International Journal of Innovation in Education

ISSN online: 1755-1528 - ISSN print: 1755-151X
https://www.inderscience.com/ijiie

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DOI: 10.1504/IJIIE.2024.10063914

Article History:

Received:	15 September 2022
Last revised:	16 September 2022
Accepted:	25 July 2023
Published online:	05 June 2024

Understanding non-designers' practices and processes in a human-centered design course

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Abstract: Human-centered design (HCD) has been identified in the literature as a useful problem-solving approach for learners. However, learning and applying HCD poses several challenges for students who are unfamiliar with this form of learning. In this paper, we analyse how a novice design team worked on a HCD class project to examine how non-designers learn about and integrate HCD practices into their project. We introduce the HCD taxonomy to define the processes and practices that students engage in. The team's design work is triangulated across multiple data sources and revealed three challenges for engaging non-designers in HCD: 1) the need for further scaffolding to support connecting practices; 2) complexity engaging in the Understand space to support empathy building and reflection; and 3) navigating tensions between the instructor as a teacher rather than a stakeholder. Our contributions include a taxonomy for teaching HCD containing processes and practices within each space and a case study application.

Keywords: HCD; human-centered design; design education; case study; design taxonomy; interdisciplinary; novice designers.

Reference to this paper should be made as follows: Lawrence, L., Shehab, S. and Tissenbaum, M. (2024) 'Understanding non-designers' practices and processes in a human-centered design course', *Int. J. Innovation in Education*, Vol. 9, No. 5, pp.1–27.

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This paper is a revised and expanded version of a paper entitled 'Human-centered design taxonomy: Case study application with novice, multidisciplinary designers' presented at *American Educational Research Association*, Virtual, April 2021.

1 Introduction

Human-centered design (HCD) is a problem-solving approach that uses design thinking processes and practices to identify the unmet needs of a population to develop solutions collaboratively and iteratively (Brown, 2008). In education, HCD is a design-based pedagogy that provides students with opportunities to implement processes and apply content knowledge to explore and identify problems with stakeholders (Razzouk and Schute, 2012). Empathy is at the centre of HCD. In courses students reflect on their audience to come up with human-centered solutions to real-world problems (Micheli et al., 2019; Scheer et al., 2012). There is a growing interest in the integration of HCD in education (Oehlberg et al., 2012; Peyton et al., 2019) and research shows that teaching design to non-designers is an impactful form of education (Kolodner et al., 1998). Yet, one limitation of this approach is that HCD is often taught to novices through accelerated pedagogical models in courses or workshops (Schell, 2016), and less is

known about how to teach and engage non-designers in the nuanced practices of HCD (Royalty et al., 2015).

In this paper, we build on the existing definitions and models on teaching HCD to non-designers to outline a taxonomy for teaching and learning HCD that delineates specific processes and practices. Then, we describe how the taxonomy can be used as a pedagogical model to structure and teach a course that aims to engage non-designers from multiple disciplines in learning about and implementing HCD. We use a case study approach to examine how a novice design team in this course learned about and implemented HCD processes into their design project. In this paper, we share the initial investigation of the interactions that lead to integrated processes. To understand how the students engaged in HCD and integrated processes, we examined the following two research questions:

1 How did a novice design team and their instructor use HCD taxonomy during their design project?

2 How did their level of HCD integration change over time?

2 Human-centered design

Human-centered design (HCD) is a problem-solving approach that uses design thinking processes and practices to identify the unmet needs of a population in order to collaboratively and iteratively develop meaningful and innovative solutions (Brown, 2008). HCD is often focused on 'wicked problems' that are ill-defined and not conducive to conventional or incremental problem-solving methods (Buchanan, 1992). Researchers have studied important components situated in this approach, including iteration (Rees Lewis et al., 2018), sketching (Härkki et al., 2018), risk analysis (Carlson et al., 2020), and design failure (Yan and Borge, 2020), leaving unexamined how students navigate the overarching approach. While there are well-known models that theorise the processes of HCD (Brown, 2008; IDEO, 2015), they do not provide the necessary pedagogical guidance articulating how to bring this approach to learning environments such as K-12 and higher education classrooms.

There is no simple formula for teaching HCD, and the necessary processes, practices, and mindsets are complex to enact in the classroom. To make matters more challenging, existing models and definitions of HCD are simplified representations, leaving open to interpretation how different processes are integrated in classrooms (Cross, 2011; Brown, 2008; Razzouk and Schute, 2012). Researchers have described this approach (Koh et al., 2015; Noweski et al., 2012; Pande and Bharathi, 2020), its relationship to standards (Goldman and Zielezinski, 2016), ways to measure its learning outcomes (Aflatoony et al., 2018; Goldman et al., 2012; Owen, 2007; Royalty et al., 2019) and explored the mechanisms of instruction (Royalty et al., 2015). However, researchers have yet to examine how a more granular specification of the HCD processes can

1 empower teachers to integrate HCD in their classes and their existing learning goals

2 engage non-designers in learning about the HCD processes to eventually develop expertise in implementing them over time and thus begin to use them to address and solve problems in new contexts.

This paper presents an HCD taxonomy describing the major processes that can be used by teachers to teach about and integrate HCD in their classes. The taxonomy is developed in collaboration with teachers and researchers and is the product of several rounds of revision and critique from teachers implementing the taxonomy (Lawrence et al., 2021; Shehab et al., 2021) and insights from experts in the field. The paper also describes how a group of non-designers learn about and engage in the HCD processes that are listed in the taxonomy.

3 Human-centered design taxonomy

Building on existing design thinking models, our taxonomy is a three-tiered model that outlines the complex mechanisms of the HCD approach. Within the taxonomy, we outline the three tiers as design

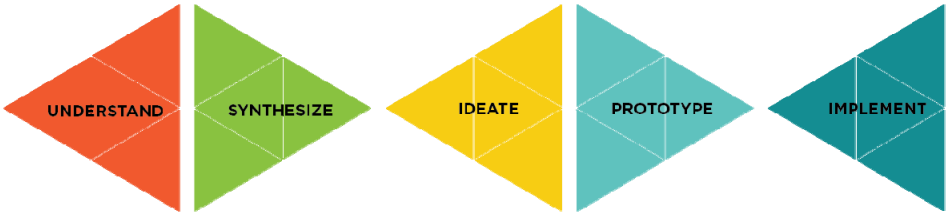
1 spaces

2 processes

3 practices.

Each design space is a unique, stand-alone component where students engage with different processes of HCD. The taxonomy consists of five spaces: *Understand*, *Synthesise*, *Ideate*, *Prototype*, and *Implement* and four processes per each space (Figure 1). While there is a general sense of linearity to this representation, it was designed intentionally to be flexible, wherein the triangles can be rearranged and duplicated to illustrate the reality of the emergent approach (Boling and Smith, 2010; Teal, 2010). As an instructional tool, spaces can be presented as a series or isolated and taught individually.

Figure 1 A representation of the HCD taxonomy and the five design spaces including *understand*, *synthesise*, *ideate*, *prototype*, and *implement* (see online version for colours)

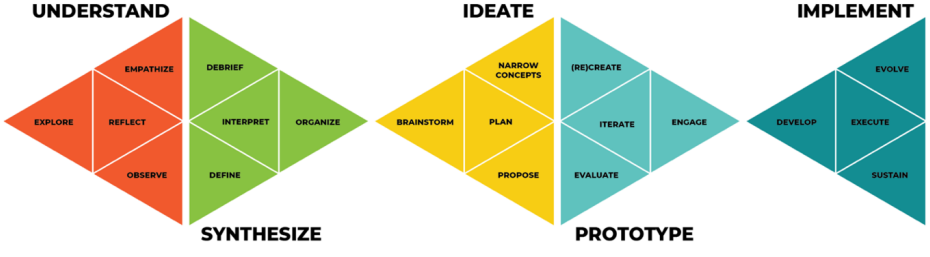


The key contribution of this work is the pedagogical practices themselves. In other words, ways in which students operationalise specific spaces and processes. Descriptions of practices outline why they are important for students' learning and using HCD. While the taxonomy describes the importance of each practice, this does not mean that all HCD projects should include all practices. The taxonomy is meant as a flexible tool for introducing the overall spaces or diving into one specific process; teachers may introduce practices over time based on their teaching goals and experience of their students.

As described by Dorst (2011), expert designers do not use practices in a prescriptive way, rather they fluidly and dynamically apply them as the problem and solution emerge.

However, to get to this high level of integration, where designers are drawing connections between practices and fluidly using them without prompt, requires a full understanding of the taxonomy and vast expertise that novice designers do not yet have. While the presumed goal is to get students to this high level, in this paper we only outline the practices and why they are important to student learning. Future work will explore how practices are used in different disciplines, what they look like in context, and how they are assessed. Below we provide our description of each space, their constituent processes, and practices (Figure 2), and the literature that informed our practices, described by the individual spaces.

Figure 2 A representation of the HCD taxonomy, including the five spaces and four practices within each space (see online version for colours)



3.1 Understand

The *Understand* space is a foundational component of HCD, where students investigate the design project by first addressing the unmet needs of a population (Brown, 2008). The *Understand* space includes exploration of a problem with users that leads to a plan of action. Within this space we define four core processes, *Explore*, *Observe*, *Empathise*, and *Reflect* with corresponding example practices (Table 1).

Table 1 The processes and practices of the *understand* space

Processes	*Definition*	*Practices*
Explore	Exploring a design project by defining what the problem is, researching it, hypothesising how it works, or discussing biases about it	Establish a common problem space Review current landscape or context Document biases and predictions
Observe	Planning to collect, gathering, or sharing already collected observations of a space or immersion with environments	Conduct observations Immerse oneself within an environment
Empathise	Planning to collect, gathering, or sharing already collected information of experiences from stakeholders, including interviews, user resources, and information from extreme users	Conduct interviews Locate user resources Identify extreme users
Reflect	Reflecting on the goals, context, or plan to explore the design project	Revisit project context Modify research plan as needed

Explore includes three practices or ways students operationalise this process during learning, including *establishing a common problem space, reviewing the current landscape or context,* and *documenting biases and predictions*. Establishing a common problem space is important so that students have a common understanding of the design project that is trying to be solved and understand that a problem space should be iterated and revised based on new information (Noel and Liub, 2017). The second practice, reviewing the current landscape or context, has students research existing information relevant to the design project. A challenge in doing HCD is grappling with the needs of others over the needs of the designer. To mitigate this, asking students to explicitly document their biases and predictions can prompt them to reflect on how and why their own experiences and biases can affect their designs (Papantonopoulos, 2004).

Observe includes two practices, *conduct real work observations* and *immersion with the environment*. *Observations* allow students to unobtrusively observe a situation or experience without interacting. This practice can shed light on users' natural interactions that inform what users do and how. Immersion with the environment goes beyond observation, where students become a participant observer and experience the interactions that users do, providing students with the experience of walking in a users' shoes and living the challenges or benefits they may have (Stock et al., 2017).

The *Empathise* process includes three practices, *conduct interviews, locate resources* and *identify extreme users*. The *Empathise* process prompts students to plan, collect, or share information from and with stakeholders. Conducting interviews is a critical component of HCD involving listening and acknowledging the needs of others throughout the entire design process (Brown, 2008; Siu, 2002; Twal, 2018). Locate resources allows students to explore existing information about users before and after talking to them, providing additional content to help describe what users need or how they interact. Identifying extreme users allows students to understand the boundaries of the design space and probe deeper into the needs of those who have contrasting experiences.

Finally, *Reflection* is a key component in HCD, wherein students reflect on the goals, context, or plan for the project (Lawson, 2006). There are two practices within this process, including revising the project context and modifying the research plan. Reflection is critical to employ practices from other spaces to inform the overall direction of the project and identify how new and changing information can inform the overall context and goals (Shambaugh, 2004; Welsh and Dehler, 2013).

3.2 Synthesise

The *Synthesise* space is where students synthesise what they know in new patterns or themes to develop insights, identify opportunities, and decide on the next steps (Owen, 2007; Noweski et al., 2012). In the *Synthesise* space, students use the information they have collected through the processes of the *Understand* space to converge to a common point of view to generate ideas to address the design project (Noweski et al., 2012). Within this space we define four core processes, *Debrief*, *Organise*, *Define*, and *Interpret* with corresponding example practices (Table 2).

The *Debrief* process includes two practices, *filtering content for relevance* and *prioritising information* (Pressman, 2019). The *Debrief* process allows students to share and interact with the information they have collected when they implemented the processes of the Understand space (Lee et al., 2015). Students filter content for relevance

by examining the collected information and making decisions on what may be relevant to their design project. They prioritise information based on the consistencies that emerge from what the students thought is relevant to their design project.

The *Organise* process includes three practices, *collapsing content, finding themes,* and *developing insights* (IDEO, 2015). The *Organise* process allows students to combine information from multiple sources and generate themes and insights from these resources that can direct them towards design and research opportunities (Razzouk and Schute, 2012). Students collapse content by comparing and contrasting prioritised information from multiple resources. They find themes through identifying and examining emerging patterns. Based on these themes, students will develop insights about the users or their needs that will help them progress towards identifying design opportunities.

Table 2 The processes and practices of the *synthesis* space

Processes	*Definition*	*Practices*
Debrief	Sharing raw information collected from the understand space to stakeholders or team members	Filter content for relevance Prioritise information
Organise	Developing themes from data collected during the Understand space or ideas shared within the group, drawing comparisons across ideas, or developing insights about the project that draw multiple ideas together	Collapse content Find themes Develop insights
Define	Identify design opportunities through creating 'how might we' (HMW) questions or discussing possible threads for the project to focus the scope of the design project	Identify design opportunities Develop HMW questions Define the project scope
Interpret	Using themes, collected data, and/or opportunity areas to discuss how to move the project forward or what the next steps are	Identify further research opportunities Building questions to inspire ideation

The *Define* process includes three practices*, identifying design opportunities, developing how might we* (*HMW*) *questions,* and *defining the project scope*. The *Define* process allows students to transform their insights into design opportunities that help them better frame their directions. Guided by their insights, students can identify design and research opportunities by developing HMW questions that can frame innovative thinking and suggest that a variety of solutions are possible (Brown and Wyatt, 2010; IDEO, 2015). Considering preferred HMW questions, students can start defining the project scope through discussing possible threads and trajectories for the project.

The *Interpret* process includes identifying *further research opportunities* and *building questions to inspire ideation*. The *Interpret* process allows students to think about and reflect on their next steps in light of their prioritised information, themes, insights, design opportunities, and project scope (Taboada and Coombs, 2013). Students may identify future research opportunities or gaps that require them to revisit the Understand space and implement its processes to pursue these opportunities or address the gaps. This can end up enriching their themes and insights resulting in more robust or even new design opportunities. Students may also build questions to inspire ideation by breaking down

HMW questions into simpler open-ended questions that can better guide the brainstorming process and set team members up for effective participation in ideation.

3.3 Ideate

The *Ideate* space is where designers identify, entertain, and propose possible ideas that may lead to a solution for the design project (Brown and Katz, 2011; Noweski et al., 2012). In the Ideate space, students use the HMW questions and any other questions they built to inspire ideation during the *Interpret* process to *brainstorm, propose, narrow concepts, and develop a plan of action*. Table 3 shows these processes with their corresponding example practices.

Table 3 The processes and practices of the *ideate* space

Process	*Definition*	*Practices*
Brainstorm	Planning how to structure ideation session and proposing ideas or solutions to the problem, and developing themes of proposed ideas from the brainstorming session	Ideation of potential solutions
		Collapse ideas
		Defer judgement
		Chunk and find themes
Propose	Communicate the proposed idea(s) to users or stakeholders to collect and integrate feedback	Communicate suggested ideas
		Iterate in response to new information
		Come up with alternative ideas
Narrow concepts	Identifying which concepts are the most viable to move forward	Revisit users and stakeholders needs
		Examine available resources
		Make decisions on the most viable concepts
Plan	Using developed concepts, discuss how to move the project forward or what the next steps are	Develop a plan of action

The Brainstorm process includes three practices: generating and discussing potential ideas that can lead to solutions, chunking and finding themes using the generated ideas, and deferring judgement. These practices foster an effective collaborative "search for new solutions that might not be possible through individual ideation" (Seidel and Fixson, 2013, p.21). The Brainstorm process allows students to generate diverse and wild ideas and to bundle these ideas together before selecting favourites to propose them to stakeholders for feedback. As students brainstorm, they need to defer judgement and encourage each other and stakeholders to suggest any idea that comes to mind (IDEO, 2015).

The *Propose* process includes three practices: *communicating the suggested ideas*, *iterating in response to new information and feedback*, and *coming up with alternative ideas*. These practices urge students to share the generated ideas or bundle of ideas with stakeholders or users for feedback (Gray, 2013). Based on the collected feedback, students can modify ideas or even come up with alternative ideas. *Propose* as a process allows for the inclusion of users and stakeholders in ideation before converging into concepts that can lead to prototyping potential solutions.

The process of *Narrowing Concepts* includes three practices: *revisiting users' needs, examining available resources*, and *making decisions on the most viable concepts*. After generating lots of ideas and proposing favourites, students revisit users' and stakeholders' needs and examine the resources they have to start converging on certain ideas that can combine to form viable and feasible concepts (Hutchinson and Tracey, 2015; IDEO, 2015).

The *Plan* process includes the practice of *developing a plan of action* that prepares for prototyping the developed concepts. Students need to decide what and how to prototype (IDEO, 2015; Biffi et al., 2017). Students may also decide to revisit certain processes in the *Understand*, *Synthesise*, and *Ideate* spaces to collect more information or generate more ideas.

3.4 Prototype

The *Prototype* space is where students transform selected concepts into something tangible, they can use to test and collect feedback from users and stakeholders (Brown, 2008; Noweski et al., 2012). The goal of this space is not to finish the project but to learn the strengths and weaknesses of a concept to identify directions for future prototyping efforts (Brown, 2008). Table 4 shows the Prototype space processes and example practices.

Table 4 The processes and practices of the *prototype* space

Process	*Definition*	*Practices*
(*Re*)*Create*	Construct prototypes of their proposed physical, digital, or experiential concept through preliminary model (e.g., physical model, sketch, etc.)	Create prototypes of the proposed physical, digital, or experiential concept
Engage	Communicate the created prototype to users, stakeholders and/or teammates and collect feedback	Engage users, stakeholders and/or teammates in the created prototype
Evaluate	Diagnose problems and describe behaviours. Reflect on feedback to propose iteration	Evaluate the engagement process with users, stakeholders and/or teammates
Iterate	Explore multiple variations of the concept	Use feedback from users, teammates or stakeholders to revise prototypes to build more effective or usable design

The *Create* process includes the *construction of a prototype* of a proposed physical, digital, or experiential concept. A prototype can be anything that has a physical form that someone can interact with (Carroll, 2015, p.62). They do not have to be detailed or perfect (Noweski et al., 2012), and can take different forms, such as sketches, storyboards, role-plays, physical objects, or services.

The *Engage* process includes the *communication of the created prototype*(*s*) to users, stakeholders, or teammates. A major characteristic of HCD is the inclusion of all project players in the different stages of identifying the problem and developing a solution. In the *Prototype* space, students use the created prototypes to engage users, stakeholders, or teammates, explain it to them, and test it with them (Chu et al., 2017; Noweski et al., 2012). Students closely collect feedback from all project players. The feedback includes

all commentary about the prototype such as describing interactions, diagnosing problems, or affirming or corrective comments.

The *Evaluate* process includes three practices: *diagnosing problems and describing behaviours* and *reflecting on feedback to propose iteration*. After engaging all project players with the created prototype, students need to diagnose problems in their prototype and describe the behaviour of all project players when they encounter the prototype (Cassim, 2013). Students need to reflect on their findings and propose an iteration plan (Rees Lewis et al., 2018) through thinking about and prioritising the different ways to integrate the collected feedback as they revise or recreate their prototype.

The *Iterate* process includes the *exploration of multiple variations of the concept* in light of the findings from the Engage and Evaluate processes (Gal and Lewis, 2018). Students implement their iteration plan to explore the multiple variations of the concept and start converging into a final prototype that can act as a possible solution that can be implemented in the market.

3.5 Implement

The *Implement* space is where students prepare to take the project to the market by *Developing* their idea, *Evolving* the concept, identifying a plan to ensure solutions are *Sustainable*, and *Executing* their design into the hands of users (Table 5). The *Implementation* space is a culmination of the preceding iterative spaces, to test how a design will function in practice, with the expectation that further iterations will be necessary to sustain and evolve the idea over time.

Table 5 The processes and practices of the *implement* space

Process	*Definition*	*Practices*
Develop	Develop a plan for execution to make the idea or concept a reality; communicate the solution to stakeholders and investors	Communicate design Develop a plan for execution
Evolve	Plan for, collect, and implement user feedback to ensure implementation is successful	Continue to evolve and improve the solution based on user feedback
Sustain	Ensure the implementation is sustainable in the context by monitoring and evaluating social and environmental contexts	Plan for sustainability (e.g., environmental, societal, business) Monitoring and evaluation
Execute	Execute functional version of the implementation to users	Creating functional iteration of the design concept

The *Develop* process includes two practices, *communicating design* and *developing an execution plan.* This process includes the initial steps for planning how to bring a design idea to fruition. Students must share their design with stakeholders and funders to explore how it might be useful with users and develop a plan for how to polish and execute the idea.

Implementing a design is not a one-time event but requires students to continuously *evolve and improve the solution based on user feedback.* The *Evolve* process specifically prompts students to return to the previous spaces, because to create a successful

implementation, students must ensure that all decisions are meeting users' needs (Brown, 2008; Twal, 2018). This process is especially important for teachers and students to emphasise the iterative nature of this work; even when a solution has been identified does not mean that the design work is complete.

The *Sustain* process includes two practices, *plan for sustainability* and *monitor and evaluate.* During the implementation space, students must ensure that their design is sustainable by monitoring and evaluating its social impacts and its potential (Kuijer and De Jong, 2011). This can take many forms including discussions with users (*Understand space*), developing ideas for sustainability (*Ideate space*), or prototyping features or ideas to make a design more sustainable (*Prototype space*).

Finally, students must *Execute* the design so that users can interact with it; this process includes *creating a functional iteration of the design concept.* This process builds on the assumption that students have iteratively engaged in *Prototyping and* received feedback from users to inform their *Implementation* (Gal and Lewis, 2018). *Execution* of a design does not mean the process is over, as designs often go through multiple rounds of iteration based on insights that are learned when a design is implemented in its intended context.

4 Theoretical framework

While it is necessary to outline specific HCD practices that illustrate how students operationalise HCD processes in their learning, it is not enough to simply say that students have become proficient with these practices. Theoretically, research tells that novice designers typically follow instructions as presented (Cross, 2004), with some degree of flexibility as unprompted students naturally move between processes depending on their problem-solving approach (Welch, 1999). Expert designers do not use practices in a prescriptive way, rather they fluidly and dynamically apply them as the problem and solution emerge. However, to get to this high level of integration, where designers are drawing connections between practices and fluidly using them without prompt, requires a full understanding of the taxonomy and vast expertise that novice designers do not yet have. Accomplishing the goal of solving complex problems for novice designers while moving fluidly and making connections, takes a vast amount of time learning, applying, and reflecting on each of these practices and what they mean for design.

Our paper demonstrates one metric for assessing the quality of students' *integration of HCD*. Linn et al.'s (2013) theoretical perspective on knowledge integration informs our understanding of integrating HCD. They theorise knowledge integration as a learning process of making connections across an existing repertoire of ideas and new information. Well defined instructional support and ample time aid students as they create, refine, and strengthen learning connections (Linn et al., 2002). Time is especially important for novices who have less experience making connections and lack the mechanisms to untangle the necessary conditions of learning (Linn et al., 2013). Similarly, novice designers enact HCD differently than experts, often spending little time framing the problem, engaging in fewer iterations, and jumping quickly from problem to solution (Cross, 2011; Kali et al., 2011). Building connections across practices and spaces requires extensive expertise in HCD (Dorst and Cross, 2001; Guindon, 1990). Applying practices and design reasoning to problems in an effective way requires a level of 'designerly ability' (Dorst, 2011, p.531) that comes with experience. The differences

between novice and expert designers, like that of knowledge integration, can be attributed to a lack of connections across the HCD spaces and limited scaffolding that explicitly connects practices. Therefore, how, and when practices are enacted by novice designers remains important to enable them to derive these connections across spaces and improve their learning about HCD.

5 Methods

5.1 Design

We applied a case study design (Stake, 1995) to study the interactions of students in one group to closely examine and understand how these students engaged in the different HCD processes that were outlined by the taxonomy and how their understanding and implementation of these processes changed over time. The study was approved by the Institutional Review Board and all participants consented to be a part of the research.

5.2 Participants

In Fall 2019, 9 students (3 Males, 6 Females) participated in an Introduction to Design Thinking course that was offered by a Design Center at a Midwestern University. The course was taught by an instructor who held a graduate degree in design and had been teaching design for several years. In addition to her design background, she was involved in the co-design process of building the taxonomy and designed its integration into the course. In this study, we analyse the interactions of one group of three students and their instructor who all consented to be a part of the research. The three students comprised one design team, including a first-year graduate student in education (Mary), a senior undergraduate student in civil engineering (Justin), and a first-year graduate student in architecture (Mae).

5.3 Context

The course integrated the HCD taxonomy in its content and was designed to engage students from non-design disciplines in HCD processes through three sequential projects over a 16-week semester. Each week, the instructor and the students met for an hour and 50 min. This time was used by the instructor to

1 present the different spaces, processes, practices of the taxonomy
2 introduce the design projects
3 3 run workshops
4 allow groups to share their progress on the projects for feedback.

This case study reports on one four-week design project, which is the second project of the semester. The design team was asked to select a subculture of which they did not identify, explore the landscape, identify a problem, and come up with potential solutions using insights from users. The group reported in this paper chose to explore coffee fanatics, in this case, their clients were coffee drinkers. Over the four-week project, the teacher prompted the students to work within the first four spaces. In the first week, the

teacher asked the groups to focus on the *Understand* space, exploring the needs of coffee drinkers; during the second week, the group was prompted to continue their user research and begin synthesising data, continuing in the *Understand* space and bridge to the *Synthesis* space. After the students had collected data and defined themes, the instructor advised students to move their insights from the *Synthesis* space into opportunity areas and design concepts. During the fourth week, the groups were asked to refine these concepts based on user feedback and create initial prototypes of these concepts, practicing both the *Ideate* and *Prototype* spaces.

5.4 Data collection

We collected multiple data sources to understand how the group integrated the HCD processes in their project. We collected video and audio recordings of the groups when they presented their progress on the design projects during class time, including feedback from the instructor. Additionally, one student from the group audio recorded the out-of-class working sessions that they held to make progress as a team. To understand how the instructor interacted with the HCD taxonomy, one researcher attended all class meetings. During the meetings, the researcher collected classroom observations on how the instructor communicated the taxonomy to the students. We also collected instructional materials including the slides the instructor presented during class and the project description. Finally, we collected students' self-reflections on their perceptions of their HCD knowledge and group project. In the reflections, each team member was asked to reflect on the design spaces they engaged in, challenges they had, what they would improve, and how their team worked together.

5.5 Analysis

To analyse our data, we first transcribed audio and video data in playscript form (Sullivan and Forrester, 2018) and applied the taxonomy processes as a coding scheme to the group's working sessions and presentations (see Table 1; Cohen's Kappa: 0.84). We analysed the working sessions by turns of talk and the presentations at the slide level. These codes were not mutually exclusive, wherein a group member could reference or use multiple processes within one unit of analysis. To further explore the depth the group integrated HCD processes, we developed a coding scheme (Table 6; Cohen's Kappa: 0.81) building on Linn et al.'s (2002) knowledge integration theory, to identify how the group connected processes within their conversations and presentations. Next, using the HCD taxonomy, we content-logged the observations and the instructional materials for presence of processes, which were used to confirm and elaborate on audio and video data collected in class and working meetings. We conducted content analysis to describe the contents of each team members' reflection.

We analysed this case study using the taxonomy and integration framework to demonstrate both how a novice team applied the taxonomy in their learning and the utility of these components in deconstructing and understanding how HCD is taught in an interdisciplinary context. Therefore, we triangulate data across all data sources to provide a rich description of how the team and instructor used the processes during the project and how the team integrated processes together. We identified that this novice design team went through the processes as expected based on the framing of the assigned project, however, we also revealed that their application of these processes held some

limitations and lacked connections desired in this design-based approach. In the sections below we describe the analysis of each data source, followed by triangulation of data sources by research question.

Table 6 HCD integration coding scheme

Code	*Definition*	*Example*
Low-integration	Simply stating that a process exists or needs to be completed or has been completed	"I think we need to interview people." "We need a plan for this research."
Mid-integration	Explaining or describing how a process was used	"I went to Café Benne, a coffee shop on Green Street and saw people sitting in small groups."
High-integration	Explaining or describing how a process was used and elaborating on what it means or why it matters for the project	"It would be interesting to see if the two groups that we found here align with what was in our first framework, we can see if our findings align and then figure out if we want to ask different questions in our next interviews."

6 Results

6.1 Instructional materials and observation notes

The instructor presented twice to the class, both in the first two weeks of the project. The first presentation was a quick seven slide introduction to the project. She first shared the goal for the project of understanding and designing for a population of which they did not belong. She went over the first taxonomy space, *Understand*, to recap what the class had learned and applied in the first project and how they would be leveraging those practices in the next project. The instructor shared examples of how in the previous project, groups had conducted interviews and observations and discussed how teams in the second project would be practicing similar practices and adding on new taxonomy spaces. To wrap up the presentation the instructor shared the timeline for this project, the presentations the groups would be giving every week, and separated the class into teams. Through content logging, we found that the presentation covered three taxonomy spaces: *Understand, Synthesis,* and *Ideation.* The instructor walked through every practice in the *Understand* space, and only lightly introduced *Synthesis* and *Ideation*, since her next presentation would dive into these spaces more thoroughly.

In the second class, the instructor gave a longer presentation about the taxonomy, specifically the *Synthesis* and *Ideation* spaces. The instructor did an overview of the full taxonomy and highlighted where the *Synthesis* and *Ideation* spaces fell in the larger process. The focus of the presentation was describing the practices of these spaces and showing examples of what they look like in practice. The instructor gave many examples for how to tell a story about your user, look for patterns in the data, extract insights, communicate them in frameworks, and generate ideas from this process. Examples ranged from user experiences of cancer patients, Lyft drivers, and people saving for retirement. She described how these example design cases moved through practices to generate ideas to support their users. After describing the examples, she revisited the timeline for the project and answered questions about deliverables.

6.2 Group work and presentation video data taxonomy use

To explore how the team used the taxonomy throughout their project, we coded group work and presentations for presence of the taxonomy. Throughout the project, the team engaged the most with the *Understand* space (50%), followed by the *Synthesis* (37%), *Ideate* (9%), and *Prototype* (4%) spaces. Across the project, Mary contributed the most during group work sessions (57% of all turns of talk) and in the presentations (40% of all slides), followed by Mae (24% of turns of talk, 34% of slides) and Justin (19% of turns of talk, 26% of slides). While Mary contributed most to the groups' conversations, all three members' engagement with the taxonomy was similar. Table 7 shows that all three group members spent a comparable proportion of their turns of talk and presented slides in the same spaces. For example, each participant spent roughly half their time in the *Understand* space. This shows that even though Mary had significantly more opportunity to practice these processes with the group, all team members moved through the spaces in a way that aligned with the teacher's instruction (e.g., most work in the *Understand* and *Synthesis* spaces, with introduction to *Ideate* and *Prototype*).

Table 7 Proportion of taxonomy spaces used by group member

Space	*Mae*	*Mary*	*Justin*
Understand	47%	51%	53%
Synthesis	42%	37%	31%
Ideate	8%	8%	9%
Prototype	3%	3%	7%
Implement	0%	0%	0%
Total	100%	100%	100%

6.3 Group work and presentation video data taxonomy use

To explore how the team used the taxonomy throughout their project, we coded group work and presentations for presence of the taxonomy. Throughout the project, the team engaged the most with the *Understand* space (50%), followed by the *Synthesis* (37%), *Ideate* (9%), and *Prototype* (4%) spaces. Across the project, Mary contributed the most during group work sessions (57% of all turns of talk) and in the presentations (40% of all slides), followed by Mae (24% of turns of talk, 34% of slides) and Justin (19% of turns of talk, 26% of slides). While Mary contributed most to the groups' conversations, all three members' engagement with the taxonomy was similar. Table 7 shows that all three group members spent a comparable proportion of their turns of talk and presented slides in the same spaces. For example, each participant spent roughly half their time in the *Understand* space. This shows that even though Mary had significantly more opportunity to practice these processes with the group, all team members moved through the spaces in a way that aligned with the teacher's instruction (e.g., most work in the *Understand* and *Synthesis* spaces, with introduction to *Ideate* and *Prototype*).

6.4 Group work and presentation video data taxonomy use

To understand how the group made connections across spaces, we coded each turn of talk and presentation slide to identify how the group connected processes using low-, mid-,

and high-integration categories. While each group members' engagement with the taxonomy spaces was similar, there were differences regarding the level of integration each group member was able to achieve. Mary engaged in the most instances of high integration in both group work and presentations with a total of 19 instances of high integration, whereas Justin and Mae were only able to achieve high integration three and two times respectively (Table 8). When compared to the contribution to the discussion and presentations, Mary contributed the most to the group, which means she also had the most opportunities to vocalise the high integration she was able to achieve.

Table 8 Proportion of group members' level of engagement by format type

Level of integration	*Format*	*Mary*	*Justin*	*Mae*	*Total*
Low	Group work (turns of talk)	54 (59%)	19 (21%)	19 (21%)	92 (100%)
	Presentation (slides)	5 (50%)	3 (30%)	2 (20%)	10 (100%)
Mid	Group work (turns of talk)	37 (49%)	14 (19%)	24 (32%)	75 (100%)
	Presentation (slides)	12 (32%)	10 (27%)	15 (41%)	37 (100%)
High	Group work (turns of talk)	15 (83%)	2 (11%)	1 (6%)	18 (100%)
	Presentation (slides)	4 (67%)	1 (17%)	1 (17%)	6 (100%)

Table 9 outlines the frequency and percentage of low-, mid-, and high-integration during group work and presentations. Most of the turns of talk during group work were low-integration where the group was stating what was done and needed to be completed, followed by mid-integration where they were explaining how the process was used. In presentations, however, the majority of the slides they presented on were mid-integration. This is not surprising as during presentations the group was describing what they did and how they did it. In both group work and the presentations, there were few instances of high-integration, especially considering the majority of the high-integration connections that were made were from Mary.

Table 9 Percent integration code by group work and presentation

	Low-integration	*Mid-integration*	*High-integration*	*Total*
Group work	92 (50%)	75 (40%)	18 (10%)	185 (100%)
Presentation	10 (19%)	37 (70%)	6 (11%)	53 (100%)

Each instance of the talk was coded for the presence of the taxonomy processes. These processes were not mutually exclusive, meaning more than one process could be coded in a single turn of talk or presentation slide (e.g., discussing an observation that led to a HMW question). Each turn of talk or slide had a range of one to six processes each (Figure 3). 45% of all instances had only one process coded, whereas 1% had six processes.

To further understand the relationship between the number of processes per turn and the level of integration, we analysed their frequency within their group work and presentations. Figure 4 visualises the level of integration by the number of processes per turn. All turns and slides where the group used five or six processes, were also coded as high-integration. Meaning students who used five or six processes also described the

processes and made connections to why it mattered for the project. Suggesting that as members of the team incorporated more processes together, they were more likely to achieve high-integration of HCD processes. Across group work there was a trend; the more processes present in a turn of talk, the more likely it was to be high-integration. In the groups' presentations, this trend does not appear as strongly, as there are fewer instances of low-integration. During presentations the teams did more synthesising across processes and describing why they did specific tasks, as was presented by the teachers as a requirement for the course.

Figure 3 Number of processes coded per turn (see online version for colours)

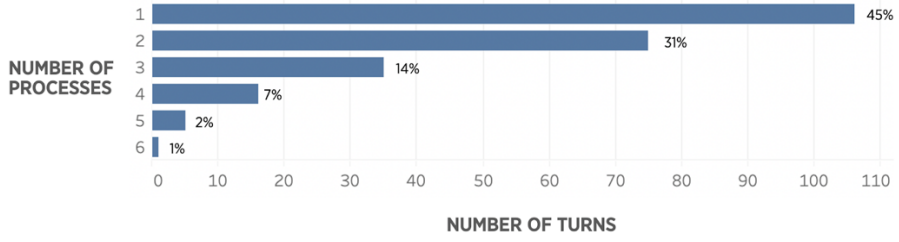
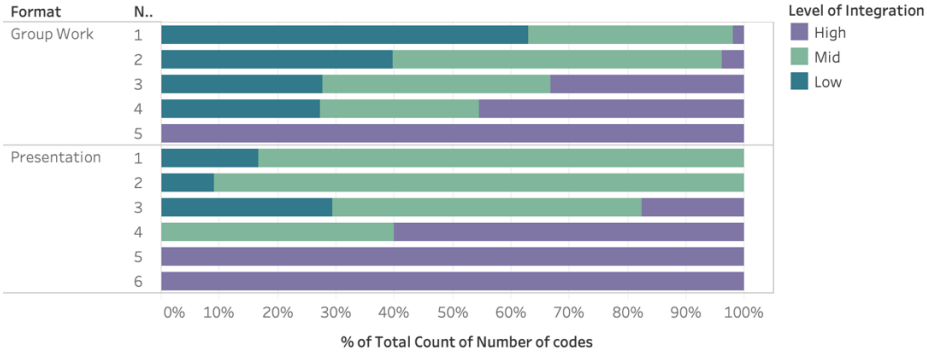


Figure 4 Level of integration by the number of processes per turn by group work and presentation (see online version for colours)



6.5 Reflections

All three students completed a reflection at the end of the project to reflect on their project, the design spaces they worked within, challenges they experienced, and how their team worked together. Each student wrote a one-page reflection with bulleted points in response to the probing questions that were provided. The whole group found the project to be interesting and enjoyable and described that they learned more about how HCD can be useful for designing for a population that you do not belong to.

Regarding challenges during the project, Mary described the tension between her training in the engineering design process and HCD. She explained that she had previously thought about design as creating the most optimal performance for the final design rather than the specialised experience of a user, but that including users in the process helped to improve their ideation. Mae wrote that the most challenging aspect of the project for her was conducting the interviews. Delivering interview questions

appropriately is challenging, she explained, "*Sometimes people may feel uncomfortable when we [only] deliver our interests*". Justin elaborated on this challenge of focusing on what the designer wants compared to the user.

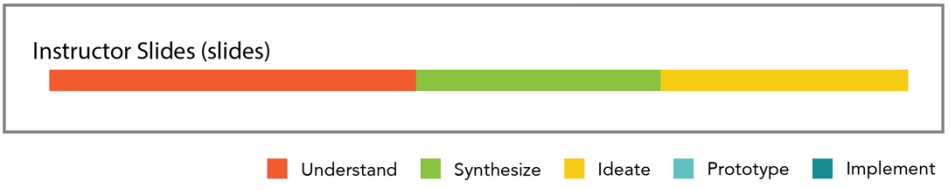
> "I had to be very intentional that my ideas weren't based off of what I wanted but were off of what my research pointed to. Regardless of the results, I wanted to display a concept that pertained and met the needs of the research."

He discussed that even when research insights differed from what he wanted he tried to focus on what the users were saying. Overall, all three group members shared that they found their collaboration to go well and that the team worked well together to create their own prototypes.

6.6 Triangulation by research question

To answer our first question, *how did a novice design team and their instructor use HCD spaces during their design project*, we describe the group's use of the taxonomy over time across data sources. Throughout the project, the group continued to iteratively move through the taxonomy spaces. To kick start the project, the instructor gave a short presentation at the end of the first project introducing the scope and reviewing the taxonomy spaces. In the presentation she primarily covered the *Understand* space, but also reiterated the *Synthesis* and *Ideate* spaces, and how they will be using them in the project (Figure 5).

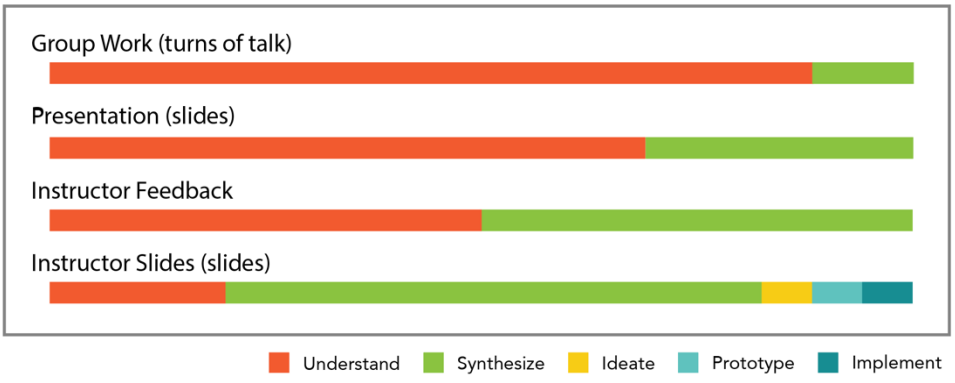
Figure 5 Frequency of taxonomy spaces in project introduction (see online version for colours)



After the instructor's introduction the group had a short working session, followed by an in-class presentation of the progress they made (Figure 6). In week one, the group predominantly used the *Understand* space, with some *Synthesis* during their group work session. Each group member shared findings from their observations from two locations including coffee shops, libraries, bus stops, and areas where students on campus were moving between buildings and drinking coffee. The focus of their discussions centered around what they found and observed (*Understand*) and discussed some emerging similarities (*Synthesise*). In the class presentation, the group shared the work they had done with users and provided some emergent insights. Each member of the team described the location that they observed and what they found. After their presentation, the instructor provided feedback from the *Understand* and *Synthesis* spaces and outlined potential areas the group could dive into deeper and how they might do so. After the group presented and received feedback, they touched base as a group and decided to start interviewing and conduct more observations based on the feedback provided by the instructor. In this first week, the group spent most of their time in the *Understand* space, but the instructor split her time between providing feedback on their *Understand* space while also sharing potential areas to explore in both the *Understand* and *Synthesis*

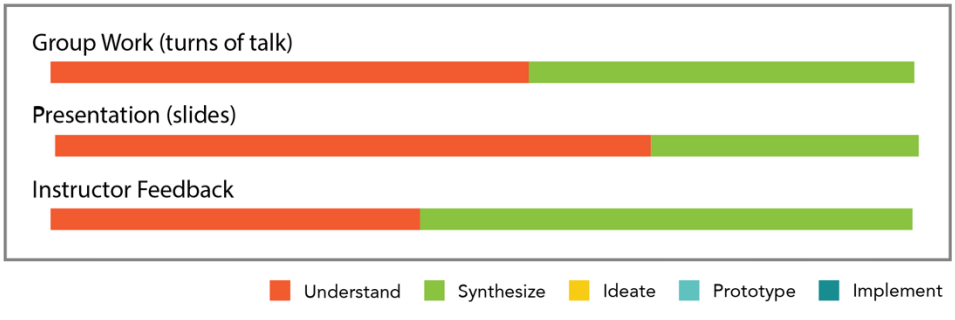
space. This was reiterated in the instructor's presentation where she focused mostly on *Synthesis* to move students into this space in the next week.

Figure 6 Frequency of taxonomy spaces in week 1 (see online version for colours)



During their working session in week two, the group focused primarily on the *Understand* and *Synthesis* spaces (Figure 7), where they again shared their findings from their observations and interviews and briefly started generating ideas in the *Ideate* space based on their insights. Each member of the group interviewed at least one person who they identified as a coffee fanatic, mainly focusing on people that they knew. Mary specifically had ideas about how she might develop an app to connect coffee drinkers and help them track their consumption, and Mae and Justin both supported the idea and provided brief feedback encouraging her idea. In their presentation, each group member presented their work in the *Understand* and *Synthesis* spaces to further describe the additional work they had done to engage with the users. While the group discussed ideation briefly in their meeting, the focus on this meeting was sharing insights from their interviews and observations. After the presentation, the instructor provided feedback on the *Understand* and *Synthesis* spaces and demonstrated how the group could transition into the *Ideate* space.

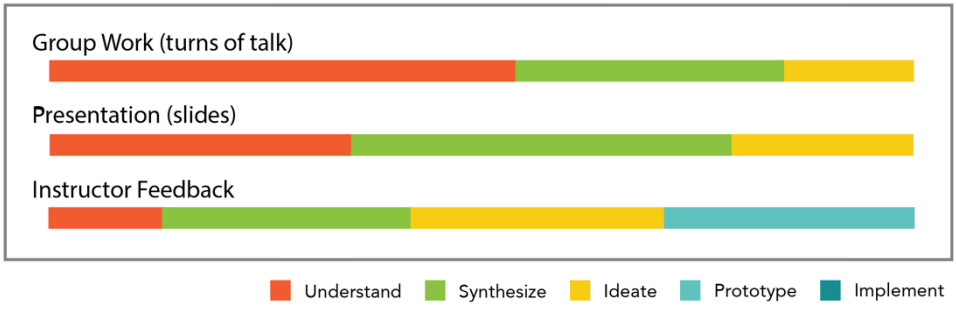
Figure 7 Frequency of taxonomy spaces in week 2 (see online version for colours)



In both their group work and presentation in week three, the group continued to use the *Understand, Synthesis*, *Ideation* spaces (Figure 8). During this week, each group member had identified a project idea that they were interested in based on their insights from users

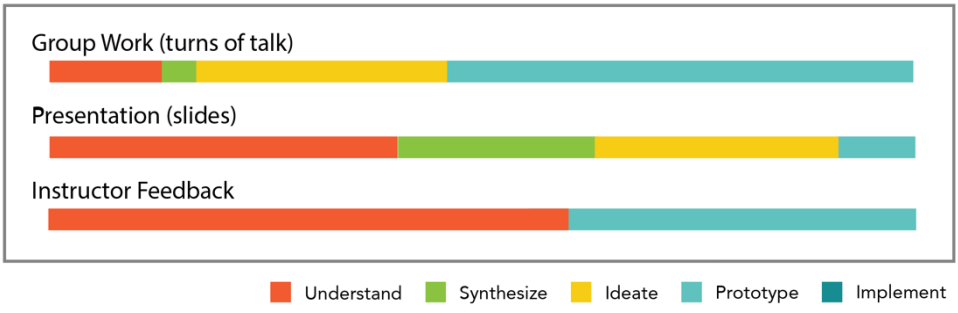
and started to generate ideas around the three topic areas. Mae focused on the concept of pop-up coffee events, Mary focused on a community centered coffee tracking app, and Justin focused on locations that let you make your own coffee alone or with support. While the group described how they got their ideas from talking with users, all three ideas came to them during conversations with users but were not directly tied to things that users brought up. In the class presentation, the group presented their user research, insights from the *Synthesis* space, and individually presented their three initial directions. During the feedback portion, the teacher provided feedback and again introduced how the group might move their ideas from the *Ideate* space to the *Prototype* space. During her feedback the instructor applauded the groups' extensive user research and insights, and shared ideas for additional research and users that they might dig into to inform their process.

Figure 8 Frequency of taxonomy spaces in week 3 (see online version for colours)



In the final week, the group worked mostly in the *Prototype* space but also integrated processes from the *Understand*, *Synthesis*, and *Ideate* spaces to discuss how their work with users and insights lead to their prototypes (Figure 9). Their fourth group working session was the shortest of all sessions, as the group described their project ideas and decided to work on them separately. During their presentation, the group covered the entirety of their project, spending a lot of time discussing their work in the *Understand* space, but also describing their work in the *Synthesis* and *Ideation* spaces, while briefly presenting their prototypes at the end. In their final presentation, each group member shared their concept and prototype that would meet the needs of the users they had interviewed and observed.

Figure 9 Frequency of taxonomy spaces in week 4 (see online version for colours)



After the presentation, the instructor provided feedback on the groups' prototypes and elaborated on how the group might revisit the *Understand* space to iterate on their prototypes by receiving feedback from their users, illustrating how the HCD process would continue if they were to carry on with the project.

To answer our second research question, *how did the group's level of HCD integration change over time,* we look at their use of the taxonomy spaces over time. Over the four weeks, the students continued to iterate on the taxonomy spaces over time, revisiting spaces to introduce new information and reflect on past data and insights they had generated. From the instructor's perspective, she provided feedback to the students on the spaces they presented during their presentation, while also modelling what the next phase of the process might look like. In group working sessions, the group members explicitly picked up and applied the feedback or suggestions that were presented by the instructor. In these instances, the group often used the teacher as a reason to move forward with ideas rather than information collected from the users. For instance, in one work session, the group was discussing the framework and what information they should include from their users when one group member justified using one piece of data over another because "*I think that's the kind of thing [the instructor] wants to see.*" In other cases, the group changed the questions they were asking users in interviews because "*[the instructor] likes when we ask things like that*". This shows that feedback and the modelling that the instructor provided in presentation feedback was directly applied in their group working sessions and helped to progress their HCD process forward.

Next, we analysed the group's integration over the four weeks by group work sessions and presentations (Table 10). During group work, the most high-integration occurred in week three of the project, with no high-integration in week four. The lack of high-integration in week four is likely because the group was using processes in the *Ideate* and *Prototype* spaces they had not yet used. Across group members, Justin's two instances and Mae's single instance of high-integration were from week three, indicating that all of the high-integration achieved in week one and two were from Mary.

Table 10 Level of integration during group work by week

	Low-Integration	*Mid-Integration*	*High-Integration*
Week 1	55%	37%	8%
Week 2	47%	41%	12%
Week 3	42%	38%	19%
Week 4	46%	54%	0%

In the class presentations, the group displayed more mid-integration and less low-integration across all weeks (Table 11). During presentations, the group was explicitly prompted by the instructor to describe what they had done and why, meaning they were explicitly instructed to use more mid- and high-integration by the teacher. While instruction from the teacher to provide more explanations does not guarantee that students will enact that strategy, or enact it well, these results show that the teacher's instructions may have played a role. The group did not engage in high-integration during week one or two, but had more in the last two weeks of the project, reiterating that the group improved on their use of the processes with more practice. While week 4 of group work had no high-integration, where the students were demonstrating the use of

processes they had not yet used, their week 4 presentation had the most high-integration. This is because during the fourth-week presentation the group achieved high-integration by presenting previously used processes into their descriptions of new processes.

Table 11 Level of integration during presentations by week

	Low-Integration	*Mid-Integration*	*High-Integration*
Week 1	20%	80%	0%
Week 2	15%	85%	0%
Week 3	17%	67%	15%
Week 4	22%	56%	22%

7 Discussion

While previous literature acknowledges the importance of teaching and learning HCD, few studies unpack how the overarching approach is used by students. Using knowledge integration theory (Linn et al., 2013) and our taxonomy, we sought to understand how HCD processes were used by a novice design team and to what extent they made connections across spaces and processes. From this case study we share three key challenges, including

1 the need for further scaffolding to support more connections across spaces

2 engaging in the understand space is a critical yet challenging staple for empathy building and reflection

3 novice designers struggle to navigate the tensions between the instructor as a teacher and facilitator rather than a stakeholder.

Need for further scaffolding to support connection across spaces. Across the four weeks, the group was able to engage in some high-integration, wherein they elaborated on why they were doing what they were and how it was leading to the process and often included the use of many spaces together. However, these instances were few across the board and the majority of these were from one team member. Yet, all four were able to achieve some high integration. Looking across weeks we found that most of the high integration took place in the presentations, showing that the presentation format prompted them to reflect and share their work in this way. While this approach was effective in getting team members to elaborate on their ideas and build connections, additional scaffolds could make this process more explicit.

Challenges in engaging in the understand space to support empathy building and reflection. Regarding the needs of the user, novice designers often have problems grappling with others' needs, desires, and goals (Carlson et al., 2020). In this case, the team moved rapidly from exploring the users' needs to ideating, one member of the team proposed the idea that became her final project in the second week of the semester with little iteration or revision based on new data being collected (Noel and Liub, 2017). Additionally, rather than building one solution that was best for the user, this team developed three separate ideas that each team member found most interesting. The team decided to move forward with ideas and prototypes that were most interesting to

themselves, rather than coming together to create something that was most useful for the user. While the individual project ideas did stem from user research, in reflections, the group emphasised the challenges of fore fronting their own ideas rather than users. Additional scaffolds and reflections within the process to prompt students to explicitly draw connections between their research and ideas may support high-integration thinking and build empathetic design processes among students.

Importance of the role of the instructor. Similar to findings in the literature, novice designers follow instructions and feedback provided by the instructor of the course (Cross, 2004). In our case, many of the ideas the group moved forward were tied explicitly to needs or ideas from the teacher rather than from users – showcasing issues of power dynamics in teaching HCD (and teaching generally). While the team reflect on the challenges of moving forward with users' ideas vs. their own, no one reflected on picking up ideas from their instructor. In this case, the instructor modelled how they might move forward with ideas, revisit user insights, and collect more data. Week to week students discussed this feedback and make direct changes or decisions to follow it exactly. In any classroom, it's hard to move past traditional classroom dynamics, making it more challenging in design courses to account for someone else's needs rather than their own or their teacher's. This calls for reflection of how teachers might reinforce the goals of this process with students by centering the needs of users rather than the students' or teacher's and reiterates the need for scaffolds to support students in documenting where their ideas are coming from and how they do or do not map to users' needs.

7.1 Theoretical implications

We build on knowledge integration theory and describe the first exploration of *HCD integration*. Through our adaptation of Linn et al.'s knowledge integration theory (2013), we highlight that to achieve higher levels of integration, students need to make connections across spaces. This theoretical contribution broadens existing models of HCD by examining not only *if students engaged in taxonomy spaces*, but *the extent that students can build across these spaces* to create connections that reinforce learning of HCD. Our analysis highlights those processes are interrelated across spaces, meaning connections that are created are not limited to spaces, but span multiple, and when students were able to integrate many processes, they were, in turn, achieving high-integration.

To support high-integration of HCD requires students to have an in-depth understanding of the overarching process that novice designers often lack (Dorst, 2011; Dorst and Cross, 2001; Guindon, 1990). To build and support these connections across spaces, scaffolding is needed to assist novice designs to build and sustain these connections. The usefulness of scaffolding is illustrated in the presentations, where students were able to achieve high-integration because the instructor set the expectation that the group was to present their ideas and describe *why* and *how* they made decisions based on the progress of their project. Suggesting that by presenting guidelines regarding expectations, the group was able to achieve more high-integration. Future work around the taxonomy outlined in this paper needs to outline how these processes can be scaffolded to help students move from novice human-centered designers to experts in ways that are equitable and inclusive. Questions to explore include,

- How might students build and improve their repertoire of HCD skills over time?
- How might teachers scaffold how students build this repertoire?
- How might students reflect on and learn about their role in power dynamics and ethics in HCD?
- How might teachers support students in not only recognising that these issues of power and ethics exist in HCD but also reflect on ways to mitigate and eliminate them?

Finally, while the purpose of this paper is to investigate a fine-grain analysis of what this learning process looks like in a case study design, additional exploration is needed to examine a larger sample size to further understand the relationship between integration levels and HCD learning outcomes.

8 Conclusions

While this group highlights the challenges of teaching HCD, these findings are not surprising for a novice design team (Dorst, 2011). Teaching HCD to novice designers is not an easy endeavour. To be done well takes time to get to higher integration of learning, applying, and reflecting on each of these processes and what they mean for design, requiring more than one introductory course. These findings are important to reinforce the idea that HCD is not a simple process as suggested by other simplified models (Brown, 2008; IDEO, 2015). Rather, HCD is a complex, messy form of design that cannot be taught quickly or conveniently. Specifically in this paper, we build on existing literature on HCD and present a taxonomy that delineates specific practices of what it means for students to learn and apply HCD. We then presented an analysis of one group's use of the taxonomy and described their integration of HCD over time to explore what it looks like when the taxonomy is used by a novice interdisciplinary team. Our findings support the idea of nonlinearity within the HCD (Boling and Smith, 2010; Brown, 2008) and show that students follow instructors and go through the motions of the design process, mirroring findings in the literature (Cross, 2004; Welch, 1999). However, the depth and connections to which they engaged with the HCD approach is limited. Existing models of HCD simplify the process and reinforce the expectation that while HCD is a complex process, it can be simply learned and applied by anyone. In theory, this is an inclusive approach, as it reinforces the idea that simply attending a workshop, seeing a talk, or taking a class, can allow you to become an expert in applying these tools. Our findings illustrate the complexity of using and integrating these practices for novices. While HCD is a valuable problem-solving approach, open questions remain about how to support novice designers to practice the reflection and depth we aim to see in this approach.

References

Aflatoony, L., Wakkary, R. and Neustaedter, C. (2018) 'Becoming a design thinker: assessing the learning process of students in a secondary level design thinking course', *International Journal of Art and Design Education*, Vol. 37, No. 3, pp.438–453.

Biffi, A., Bissola, R. and Imperatori, B. (2017) 'Chasing innovation: a pilot case study of a rhizomatic design thinking education program', *Education + Training*, Vol. 59, No. 9, pp.957–977.

Boling, E. and Smith, K. (2010) 'Intensive studio experience in a non-studio masters program: student activities and thinking across levels of design', in Durling, D., Bousbaci, R., Chen, L., Gauthier, P., Poldma, T., Roworth-Stokes, S. and Stolterman, E. (Eds.): *Design and Complexity – DRS International Conference 2010*, 7–9 July, Montreal, Canada, pp.1–15.

Brown, T. and Katz, B. (2011) 'Change by design', *Journal of Product Innovation Management*, Vol. 28, No. 3, pp.381–383.

Brown, T. and Wyatt, J. (2010) 'Design thinking for social innovation', *Development Outreach*, Vol. 12, No. 1, pp.29–43.

Brown, T. (2008) 'Design thinking', *Harvard Business Review*, Vol. 86, No. 6, p.84.

Buchanan, R. (1992) 'Wicked problems in design thinking', *Design Issues*, Vol. 8, No. 2, pp.5–21.

Carlson, S.E., Lewis, D.G.R., Maliakal, L.V., Gerber, E.M. and Easterday, M.W. (2020) 'The design risks framework: understanding metacognition for iteration', *Design Studies*, Vol. 70, p.100961.

Carroll, M. (2015) 'Stretch, dream, and do-a 21st century design thinking & STEM journey', *Journal of Research in STEM Education*, Vol. 1, No. 1, pp.59–70.

Cassim, F. (2013) 'Hands on, hearts on, minds on: design thinking within an education context', *International Journal of Art and Design Education*, Vol. 32, No. 2, pp.190–202.

Chu, P.Y., Hung, H.Y., Wu, C.F. and Te Liu, Y. (2017) 'Effects of various sketching tools on visual thinking in idea development', *International Journal of Technology and Design Education*, Vol. 27, No. 2, pp.291–306.

Cross, N. (2004) 'Expertise in design: an overview', *Design Studies*, Vol. 25, No. 5, pp.427–441.

Cross, N. (2011) *Design Thinking: Understanding How Designers Think and Work, Bloomsbury Academic*, London, UK.

Dorst, K. (2011) 'The core of 'design thinking' and its application', *Design Studies*, Vol. 32, No. 6, pp.521–532.

Dorst, K. and Cross, N. (2001) 'Creativity in the design process: co-evolution of problem–solution', *Design Studies*, Vol. 22, No. 5, pp.425–437.

Gal, D. and Lewis, M. (2018) 'Designing a programmatic digital learning environment: lessons from prototyping', *Journal of Educational Technology Systems*, Vol. 46, No. 3, pp.315–328.

Goldman, S. and Zielezinski, M.B. (2016) 'Teaching with design thinking: developing new vision and approaches to twenty-first century learning', *Connecting Science and Engineering Education Practices in Meaningful Ways*, Springer, Cham, pp.237–262.

Goldman, S., Carroll, M.P., Kabayadondo, Z., Cavagnaro, L.B., Royalty, A.W., Roth, B. and Kim, J. (2012) 'Assessing d. learning: capturing the journey of becoming a design thinker', *Design Thinking Research*, Springer, Berlin, Heidelberg, pp.13–33.

Gray, C.M. (2013) 'Factors that shape design thinking', *Design and Technology Education*, Vol. 18, No. 3, pp.8–20.

Guindon, R. (1990) 'Knowledge exploited by experts during software system design', *International Journal of Man-Machine Studies*, Vol. 33, No. 3, pp.279–304.

Härkki, T., Seitamaa-Hakkarainen, P. and Hakkarainen, K. (2018) 'Hands on design: comparing the use of sketching and gesturing in collaborative designing', *Journal of Design Research*, Vol. 16, No. 1, pp.24–46.

Hutchinson, A. and Tracey, M.W. (2015) 'Design ideas, reflection, and professional identity: how graduate students explore the idea generation process', *Instructional Science*, Vol. 43, No. 5, pp.527–544.

IDEO (2015) *The Field Guide to Human-Centered Design*, https://www.designkit.org/resources/1

Kali, Y., Goodyear, P. and Markauskaite, L. (2011) 'Researching design practices and design cognition: contexts, experiences and pedagogical knowledge-in-pieces', *Learning, Media and Technology*, Vol. 36, No. 2, pp.129–149.

Koh, J.H.L., Chai, C.S., Benjamin, W. and Hong, H.Y. (2015) 'Technological pedagogical content knowledge (TPACK) and design thinking: a framework to support ICT lesson design for 21st century learning', *The Asia-Pacific Education Researcher*, Vol. 24, No. 3, pp.535–543.

Kolodner, J.L., Crismond, D., Gray, J., Holbrook, J. and Puntambekar, S. (1998) 'Learning by design from theory to practice', *Proceedings of the International Conference of the Learning Sciences*, Vol. 98, December, pp.16–22.

Kuijer, L. and De Jong, A.M. (2011) 'Practice theory and human-centered design: a sustainable bathing example', *Nordes*, No. 4, pp.1–7.

Lawrence, L., Shehab, S., Tissenbaum, M., Rui, T. and Hixon, T. (2021) 'Human-centered design taxonomy: case study application with novice, multidisciplinary designers', Paper Accepted at the *American Educational Research Association*, Virtual Conference, 9–12 April, pp.1–11.

Lawson, B. (2006) *How Designers Think: The Design Process Demystified*, Routledge, Oxford.

Lee, J.S., Baskerville, R. and Pries-Heje, J. (2015) 'The creativity passdown effect: applying design theory in creating instance design', *Information Technology and People*, Vol. 28, No. 3, pp.529–543.

Linn, M.C., Clark, D. and Slotta, J.D. (2003) 'WISE design for knowledge integration', *Science Education*, Vol. 87, No. 4, pp.517–538.

Linn, M.C., Davis, E.A. and Eylon, B.S. (2013) 'The scaffolded knowledge integration framework for instruction', *Internet Environments for Science Education*, Vol. 47, pp.75–100.

Micheli, P., Wilner, S.J., Bhatti, S.H., Mura, M. and Beverland M.B. (2019) 'Doing design thinking: conceptual review, synthesis, and research agenda', *Journal of Product Innovation Management*, Vol. 36, No. 2, pp.124–148.

Noel, L.A. and Liub, T.L. (2017) 'Using design thinking to create a new education paradigm for elementary level children for higher student engagement and success', *Design and Technology Education*, Vol. 22, No. 1, pp.1–12.

Noweski, C., Scheer, A., Büttner, N., von Thienen, J., Erdmann, J. and Meinel, C. (2012) 'Towards a paradigm shift in education practice: developing twenty-first century skills with design thinking', *Design Thinking Research*, Springer, Berlin, Heidelberg., pp.71–94.

Oehlberg, L., Simm, K., Jones, J., Agogino, A. and Hartmann, B. (2012) 'Showing is sharing: building shared understanding in human-centered design teams with dazzle', *Proceedings of the Designing Interactive Systems Conference*, June, New Castle, UK, pp.669–678.

Owen, C. (2007) 'Design thinking: notes on its nature and use', *Design Research Quarterly*, Vol. 2, No. 1, pp.16–27.

Pande, M. and Bharathi, S.V. (2020) 'Theoretical foundations of design thinking–a constructivism learning approach to design thinking', *Thinking Skills and Creativity*, Vol. 36, p.100637.

Papantonopoulos, S. (2004) 'How system designers think: a study of design thinking in human factors engineering', *Ergonomics*, Vol. 47, No. 14, pp.1528–1548.

Peyton, T., Prasad, A., Liu, S. and Pena, J. (2019) 'Teaching human-centered design in CSE programs', *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, February, Minneapolis, MN, USA, pp.1246–1247.

Pressman, A. (2019) *Design Thinking: A Guide to Creative Problem Solving for Everyone*, Routledge, London.

Razzouk, R. and Schute, V. (2012) 'What is design thinking and why is it important?', *Review of Educational Research*, Vol. 82, No. 3, pp.330–348.

Rees Lewis, D.G., Gorson, J., Maliakal, L.V., Carlson, S.E., Riesbeck, C.K., Gerber, E.M. and Easterday, M.W. (2018) 'Planning to iterate: supporting iterative practices for real-world ill-structured problem-solving', *International Conference of the Learning Sciences (ICLS)*, London, pp.9–16.

Royalty, A., Chen, H., Roth, B. and Sheppard, S. (2019) 'Measuring design thinking practice in context', *Design Thinking Research*, Springer, Cham, pp.61–73.

Royalty, A., Ladenheim, K. and Roth, B. (2015) 'Assessing the development of design thinking: from training to organizational application', *Design Thinking Research*, Springer, Cham, pp.73–86.

Scheer, A., Noweski, C. and Meinel, C. (2012) 'Transforming constructivist learning into action: design thinking in education', *Design and Technology Education: An International Journal*, Vol. 17, No. 3, pp.8–19.

Schell, J. (2016) *Design Thinking Has a Pedagogy Problem. and a Way Forward*. School of Design and Creative Technologies – The University of Texas at Austin, Retrieved from https://designcreativetech.utexas.edu/design-thinking-has-pedagogy-problem-way-forward

Seidel, V.P. and Fixson, S.K. (2013) 'Adopting design thinking in novice multidisciplinary teams: the application and limits of design methods and reflexive practices', *Journal of Product Innovation Management*, Vol. 30, pp.19–33.

Shambaugh, N. (2004) 'Using student-developed scenarios to couple design and reflection', *TechTrends*, Vol. 48, No. 3, p.26.

Shehab, S., Lawrence, L., Tissenbaum, M., Rui, T. and Hixon, T. (2021) 'Integrating human-centered design in higher education courses: evaluating the first iteration', *Paper Accepted at the American Educational Research Association, Virtual Conference*, 9–12 April, pp.1–8.

Siu, K.W.M. (2002) 'Reception of users: respecting the perspectives of users for creative thinking in design', *The International Journal of Creativity and Problem Solving*, Vol. 12, No. 2, pp.75–84.

Stake, R.E. (1995) *The Art of Case Study Research*, Sage. London.

Stock, K.L., Bucar, B. and Vokoun, J. (2017) 'Walking in another's shoes: Enhancing experiential learning through design thinking', *Management Teaching Review*, Vol. 3, No. 3, pp.221–228.

Sullivan, C. and Forrester, M.A. (Eds.) (2018) *Doing Qualitative Research in Psychology: A Practical Guide*, Sage, Washington DC, USA.

Taboada, M. and Coombs, G. (2013) 'Liminal moments: designing, thinking and learning', *DRS//CUMULUS Oslo 2013: Proceedings From the 2nd International Conference for Design Education Researchers*, Oslo, Norway, ABMmedia, pp.1802–1814.

Teal, R. (2010) 'Developing a (non-linear) practice of design thinking', *International Journal of Art and Design Education*, Vol. 29, No. 3, pp.294–302.

Twal, N. (2018) 'Want to create lasting change? Listen first, design second', *The Learning Professional*, Vol. 39, No. 2, pp.14–16.

Welch, M. (1999) 'Analyzing the tacit strategies of novice designers', *Research in Science and Technological Education*, Vol. 17, No. 1, pp.19–34.

Welsh, M.A. and Dehler, G.E. (2013) 'Combining critical reflection and design thinking to develop integrative learners', *Journal of Management Education*, Vol. 37, No. 6, pp.771–802.

Yan, S. and Borge, M. (2020) 'Learning from design failure, collaboratively', *International Conference of the Learning Sciences (ICLS)*, Nashville, TN, USA, pp.302–309.