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Towards Bringing Human-Centered Design to K-12 and Post-Secondary Education

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Abstract: Human-Centered Design (HCD) is a growing field that has the potential to positively impact students' learning. A general consensus on the terms, practices, scaffolds, and assessments of HCD can foster its effective implementation in K-12 and post-secondary education. This session brings together researchers whose work is focused on implementing HCD across K-16 classrooms. It aims to develop a coherent definition of HCD, its methods, practices, and assessments, to help frame the field and reduce ambiguity at a critical time in its broader adoption.

Introduction

Engaging students in problem solving experiences during project or problem-based learning has long been shown as a particularly effective means for students to learn both content and thinking strategies (e.g. Hmelo-Silver, 2004). While effective, many of the problems that students are tasked with in these curricula do not have a direct connection to their lives and experiences outside of the classroom. This disconnect between the content and their lived lives has been shown to cause students, particularly those underrepresented in STEM, to self-deselect from many career pathways, because they cannot envision how what they learn will have an impact on them and those they care about (Valla & Williams, 2012). In response, Human-Centered Design (HCD) is an approach that focuses problem-solving on the real needs of real people (Brown, 2008). In many ways, HCD has been shown to help students develop human-centered, experimental, collaborative, metacognitive, communicative, and creative mindsets (Goldman et al., 2012; Razzouk & Shute, 2012). With these mindsets, students become better prepared to effectively engage in future learning endeavors and actively participate in today's globally competitive world.

While, there has been increasing research into how we can best engage students in HCD in K-16 classrooms (Caroll et al., 2010; Zoltowski, Oaks, & Cardella, 2012), we still lack a general consensus on the terms, practices, scaffolds, and assessments that are needed for us to effectively implement and scale HCD integration. This lack of consensus makes it difficult for researchers, teachers, and policy makers to understand the best practices for implementing HCD in their classrooms, to assess the efficacy of an implementation, or to dive deeply into an implementation for iterative refinement. Given the increased interest in HCD as an approach across the educational spectrum, there is a need to develop a more unified consensus around the terms, practices, scaffolds, and assessments, or we risk a fragmented landscape.

Objectives

The symposium features researchers whose work on implementing HCD across K-16 classrooms focus on: 1) defining the design thinking processes and practices that are associated with HCD; and 2) providing exemplar approaches to integrate and support the teaching and learning of HCD. Lawrence and her colleagues introduce an HCD taxonomy that defines the HCD processes and practices and can inform the design and implementation of HCD curricula. Shehab and his colleagues present a case of integrating HCD in an undergraduate food science capstone course that positively impacted students' knowledge of implementing the HCD processes and using the HCD skills. Dhvani and her colleagues propose an instructional model that integrates the practice of (human-computer interaction) HCI education that takes an HCD approach in K-12 education by outlining the roles and responsibilities of learners and facilitators, prioritizing learner's agency in the process of learning. Lewis and his colleagues present a design and researcher assessment approach for coupled iteration in design that can help students learn to better create designs to meet human needs. Spencer and his colleagues present a researcher assessment approach that assists students in identifying risks in the domains in which they will practice HCD to reduce uncertainty and improve their designs. Royalty and his colleagues propose a reflective tool that can be used to assess and capture how students develop HCD practices. Finally, Goldman and her colleagues show how HCD can also be used by teachers to conduct their own educational design projects to better understand and support their students. Together, these contributions aim to provide a single venue to synthesize the current terms, practices, methods, and assessment of HCD. The symposium aims to develop a coherent and robust understanding of HCD, and its uses in curriculum and instruction, to help frame the field and reduce ambiguity at a critical time in its broader adoption. The symposium also offers methods and assessments that researchers can use to understand the efficacy of their HCD instructional designs.

Session format

The symposium will start with each researcher giving a six-minute talk to introduce the participants and attendees to their work across the symposium's two themes. Next, the discussant will facilitate conversations between researchers on critical issues emerging out of our shared approaches to HCD such as: What are the challenges of integrating HCD in non-design focused curricula, and how can we address them? How do we effectively scale implementation of HCD in K-16 classrooms? How as researchers, do we know if our designs are having the impact we want? Finally, the symposium will close with an open discussion with attendees to identify areas of further research and collaborations that can help us better bring HCD to K-16 education.

Implications

We believe that this session will provide a foundation in a new and growing field. It will solidify the meaning of HCD in order to avoid ambiguity. It will also facilitate the work of researchers and practitioners around the design and implementation of HCD instruction and activities in K-16 classrooms.

Implementation of a Human-Centered Design taxonomy with a novice, multidisciplinary design team

LuEttaMae Lawrence, Saadeddine Shehab, and Mike Tissenbaum

HCD is a problem-solving approach that identifies the unmet need of a population in order to collaboratively and iteratively develop solutions (Brown, 2008). Researchers have studied important components situated in this approach, including iteration (Lewis et al., 2018), sketching (Härkki et al., 2018), and design failure (Yan & Borge, 2020), leaving unexamined how students navigate the overarching approach. While there are well known models that theorize the processes of HCD (Brown, 2008), they do not provide pedagogical guidance that articulates what this learning looks like and how to support it. Therefore, we have developed an HCD Taxonomy that outlines five design spaces (understand, synthesize, ideate, prototype, and implement) (See Figure 1) and practices that describe how students operationalize specific spaces. This taxonomy was designed iteratively with designers, researchers, and teachers from multiple disciplines to develop a flexible tool that can be used across contexts. The goal of this taxonomy is for teachers and designers to develop curricula, learning objectives, and assessments based on what space they are teaching and the practices they want their students to implement. In this case study, we present findings on how the taxonomy emerged during a novice team's HCD approach. Toward this end, we aim to understand how this novice team used HCD practices during their design project.

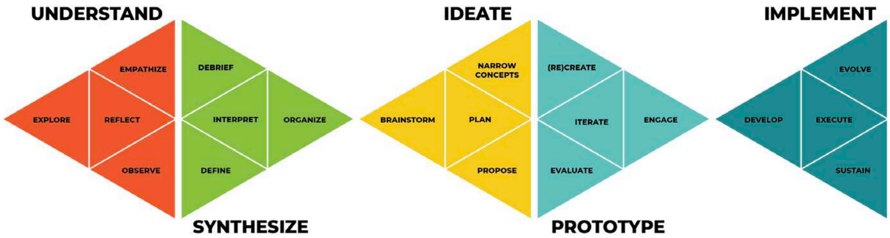

Figure 1. The HCD Taxonomy

We report on a five-week design project from an Introduction to Design Thinking course that teaches students from non-design disciplines about HCD. Three members comprised the design team, a first-year graduate student in education, a senior in civil engineering, and a first-year graduate student in architecture. The instructor assigned a project to select a subculture of which they did not belong and develop three frameworks to address a problem for this subculture. We collected instructional materials, audio recordings of the team's meetings, video recordings of their in-class presentations, and a reflection and post-survey from each team member. We leveraged knowledge integration theory (Linn, Clark, & Slotta, 2002) to analyze the design process and understand how HCD practices can be interconnected to achieve higher levels of integration and can be built over time.

Using our taxonomy and knowledge integration theory (Linn, Eylon, & Davis, 2013), we sought to understand how HCD practices were used by a novice design team and to what extent they made connections across spaces and practices. While this team iteratively used the taxonomy spaces, our findings highlight the challenges of teaching HCD to beginners and the differences among students. Within this group, only one student was able to achieve high levels of integration more than a single instance. We also found that while the group went through the motions of HCD, their process and final results did not always align to the overarching goals. Our paper highlights the complexity and challenges of teaching with the HCD taxonomy, and we share learning considerations to scaffold this process for beginners so that they may achieve higher levels of integration.

Integrating Human-Centered Design in a food science capstone course: A case study

Saadeddine Shehab, LuEttaMae Lawrence, and Mike Tissenbaum

The integration of HCD in post-secondary education can help undergraduate students come up with innovative solutions to authentic and complex problems that are relevant to their field of study (Withell & Haigh, 2013). Lately, there has been some work around the implementation of HCD in undergraduate classrooms (Puente, van Eijck, & Jochems, 2013); nevertheless, much of this work has been mainly reported from a theoretical or design-focused lens, rather than empirical evaluation, especially in STEM disciplines. This case study describes the integration of HCD into a food science capstone course through a) defining HCD and food science learning goals, b) providing scaffolding tools that support students' engagement and learning of HCD, c) creating opportunities for formative assessment and revisions, and d) promoting students' participation and collaboration (Barron et al., 1998). The study explores the students' experiences in this course to provide evidence-informed insights of instructional models that effectively integrate HCD in post-secondary STEM courses.

This study is part of a broader design-based implementation research initiative led by the Siebel Center for Design at the University of Illinois at Urbana-Champaign, which collaborates with faculty members to integrate HCD in their courses. The study took place in an undergraduate food science capstone course in which students solve authentic food science problems while developing novel food products. In Fall 2019, the 42 students who took this course worked in small groups to develop a food product using HCD. Each week, students attended two 50-minute lectures and one 4-hour lab section. The lectures were focused on introducing the students to the different processes and practices of HCD and the principles of food product development. The laboratory sessions were focused on engaging the groups in activities to implement HCD and using the principles of food product development in refining and prototyping their concepts and thinking about the actual implementation of their design in the food science industry.

Pre- and post-surveys were collected from the students to measure the impact of the course on their knowledge of implementing the HCD processes and using the HCD skills, and to assess if the students accomplished the food science learning goals. Classroom observations were collected during the lectures and the laboratory sessions. The video and audio recordings of the students' presentations of their final concepts and their final products were collected from the six consented groups. Interaction analysis of the presentations indicated that integrating HCD in the course helped the groups to systematically approach the development of their food products through empathizing with the users, synthesizing design opportunities, and applying principles of food product development in ideation and prototyping. A paired sample t-test was conducted using students' responses to the pre- and post-survey items and results indicated significant differences suggesting a positive impact of the course on students' knowledge of implementing the HCD processes and using the HCD skills, and that students accomplished the food science learning goals. These findings support the use of an instructional model that can help teachers teach about and through HCD in STEM post-secondary classrooms, including scaffolding and assessment tools.

Embedded design: An approach to support learning of Human-Centered Design practices

Dhvani Toprani, Mona AlQahtani, Yu Xia, and Marcela Borge

Creating learning environments for human-computer interaction (HCI) education for children requires taking a broader perspective towards learning that goes beyond focusing on teaching domain knowledge to include higher-order metacognitive, socio-emotional, and socio-metacognitive skills. However, formal education's emphasis on domain knowledge deprioritizes engaging learners in learning about and practicing these higher-order skills, making it challenging to integrate HCI education into K-12 (Collins & Halverson, 2018; Duschl & Bismark, 2016). Within an increasingly connected world, HCI designers require to not only know but also practice sophisticated thinking processes (Carroll, 2013). Building upon previous work on instructional support for children to iterate and solve ill-structured, real-world design problems (Collins et al., 1991, 1989; Jonassen 2000), and integrating HCD approaches we propose an instructional model, i.e., embedded design framework, for designing learning environments that foster higher-order skills to integrate HCI education into K-12 (Borge et al., 2020). The goal of embedded design is to create human-centered learning environments that focus on teaching through practice where learners have the agency to craft their learning experiences.

This framework is developed from an ongoing research project with eight to twelve years old children in an afterschool club, where children engage with playful design challenges within an HCI context. Children worked in groups of three, using different technologies like Lego, Minecraft, and Makey-Makey. Each session was structured to give children forty-five minutes to do hands-on designing with their group members, and the instructors used ten to fifteen minutes at the beginning and end of the session for whole-class discussion to introduce the design challenge and reflect on groups' design and collaborative processes.

As an instructional tool, embedded design framework proposes six core principles for facilitators and learners (See Table 1). These principles emerge from case studies drawn from one year of the afterschool club data. It embraces learners' agency by allowing their experiences and needs to be the main driving force of community rules, future discussions, and activities. As needed, facilitators observe learners and create perspective shifting opportunities to help learners discern complex concepts. They provide learners with activities where they can take over different roles within an HCI design context as both users and designers. Facilitators take over the role of orchestrators as they engage learners in reflective discussions where they help them recognize their needs as well as the needs of others in their community. As a community and across time, facilitators work as connectors of experiences as they help learners make sense of previous events in relation to current and future ones. In doing so, community experiences become objects to reflect on, making abstract concepts accessible and attainable by learners.

Table 1: Principles of Embedded Design and the Roles and Responsibilities of Learners and Facilitators.

Principles	Roles and responsibilities
Learners as Agents, Actively Participating in Domain Thinking Processes	
Learners as primary learning agents	Learners spend the majority of the time in control of their own learning experiences. They work on self-directed projects with peers, making collective decisions about what they will design and how they will spend club time.
Learners as central participants	Learners are taking an active role in different aspects of design, even during expert modeling, by playing an important complementary role that the expert must interact with, i.e., user for the designer, builder for the planner, etc.
Learners as anchors of the sense-making & solution process	Learners' perspectives/feelings during the process of design anchor collective sense-making during reflection. These concrete experiences are used as objects of thought to understand problems and devise solutions.

Principles	Roles and responsibilities
Facilitators as Learning Designers, Orchestrating Co-Construction of Knowledge	
Facilitators as creators of perspective shifting events	Facilitators create opportunities for learners to experience a design event from different perspectives, i.e., the learner takes on the role of designer receiving feedback from potential users and then takes on the role of a potential user providing feedback to the designer.
Facilitators as orchestrators of ongoing reflection	Facilitators lead reflective activities where the facilitator prompts learners to share their thoughts, feelings, and concrete experiences; learners' contributions are used as a means to connect the situated practice to expert practice, help learners identify important expert practices and existing problems in their own practices, and to understand why these problems occur. Facilitators also help learners to understand and develop shared goals and concrete plans for improving existing practices.
Facilitators as connectors of experiences	Facilitators observe learner activity, taking notes on important topics to discuss and analyze during community reflections. Individual and team experiences are shared with the community to develop shared understanding of important processes, dispositions, and values embodied by different experiences. These shared experiences can then be used as shared references to make sense of future events.

Embedded design contributes to the practice of HCI education that takes an HCD approach by outlining the roles and responsibilities of learners and facilitators, prioritizing learner's agency in the process of learning. By prioritizing agency, the higher-order skills required for HCI education are learned around the authentic experiences of the learner, giving them the opportunity to practice these abstract skills rather than learning it as technical knowledge. The six principles outlined within embedded design are developed with the aim of helping educators redesign their learning environments of HCI education by giving agency to children and broadening our perspective of learning.

Planning to Iterate: Designing to support and assess iteration in design

Daniel Rees Lewis, Spencer Carlson, and Matthew Easterday

To meet the needs of the stakeholders they are designing for, HCD students must learn how to iterate effectively. Iteration is a vital practice because real-world design problems are highly ill-structured, with "ambiguous specifications of goals, no determined solution path, and the need to integrate multiple knowledge domains" (Jonassen 2000, p. 80). To create solutions that support stakeholder needs, expert designers conduct *coupled iterations* in which they simultaneously (a) learn more about the nature of the problem, including stakeholder needs, (b) learn more about the extent to which their design is effective in addressing the problem, and (c) change the design in accordance with what is learned (Adams, Turns, & Atman, 2003). In short, we argue that if we are not supporting students to continually apply what they have learned about their problem, stakeholders and current design to their future design, we are not teaching them the core skill in HCD.

We present Planning-to-Iterate (Rees Lewis et al., 2018), a design and researcher assessment approach for coupled iteration in design. Planning to Iterate supports iteration by (a) facilitating discussions and prompting teams to conduct a planning process of representing the problem, prioritizing unknowns, and making iteration plans; (b) using two templates, the design canvas and iteration plan; (c) providing and prompting use of guiding questions that drive students to consider common pitfalls, and examples.

We created the assessment in Planning to Iterate for researchers to understand the extent teams are conducting coupled iteration—that is, to what extent are teams gathering information on problems and solutions to inform revisions to their design. Assessment involves videoing and analyzing weekly student Planning to Iterate sessions. We analyze weekly student planning through applying three codes in video analysis: (a) *problem learning* which to capture team reports of learning about aspects of the problem, (b) *solution learning* which captures reports of learning about the design, and (c) *solution revision* to capture reports of plans to change the solution based on reported learning. We code for teams conducting coupled iterations when problem learning (code a) and solution learning (code b), informed solution revisions (code c).

Our goal with Planning to Iterate has been to create scaffolds and assessments for supporting coupled iteration. Initial work in Planning to Iterate shows that compared to a far more intensive face-to-face coaching, student design teams supported by Planning to Iterate conducted more coupled iterations and created more effective designs (Rees Lewis et al., 2018). In doing so, we can help students learn to better create designs to meet human needs.

The Design Risks Framework: *Risks* as a key learning goal in Human-Centered Design

Spencer Carlson, Daniel Rees Lewis, and Matthew Easterday

Iteration is the strategic management of the design process to refine one's understanding of the problem and advance a solution (Adams et al., 2003). As such, iteration is a defining characteristic of effective design processes (Adams et al., 2003; Crismond & Adams, 2012). Design practitioners recognize that effective iteration requires designers to identify *risks*—gaps in their knowledge of the problem stakeholders, and the current design that could lead them to design something that does not support stakeholders' needs—so that they can plan iterations in which they learn more about those unknowns and update their design solution if necessary (Bland & Osterwalder, 2019). While this skill is of general importance across design domains, the underlying knowledge varies by domain. For example, toy designers must learn to identify the risk that their toy might be a choking hazard while social media designers must learn to identify the risk that their platform might radicalize users.

We must teach students to identify risks in the domains in which they will practice HCD. This requires assessment methods to measure students' ability to identify risks in a given design domain. We present the Design Risks Framework (Carlson et al., 2018), a researcher assessment approach for identifying risks in HCD. In this approach, students construct an external representation of their knowledge about the problem, stakeholders, and their current design. Then, students attempt to identify risks by reflecting on the gaps in their knowledge that could lead them to design the wrong thing. Next, a researcher with design expertise (or a design instructor) reviews the students' problem representation to identify risks. Last, the researcher compares the risks they (or the instructor) identified, with those the students identified. This allows researchers to measure students' ability to identify risks in their projects relative to that of an expert. Over time, this method also enables researchers to develop a list of the key risks that students must learn to identify in a given design domain—thereby defining in detail a critical learning goal for HCD learning environments in that domain. This list could be used to create rubrics or checklists that instructors might use for formative assessment of students' ability to identify risks.

Our goal with the Design Risks Framework has been to assess students' ability to identify risks in specific design domains. In initial work assessing novice designers completing service design projects, researchers used the Design Risks Framework approach to assess a large number of domain-specific risks that students struggled to recognize in their projects (Carlson et al., 2018). By focusing on risks as a key learning goal in HCD, we can help students learn to plan iterations to reduce uncertainty and improve their designs.

Reflective Design Practice: A novel tool that captures how students develop Human-Centered Design practices

Adam Royalty, Helen Chen, and Sheppard Sheri

Learning HCD in a university setting can be "messy." Students often work in project teams on ambiguous problems (Goldman et al., 2012). In short order each project unfolds in a unique way, making understanding student growth difficult. This work utilized a tool for capturing students' design work. Furthermore, we analyzed this design work and found three ways in which students internalize the methods and mindsets of HCD.

The results come from a study of 33 students from five schools within a large U.S. research university who took a 10-week introduction to HCD course. The data were gathered using a novel digital reflection tool called Reflective Design Practice (RDP) which allows students to capture authentic work and reflect upon it longitudinally (Royalty, Chen, & Sheppard 2018). RDP prompted participants to photograph an artifact they created in their HCD course each week. The artifact could be tangible (e.g. a physical prototype) or it could be intangible (e.g. an interview protocol). For each artifact, participants were given questions to help them reflect on their creation. Participants uploaded the artifact and the associated reflections to an online folder—forming a multi-page portfolio of design work. After seven weeks, researchers conducted a semi-structured interview with each participant based on their weekly reflections. We used a grounded theory approach to analyze the weekly reflections and the interviews. The aim was to distill how students linked their own perceived growth to the academic environment in which they learned design.

The data suggest three general categories for student sense making. Supports for Learning Design are specific details of the academic environment students identified as supporting how they learn design and transfer that situated learning (Greeno Moore & Smith 1993). Self-Differentiation of Design are aspects of the academic environment that shape students' perspective of what design is and what design is not. Many of these realizations come from contrasting design work with work performed in other courses. Student Responses are the cognitive and emotional responses to design instruction that shape how students develop their own design practice.

Although Student Responses are internal, they develop through working repeatedly within the academic environment. Each general category has between five and eleven sub-categories. These initial findings can help researchers and practitioners better understand how students construct their own HCD practice. It may be the case that students learn HCD in ways that instructors do not perceive or account for.

Empathy development in design thinking for improving access and equity for students designated as English learners

Shelley Goldman, Annie Camey Kuo, Kimiko Lange, Melissa Mesinas and Rose K. Pozos

Design thinking during HCD begins with understanding a problem holistically and from the eyes of the people for whom one is designing and iterates with cycles of prototyping and feedback (Goldman & Kabayadondo, 2016). We report on a three-year, four school district research practice partnership (RPP) (Coburn, Penuel, & Giel, 2013) to use design thinking with K-8 teachers and administrators to design solutions for supporting students designated as English learners (DELs). As of 2018, DELs comprise approximately 19.3% of public school students in California (McFarland et al., 2019). DELs are present in nearly every district, yet not all schools serving DELs have specialized teachers or resource programs. The districts in our study lacked specialized supports for DELs and had low numbers of DELs (10% or less), a situation not yet addressed by research or policy.

Our RPP employed design thinking in conjunction with hybrid professional development workshops (Rutherford-Quach, Kuo, & Hsieh, 2018) to help teachers and administrators build capacity for understanding and supporting DELs. The goal was to raise collective awareness of, and attention to, systematic educational inequities surrounding DELs such as social isolation and lack of specialized language learning services, and to support teachers and administrators in designing change to many aspects of their DELs' experiences.

Empathy development was a key component of the training and the design thinking approach. The educators generated 18-24 solutions for students each year. We relied on empathy exercises with teachers throughout the design thinking process. HCD work stretched throughout the design process and was especially evident during prototyping, feedback, and iteration cycles. Resulting designs ranged from new classroom languaging strategies, to relationship building, to reorganizing specialized staff, to focused professional development. The designs were responsive to individual students and small groups, whole classes, and district and structural systems.

Data were gathered using an ethnographic approach, with documentation of the participants' design processes, with a goal of capturing small changes in practice and mindsets over time. We administered pre- and post-year surveys, collected field notes, written artifacts from participants, video and audio recordings of meetings, and focus group reflections. The role of empathy and the attention to students' needs in the designs turned out to be a key factor in effective design projects. We present an analysis of survey results and resulting educator design project analyses to show how the empathy orientations impacted educators' work on behalf of students. We identify connections between the empathy work educators completed and their perceptions of their DEL students' abilities (e.g. exhibiting asset-based rather than deficit-based views) and achievements (being situated in the system rather than in the children). Findings show robust changes in classroom instructional practices, a few examples of systems change, and uneven awareness of and attention to inequitable social and educational access for DELs. Empathy was essential to the progress that was made.

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