of is. Rather than just the aesthetic itself."*

Other students recognized their prior prejudices against design and were able to reframe their conceptions of the discipline, especially when they realized just how much design work goes into creating a technical artifact:

> P29, interview: *"While I knew that design was important and complex, I wasn't aware of the depth of the issues that design entails. This is mostly due to my lack of design experience before this class, but I also think that design is often looked down upon by the rest of the STEM community as being too "artsy" and feminine and while I had tried to be aware of those biases I still think I was mildly prejudiced against design due to that. [...] My perspective on design in general definitely improved. By seeing the specific ways design is used and its importance, I was able to let go of a lot of the biases I had associated with design and respect it a lot more."*

Not only did students gain better understandings of design overall, but many of them specifically reported better understandings of design bias, design exclusion, and the importance of inclusive design. Some students who were less familiar with inclusive design at the start of the class relayed how they broadened their definition of inclusion over time to more than just conventional accessibility concerns:

> P40, interview: *"I ha[d] heard of the term inclusive design before but not familiar with it. I considered it as design that aims to make more people accessible to it and specifically it could benefit disabled people. [...] I got to know what inclusive design really represents and how it works to increase the accessibility at the same time eliminating exclusions from users, which really attracted me."*

Others mentioned their surprise at the complexity of practicing truly inclusive design when creating an artifact, even if they were ideologically committed to access and inclusion in the first place.

> P29, interview: *"I already was well aware of the importance of accessibility and inclusivity in technology (and just in general). I think the only thing that really changed was that I gained a better understanding of just what goes into achieving those kinds of technologies and how complicated and difficult it can be, especially when a lot of the technology field doesn't realize its importance."*

*5.4.2 CIDER activities challenged students to consider new perspectives on inclusion.* When we asked what aspects of the course had had the most impact on students' newfound understandings of inclusion, some students specifically attributed their newfound appreciations of inclusive design to the CIDER activities[4], even before we prompted them to consider the CIDER activities in particular.

> P12, interview: *"I didn't have much experience with inclusive design before the class, but I feel as though I have learned and understood the importance of inclusive design over the course of the class. [...] The weekly inclusive design activities were very helpful to put things into context and put skills into practice."*

When we prompted students to reflect upon the CIDER activities in particular, many students shared positive feedback and highlighted the activities' roles in changing their perspectives on inclusive design:

> P3, interview: *"I LOVED these activities. I think that it gave us students first-hand experience to show us exactly how difficult and important inclusive design is without making us feel overwhelmed by the assignment. I learned how to better identify assumptions that designs were making and how to think of more solutions to address an assumption. [...]"*

> P12, interview: *"I enjoyed the inclusive design activities a lot and I feel like I learned the most from these activities. They helped me learn about the assumptions that common products make about their users as*

[4]Within the context of the course, CIDER activities were simply referred to as "inclusive design activities." As a result, quotes from the interviews refer to inclusive design activities rather than CIDER activities. These phrases should be interpreted as interchangeable in the context of students' quotes.

*well as assumptions that I could potentially make. I would not have thought of and reflected on these assumptions as much if these activities were not a part of the class."*

When asked if any particular parts of the CIDER activity especially contributed to their learning, two students replied that all of its parts were helpful, as P29 did:

P29, interview: *"The listing out of assumptions forced me to challenge my understanding and really try to notice things that I wouldn't have noticed at a glance. The scenarios helped me to connect the issues to real life and understand the negative ways the flaw could impact people and which people would be impacted by it. Brainstorming redesigns led to a better understanding of just how difficult it is to account for people's needs and just how ableist design standards are. Seeing other people's designs helped me to understand what things I tended to miss and try to change my perspective so that I would be more aware of those things."*

Other students specifically emphasized the benefits of the CIDER activities' *EXPAND* stage, where the educator collates and shares back the collectively generated list of assumptions that students all came up with. This stage allowed students insight into new perspectives and built out their knowledge bases with rich examples of design bias and exclusion, which they could then apply in future design processes.

P12, interview: *"Listing out the assumptions and seeing others' assumptions were very useful to me. It was interesting to see what I could come up with regarding what a product assumes about the user, because this also reflected what I assume about the user in a sense. It was also interesting to see what other classmates had come up with because there was always at least one thing I had missed."*

P40, interview: *"I felt seeing how others could think of so many ways to make a design more inclusive gives me 'aha' moment, especially when I was limited of coming up ideas."*

*5.4.3 CIDER helped students recognize their own biases and adjust their approaches to design and to life.* Finally, we asked students to share their biggest takeaways from the course, as well as whether anything they had learned had influenced their current approach to design. Some reiterated their changed perspectives on design as a discipline, and underscored their reframed perspectives of its importance, especially around accessibility:

P29, interview: *"My biggest takeaways from [course] were that I had prejudices against design that I didn't even realize, that I actively needed to change those biases which is exactly what this class did for me, and that while I had tried to educate myself on accessibility issues I still had holes in my understanding which this class helped fill."*

Others shared takeaways directly related to the importance of designing for users with differing capabilities and contexts, sometimes tying these realizations directly to the CIDER activities:

P12, interview: *"The [CIDER] activities definitely played a role in changing my perceptions of design in that they made me realize that as a designer, I can't make hasty assumptions about my user and I should strive for my designs to be inclusive of as many populations as I can include."*

P3, interview: *"Inclusive design when done successfully is extremely powerful and can really help improve the lives of those that the design is trying to serve. Design is directly linked with empathy. Inclusive design is no longer a choice. It is something that every design needs to consider and do."*

In terms of longer-lasting impacts, two students reported that they had applied their newly-gained knowledge of inclusive design to design projects they had worked on since the class's conclusion. For instance, P28 shared how they had used aspects of what they had learned through the CIDER activities to adapt a personal project they were working on:

> P28, interview: *"The assumptions other students had listed helped me realize and think about constraints other people might have and see which I would not have noticed myself. I used some of those in making my [current, personal project's] design more inclusive."*

Finally, some students reported that the course and the CIDER activities had influenced their daily lives beyond just their design work, such as in their awareness of design exclusion or their consumer habits:

> P40, interview: *" I felt I was better at identifying assumptions and coming up with solutions to increase the accessibility for a design at the end of the course. Also I began to pay attention to objects beside me and think of how they could exclude certain users from using them and could be designed to become more inclusive."*

> P3, interview: *"I think that I am just a lot more aware of the designs of products that I use. It has also shifted my purchasing habits – I wish to support companies that put in genuine efforts in inclusive design. I also evaluate the design of products that I use sometimes which was something I rarely used to do."*

## 6 DISCUSSION

Our investigation of the CIDER assumption elicitation technique explored how this method might help early designers learn inclusive design skills. The novelty in the CIDER technique's approach is twofold. First, it uses the lens of *assumptions about users* as a focus for students' critique, which is uncommon in design evaluation methods, and especially rare amongst educational methods for early designers. Second, the technique attempts to support students in *reifying*, or making concrete, understandings of how abstract ideas like inclusion are tied to actual design decisions, enabling the development of actionable inclusive design skills that can generalize across different contexts.

### 6.1 Summary of Key Results

*RQ1:* Students in the case study grew more and more confident in their abilities to practice both general and inclusive technology design over time. Nonparametric statistical analyses conducted on students' self-reported self-efficacy scores for 13 design skills showed significant increases on all skills from Week 1 of the course compared to Week 10. Many students reported that the CIDER activities played a role in building their confidence. For some students with very low initial-self efficacy, the series of CIDER activities provided a feedback mechanism for them to concretely observe their own progress over time (identifying more types of assumptions, brainstorming more redesign proposals, etc.). For others, the CIDER activities may have initially *decreased* confidence in their ability to design inclusively, because the assignments revealed just how nuanced and difficult inclusive design could be. However, after subsequent practice with later CIDER activities, these students reported recovering their confidence and gaining actionable understandings of inclusive design. The impacts of CIDER activities on students' self-efficacies are impossible to isolate due to the way they were integrated within the course, but students' self-reported perceptions indicate some potential for CIDER to help build inclusive design confidence.

*RQ2:* After completing a series of activities based on the CIDER technique, students in our case study were able to recognize and respond to many different types of design bias in software and hardware interfaces. Students surfaced embedded assumptions in a variety of HCI artifacts related to users' potential prior knowledge, their physical and mental capabilities, and their surrounding contexts, resources, and environments. Within the scope of any given CIDER activity, the particular nature of the artifact under critique seemed to influence the kinds of assumptions students surfaced, likely due to salience of different interaction styles in the artifact's design. Over time, students demonstrated increasingly more comprehensive understandings of design bias types, with the largest increases happening after the first individual CIDER activity. The collectively-generated lists created in each activity's `EXPAND` stage, which provided a means for students to engage with peers' assumptions, seemed particularly instrumental in broadening understandings of the assumption space.

*RQ3:* When we tested out a collaborative version of a CIDER activity, where student teams critiqued their own project prototypes, teams often initially struggled to objectively evaluate their own artifacts. To circumvent these difficulties, many teams relied on their prior CIDER activity experience, recalling assumptions they had identified before and returning to the existing EXPAND lists from previous individual activities for examples of different kinds of assumptions. Several teams felt it easier to surface a wide range of embedded assumption types with their teams due to the diversity of knowledge and experience that teammates contributed to the discussion. When reflecting on their experiences with the collaborative CIDER activities, teams demonstrated nuanced recognitions of design tradeoffs around the feasibility and ethics of inclusive design. Some teams relayed that their experiences identifying and responding to design bias from previous individual CIDER activities helped their group make their design more inclusive from the outset, enabling them to avoid common pitfalls that might present accessibility barriers for users. For these teams, the collaborative CIDER activities provided a mechanism for teams to more deeply reflect on their own unconscious biases and identify assumptions about users' broader contexts that they may not have had the opportunity to discuss otherwise.

*RQ4:* In post-class interviews, students shared that the insights they had gained through the CIDER activities had lasting positive impacts on their perceptions of inclusive design. Some students shared that the CIDER activities had prompted them to consider perspectives on inclusion that they would not have thought of otherwise, leading them to challenge and change their own conceptions of design work. Students who continued practicing design after the course (through design internships or work on personal design projects) reported that they had adopted more inclusive approaches to their current design processes as well. The CIDER activities even influenced some students' everyday lives, with one student reporting more attention given to the designs of objects surrounding them and another describing a shift in consumer habits to support companies that valued inclusion. Overall, the use of the CIDER technique seems to have had long-lasting impacts on students' approaches to design work and everyday life that extended beyond the classroom context.

### 6.2 Limitations

Though the data we collected throughout our case study was rich, some aspects of our study design limit the generalizability of our findings. As mentioned in Section 4.1.1, this study took place during a term of remote learning necessitated by the COVID-19 pandemic. Educators and students had to adapt to teaching and learning in new, different ways at a time when external stressors were extremely high. These considerations certainly influenced the kind of data we were able to collect when evaluating our technique, and likely the engagement and kinds of responses students gave to activities and surveys as well.

Further, several limitations arise from the context of the course within which we conducted our case study. The course was taught at a university with a strong design culture which valued accessibility, by an instructor who already had relevant expertise in inclusive design and design evaluation methods. Post-secondary computing instructors who do not have expertise in accessibility-related topics or who lack institutional support may face difficulties integrating inclusion-related content into their teaching [42, 77]. The instructor also had the freedom to design a course structure that allowed for multiple repetitions of the CIDER activity throughout the academic term, which is not always possible for HCI educators due to time or curriculum constraints [88]. If a similar case study were to be conducted with a different instructor, different students, at a different institution with a different design culture, the findings might differ based on the nuances of each learning environment.

The means and methods by which we chose to explore students' experiences using the CIDER technique are inherently accompanied by their own limitations. We used digital surveys, digital assignments, and interviews conducted over video calling platforms or email to understand students' perspectives. The digital media we used to collect data may have influenced what or how much students shared. Much of our data was self-reported by our participants, and thus is somewhat limited by students' individual abilities to reflect upon their own experiences (which can differ from person to person). As with all research that involves human participants, there is always a risk of response bias. This risk can be heightened in educational contexts where there is a power differential between educators and students, because students might be inclined to respond in particular ways to try and improve their grades or class standings. We tried to minimize response bias in several ways, such as by grading the CIDER activities based on participation only, by withholding survey responses about the activity from the instructor until after the course concluded, and by having a researcher unaffiliated with the course conduct the follow-up interviews.

Due to the way the CIDER activities were embedded within the course, it is impossible for us to make direct causal claims about the technique's impact on students' design knowledge. Conducting multiple individual CIDER activities prior to the collaborative CIDER activities certainly impacted students' processes on the collaborative activities (oftentimes for the better, as discussed in the RQ3 results), but choosing to structure the study in this way does not allow us to isolate the individual activities' specific impacts. We also cannot know for sure how much the ordering of artifacts within the series of individual CIDER activities impacted the development of students' inclusive design skills, or how exactly the activities interacted with the other aspects of the course to promote learning. To address these kinds of limitations, we collected data from a wide range of sources and used it to triangulate and lend credibility to our findings. However, future work remains to isolate the exact effects the use of the technique and the structure of activities might have on students' learning.

Finally, we acknowledge our own positionalities as researchers and educators with regards to our technique design, study design, data collection, and data analysis decisions. Each member of the research team brought their own perspectives, content knowledge, and lived experiences to bear on each part of the study design and data analysis they were involved in. Our interpretations of our findings, the data we chose to collect, and even our research questions themselves may have been different if the research team comprised of different people with their own backgrounds and lived experiences. Further, our interpretations of our results (especially those from our qualitative analyses) are influenced by our individual points of view from which we engaged with the data. We recognize that there are particular perspectives and experiences that our research team does not have access to based on our positions within academia and within society as a whole. Future work exploring inclusive design learning should also be sensitive to the ways in which researchers' and educators' standpoints might influence the questions investigated, data collected, and findings surfaced.

## 6.3 Considerations when Using CIDER to Teach Inclusive Design Skills

*6.3.1 Choosing artifacts to highlight different kinds of design bias and exclusion.* As discussed in our RQ2 results, the artifacts students critiqued influenced the types of assumptions that they identified during the CRITIQUE stages of the activities. Students tended to identify assumptions that corresponded to the artifact's most salient interaction styles—for instance, commonly identifying assumptions related to a user's hearing when analyzing the Google Home voice assistant, overlooking hearing-related assumptions when critiquing the QWERTY desktop keyboard. These findings suggest the potential for "targeted" CIDER activities that might help students recognize and ideate on specific facets of accessibility and inclusion.

These results also underscore the importance of selecting the artifacts used in CIDER activities carefully, with particular attention given to the way an artifact's interface might make certain types of assumptions more or less obvious to students. This consideration is expecially important if educators opt to do only a single activity using the CIDER technique in their classes. For instance, if the only artifact students analyzed with CIDER was a browser-based website interface (similar to our case study's Week 4 activity), students might handily identify embedded assumptions about users' prior knowledge, visual ability, context, or language fluency; but they might not as readily consider assumptions made about a user's hearing, motor, or cognitive abilities (see Table 5, row 4).

Though there is likely not a single HCI artifact that can make all types of assumptions salient, a series of CIDER activities that used the technique to showcase biases in artifacts with diverse modes of interaction might be the most effective in helping students gain a comprehensive understanding of design bias. In our case study, we saw promising results from choosing five different artifacts whose major interaction paradigms and affordances varied: By the final of the five individual CIDER activities, most students had identified most types of exclusionary assumptions at least once, indicating a base level of familiarity with those particular kinds of design bias. Future applied work involving the CIDER technique might explore the creation of a set of activities which, when done in sequence, provide opportunities for students to learn about and identify a broad range of embedded assumptions. This kind of resource might prove useful to HCI educators for use in their own classrooms.

*6.3.2 Critiquing real-world artifacts vs. critiquing students' own prototypes to surface unconscious biases.* The theoretical grounding of the CIDER technique rests partially on the notion that students should critique HCI artifacts that were designed by others. As discussed in Section 3.1, analyzing existing HCI artifacts helps students understand the need for inclusive design by revealing the ways that real-world designs can be biased against different types of users. Practically, having all students critique the same artifact also enables the creation of the collectively-generated `EXPAND`-stage list of assumptions students draw upon to build their knowledge bases for design bias. As referenced several times by students throughout our findings, the `EXPAND` lists seemed to play an important role in students' learning.

However, in the collaborative CIDER activities (RQ3), students had the opportunity to reflect on their own biases by using the CIDER technique on their own prototypes. This kind of self-reflection provides an opportunity for growth if a student (or team) recognizes and moves to mitigate their own, likely unconsciously held biases. Indeed, though teams reported that critiquing their own prototypes felt more difficult than critiquing existing artifacts, many of them also felt that they gained deeper understandings of their own biases and how they might manifest in design exclusion. This led them to modify their prototypes to increase inclusion and accessibility. Being able to reliably provide opportunities for the kind of critical self-reflection that leads to students recognizing their unconsciously held beliefs about users would be a powerful tool in any HCI educator's toolkit—though it is unlikely that the collaborative CIDER activities would have been as successful at doing so without the previous experience students gained from the individual activities. Future adaptations to the base CIDER technique might explore a combination of activities involving real-world artifacts and activities critiquing students' own prototypes, perhaps gaining the benefits of each approach.

*6.3.3 Conducting activities individually vs. collaboratively to surface different perspectives.* The individual CIDER activities students conducted throughout the term enabled them to become more aware of assumptions in their own design work (RQ2). When it came time for the collaborative activities, some teams surfaced fewer embedded assumptions overall during CIDER's `CRITIQUE` stage because they had already anticipated and addressed these assumptions in their initial design processes. On the other hand, some teams still found it difficult to self-reflect upon their own artifacts, indicating that the scaffolding provided by previous individual CIDERs might not have been enough for students to feel confident in surfacing assumptions (RQ3).

Building upon these insights, HCI educators might consider whether individual or collaborative CIDER activities (or both) best fit their learning contexts, as well as modifications to surface new perspectives. For instance, due to the variations in teams' project designs and some inherent constraints upon the format and timeline of the course, we did not deeply explore the `EXPAND` stage of the collaborative CIDERs. To provide a source of feedback and surface more assumptions, teams could be paired up and conduct collaborative CIDER activities using each others' artifacts. One could also imagine a modified collaborative activity where students `CRITIQUE` their team's design separately, then bring their list of identified assumptions to a team meeting to discuss. Yet another modification might involve alternating between individual and collaborative CIDER activities so students could engage with others' insights through the original `EXPAND` stage list format and through peer discussions, perhaps contributing to faster-developed or more comprehensive understandings of inclusive design. Future work exploring these kinds of modifications might surface insights about teamwork in post-secondary inclusive design education as well as professional team-based design contexts.

When conducting collaborative CIDER activities, educators should also be mindful of diversity among design teams. In our study, we allowed students to self-select into their project teams according to shared topics of interest. However, as mentioned in our RQ3 results, many teams reflected upon the benefits of working with students with different levels of design knowledge, backgrounds, and lived experiences, often underscoring that the diversity of perspectives amongst the team enabled them to identify more varied types of assumptions than they might have individually. Collaborative CIDER teams specifically created with student diversity in mind might be even more effective at identifying and responding to embedded assumptions.

*6.3.4 Teaching inclusive design skills in different learning contexts.* The CIDER technique was designed to address specific teaching and learning difficulties shown to arise in formal, post-secondary computing education contexts, such as HCI courses within computer science or information science programs. This choice was due in part to the expertise of the authors, but also the fact that computing departments often do not support students in developing holistic understandings of how software design impacts end users (see Section 2.1 for some examples). Given the continuing enrollment increases in computing programs [60], more and more students are graduating and entering careers where the technology they create might directly impact the lives of hundreds, thousands, or even millions of people. Instilling some sense of design responsibility through effective inclusive design education within these programs may help mitigate future potential harms.

On the other hand, formal computing education programs are certainly not the only sites of software interface design education. At several universities, entire courses of study focus on HCI/UX design and technological interaction design. These curricula might integrate one or more courses or modules that focus specifically on inclusive technology design. Correspondingly, the attitudes of students in these programs likely differ significantly from students in computing programs, such as in their initial understandings of how design impacts users, the role of designer subjectivity, and students' willingness to embrace inclusive design paradigms. In these cases, the CIDER technique might be adapted to better target the inclusion literacy levels of students. For instance, future work might explore whether it is viable to have HCI/UX design students analyze assumptions within their own designs from the outset during CIDER's `CRITIQUE` stage, as presumably these students already understand that inclusion issues exist in real-world technologies. Students in full UX design programs might also benefit from extensions of the method that integrate actual prototyping of proposed solutions from the `DESIGN` stage that improve inclusiveness, enabling even more concrete understandings of the nuances of inclusive design.

*6.3.5 Promoting inclusive design agency and responsibility.* As discussed in our analysis of the post-class interviews (Section 5.4), some students reported that the use of the CIDER technique impacted their approaches toward design work, leading them to value inclusion and attempt more inclusive practices during subsequent design projects at internships or for personal portfolios. Many of our students' reflections had a similar tone to those relayed by Kharrufa and Gray in their investigation of HCI *threshold concepts*—topics that, once understood, irrevocably change a person's perception of a discipline and their role within it [45]. These longer-lasting impacts on students' attitudes toward inclusive design are extremely promising for the efficacy of the CIDER technique in promoting a sense of responsibility for accessibility and inclusion among early designers.

However, prior work investigating early designers' development of competence at their first professional design jobs has noted the role of the surrounding organization in enabling (or preventing) early designers to enact their values in their actual design practice [31, 86]. Simply instilling a sense of responsibility for inclusion in early designers through classroom instruction may not be enough to enable them to overcome external pressures after graduation. Future work involving the CIDER technique might explore its ability to encourage students to move from simply recognizing their responsibilities as designers to becoming active advocates for accessibility and inclusion, similar to the “Activism/Advocacy” trajectory of designerly identity described by Chivukula et al. [15].

## 7 CONCLUSION

The CIDER (*Critique*, *Imagine*, *Design*, *Expand*, *Repeat*) assumption elicitation technique is an educational analytical design evaluation method to help early designers learn inclusive design skills. We evaluated the efficacy of this technique in a series of individual and collaborative activities in an introductory post-secondary interface design course, finding that it enabled students to recognize and respond to many different types of design bias. In follow-up interviews several weeks later, some students reported that their experiences with the CIDER technique had had long-lasting positive impacts on their approaches to design, encouraging them to value inclusion and consider more diverse types of users in their subsequent design work.

While this is only an initial evaluation, the results from our case study indicate great promise for the use of the CIDER technique in classroom contexts and potentially even beyond them. By using the lens of *assumptions about users* as a means to reveal instances of design bias and potential exclusion, techniques like these can help instill appreciations for and commitments to inclusive design early on in design education. In turn, these designers can contribute to the creation of more inclusive HCI artifacts, whether in professional practice or even just in their own personal design work. While education is not the only tool that will be necessary to build more inclusive futures for technology design, techniques like CIDER are a crucial initial step along the path to a world where everyone, not just stereotypical “average users,” can equitably and effectively interact with technology.

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