Students' Application of Human-centered Design in a Practical Technology Course

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This study examines the application of Human-centered design (HCD) by college students in a practical technology course, C&I 100. The course allows students to construct their own learning experiences and hands-on experience with technology use in the classroom through project-based learning. Specifically, the HCD process is applied in the Technology Leap Project (TLP), where students learn about new technologies and investigate ways to incorporate them into a K-12 classroom setting to solve real-world problems. The study contributes to an understanding of the HCD process as a potential innovative pedagogical model for prospective teachers in the educational technology field, focusing on constructivist learning and student-centered design. Findings from this study potentially provide new insights

into how students' experiences are reconstructed to respond to diverse students' needs, concerns, and interests.

Introduction

Design Thinking (DT) is a creative, human-centered approach to solving complex real-world problems (Brown, 2008). Particularly, DT begins from deep empathy and understanding of the needs and motivations of people. DT allows designers to embrace ambiguity in the design process to generate more innovative ideas that are often not easily discovered by existing methods. Promoting collaboration with people from diverse backgrounds is also key to success in project design. As a holistic and systemic approach, DT taps into capacities that human beings have but are overlooked by more conventional problem-solving practices. DT employs one's ability to be intuitive in recognizing patterns and constructing ideas that are functional and have emotional meaning. In other words, DT is integrated at the core of the process that combines feelings, intuition, and inspiration with rationales and analysis. Stemmed from Design Thinking, Human-centered design (HCD) prioritizes the needs, insights, and values of the people for which the products are designed (IDEO, 2015a). It manifests the belief that the people who face those problems every day are the ones who hold the key to their answer. It has human beings as central throughout the design process and involves seeking to understand them holistically and favors multi-disciplinary collaboration in order to make products and services useful, usable, and desirable for them (Zoltowski, et. al., 2012). HCD manifests the belief that everyone has their personal ways of understanding the world that enable them to come up with creative solutions and experience multiple ways of doing things (IDEO, 2015a). HCDers are optimistic experimenters who "tinker and test," learning from failure and forging ahead with new ideas, energy, and a creative mindset (IDEO, 2015a). In other words, the designers will diverge and converge a few times in their journey to the solution.

C&I 100 is an undergraduate course designed for future elementary educators to understand the role of technology and effective technology integration in their future classrooms. It uses multiple technology applications to increase subject matter knowledge and understanding; evaluation of technologies as effective tools of learning, and exploration of ethical and social issues related to technology. The class involves hands-on activities on the tool uses that support teaching and learning and require students to 1) share their experience as a teacher or a learner, 2) design a solution (or lesson plans) using the tools by 3) work in group projects.

This study examines the application of the Human-centered design process (HCD) by college students in the C&I 100 course from fall 2018 to spring 2019. This practical technology course allows students to construct their own learning experiences and hands-on experience with technology use in the classroom through project-based learning.

Specifically, the HCD process is applied in the course major assignment called Technology Leap Project (i.e. TLP). Accordingly, based on their interests and technological abilities, the students will 1) learn about new technologies and 2) investigate ways to incorporate the technologies into a K-12 classroom setting to solve a real-world problem that they would identify. Each project includes aspects of knowledge acquired from the students' personal experience and their research work, statement of purpose, audience, and the making elements.

By reporting the students' application of HCD in their course projects and course revisions over the two semesters, this study contributes to an understanding of the HCD process as a potential innovative pedagogical model for prospective teachers in the educational technology field. Specifically, findings from this study potentially provide new insights into constructivist learning in technology education through exploring how the adoption of HCD (re)constructs student teachers' experiences to respond to diverse students' needs, concerns, and interests. As HCD focuses on concrete human-oriented implementation, in the context of a K-12 teacher training program, it is important for these prospective teachers to understand the audience (i.e., students, teachers, parents, counselors, etc.) to design and implement a solution from a holistic understanding of their background, needs, and wants. This is the unique part and the contribution of the study.

Theoretical Framework

Design Thinking and Human-centered design in education

A growing body of research on the potentials of DT in re-imagining teaching and learning is found in the fields of education (Scheer et al., 2012; Luka, 2014; Noweski et al., 2012). Specifically, empirical studies have revealed that applying DT: (1) fosters the development of student's skills and competencies including critical thinking, problem-solving, and collaboration (Sheer et al., 2012; Noweski et al., 2012; Noel & Liub, 2017; Caroll et al., 2010; Vande Zande et al., 2014; Razzouk & Shute, 2012); (2) promotes multidisciplinary or interdisciplinary teaching and learning (Oehlberg et al., 2012; Henriksen, 2017; van de Grift & Kroeze, 2016); and (3) provides a new theoretical and pedagogical tool to educators in solving to critical educational problems in K-12 schools or colleges (Dunne & Martin, 2006; Henriksen et al., 2017; Lin & Eichelberger, 2020). Design thinking have been considered a great tool to be used in teaching and learning to develop twenty-first century skills (Kurokawa, 2013; Glen et al., 2014), as it involves joint effort to solve problems by finding and processing information in the real world, seeking people's experiences and feedback, and by applying creativity, critical thinking and communication (Ray, 2020).

In detail, Scheer et al. (2012) report that the application of DT in high school fosters student metacognitive skills and competencies tremendously. Specifically, the researchers investigated the use of DT in improving student and teacher motivation, classroom atmosphere, and student-teacher relationship using Kanning's Inventory of Social Competence - ISK (Kanning, 2009, cited in Scheer et. al, 2012). The results show that the use of the DT process allows the students to encounter new content and complex interrelations of information, solving team crises, and getting feedback for immediate results. Crucially, it fosters a positive relationship between teachers and students and gives teachers more confidence in creating and exercising collaborative project work. Mosely, Wright, and Wrigley (2018) experimented design thinking learning experience to non-designers and found design expertise and problem complexity significantly impact the value of learning experience.

Oehlberg et al. (2012) examined the impacts of two HCD-focused educational programs in the University of California, Berkeley one student-initiated course and one undergraduate certificate program on college students' learning. Through analyzing student surveys and interviews, the researchers discovered that the HCD approach in design promoted multidisciplinary conversations about design among students and broadened perspectives of design. This study shows that teaching or learning using HCD creates more intersections of multiple disciplines in learning spaces, increasing creative ideas, and innovation. Design thinking is sometimes referred to as "design-based learning", a "model for enhancing creativity, endurance, engagement and innovation" (Dolak et al., 2013). The benefit of DT in pedagogy includes the way it allows the students to work successfully in multi-disciplinary groups and enact positive, design-driven change in the world. In other words, DT approach can be considered as a problem-solving approach that deals with the solution of everyday problems (Kijima et al., 2021).

As an example, Henriksen et al. (2017) explored how learning DT through an online course entitled Learning by Design, influenced education-major graduate students' perspectives on teaching practices, educational problems, and creative learning. This study investigated 22 graduate students, most of them were K-12 teachers for one semester by collecting multiple qualitative data. The results illustrated that taking the course that approached teaching through DT led the graduate students to view the design as a new way to problem-solving in teaching practices. The study also found that graduate students positioned themselves as designers who utilized DT practices to transform educational problems of practice.

Design Thinking and Human-centered Design as Pedagogical Approaches

DT and HCD have been increasingly embedded at the course design stage through various learning activities and in group work projects as they require team work and open communication (Kijima et al., 2021). Various degrees of implementing DT and HCD were found among the existing courses, although a lack of focus on real-world problem-solving skill development in the agenda is commonly found among them. Common teaching and learning practices observed in the courses involved lectures and scholarly readings on HCD principles, testing visualization tools, and prototyping (Melles, et. al., 2011). Some scholars suggest that more project experiences linked to real-world problems should be provided to students in the HCD curricula and courses (Melles, et. al., 2011; Zoltowski et al., 2012). This is also the focus of this study: to have students experience the HCD process in a technology integration course with a focus on inquiry-based and real-world problem-solving skill development.

As an example, Melles et. al. (2011) designed a DT course that was taught simultaneously in Melbourne and Hong Kong. Specifically, the teaching component included a one-hour lecture and two hours tutorial each week for 12 weeks that aimed to help students understand the key concept of DT from the literature. The course adopted readings and lectures on implementing DT by Tim Brown from IDEO, Roger Martin from Rottman School of Management, and Shelley Evenson from Carnegie Mellon, and the d. school Bootcamp Manual (Bootcamp Bootleg d. school, 2010). Students were required to complete the readings and respond to them in a blog about the article content and application of DT in different areas. They were also charged to work in groups on a semester-long project to resolve a problem on campus related to a service or system using the DT process. Students met and worked in groups outside of the classroom for three hours per week on data collection and analysis. Melles et. al. (2011) reported lessons learned from this experiment involves difficulties in encountering DT as a teaching subject for the first time to students with diverse design backgrounds. It was difficult yet possible for students to move from a product, space, or interface design perspective to circling a broader system and organization sense. The project problem was usually and quickly defined as a product or interior design problem as opposed to a broader issue such as poor network among the students (Melles et. al., 2011).

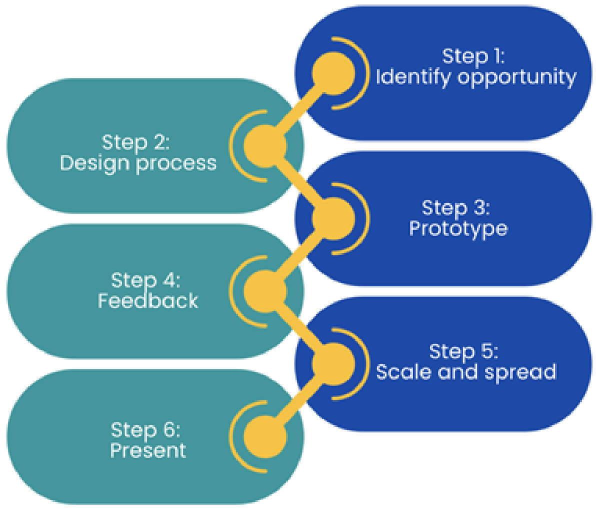
As for DT and group work, Ray (2020 presents a six-step approach when applying DT in small groups: 1) identify the opportunity; 2) design; 3) create prototypes; 4) get feedback; 5) scale and spread; and 6) present. To generate more ideas, he suggests that students are encouraged to say “yes” when they agree with each other’s ideas, and “yes, but…” when they disagree. This not only helps to avoid discouraging other students from expressing their opinions, but also to explore alternative ideas, which are essential for building prototypes. The activity starts with a problem that is offered for the students to solve. The activity comprises six steps as illustrated in Figure 1.

Step 1: Identify Opportunity. Students identify the need for the problem to be solved and who will benefit from the solution in group. Next, they will find someone external, who is personally affected by the issue, to and interview them about how the issue may affect them. This can be outside or in the classroom where the audience was invited to participate.

Step 2: Design Process. During this phase, students review the insights they collected during the interviews and brainstorm solutions using sticky notes and pens they were provided. When they finished with brainstorming, the main themes must be identified, and at this point, students from smaller groups to research the initial ideas.

Figure 1

Six Steps in Design Thinking



Note. Adapted from Ray (2020)

Step 3: Prototype. Students review the ideas and choose one prototype to execute. The prototype will need to solve one aspect of the problem. Then students select the next aspect of the problem and approach it similarly. They will draw a brainstorming map (or attaching sticky notes to paper) to visualize the thinking process for each prototype.

Step 4: Feedback. The groups will present their solutions to two or more external experts from different stakeholders for diverse feedback and perspectives.

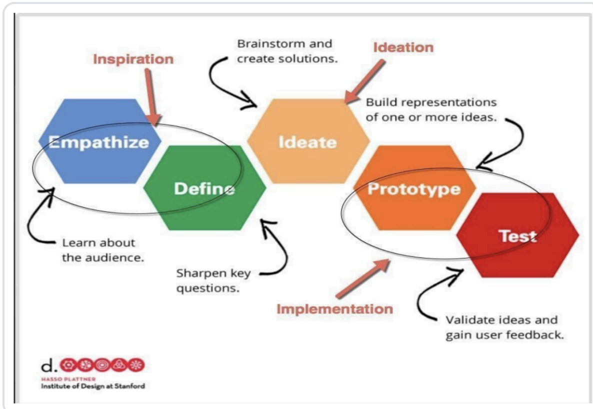
Step 5: Scale and Spread. Students continue working in groups to find the best solution to the feedback received in step 4. In this process, the teacher's help in guiding the students' ideas is needed. If the group has received numerous comments from the experts, it can be split into several smaller groups, with each group working on one issue. The sub-groups can then come together and agree on a common variant for presentation.

Step 6: Present. The groups present their solutions to the problem. In order to make the process more significant for students, the people whom the students interviewed during the first phase might be invited.

This study takes a parallel approach by employing Stanford d. school DT model that includes five stages of the DT process categorized into three phases: Inspiration, Ideation and Implementation. Activities in each phase provide students with opportunities to solve a real-world problem and offer a solution for the people who need it. The students will participate in multiple group discussions to generate as many ideas as possible and to narrow down to viable ideas with mutual agreement by the whole group. There are no bad or incorrect solutions, instead, problems can be solved in different ways that reflect the teamwork and several trials. The process may be challenging as it is time-consuming, non-linear and may extend to several lessons for a long period of time. The instructor guided the process by setting a definite timeline for each part of the activity to be done. Teachers may adapt the existing material to their pedagogical needs and to the target groups, as well as taking into consideration design thinking principles to create their own teaching and learning aids, in order to motivate students' learning.

Figure 2

Standord d. school streamlined design process



Note. Legacy, circa (2012)

Methodology

This study employed an ethnographic research approach (i.e. a qualitative research method that focuses on the behaviors, needs and context of students in the classroom) (Creswell & Poth, 2017; Corbin & Strauss, 2008; Glesne, 2015) to explore student teachers' application of DT&HCD and its impact on their engagement and learning in the C&I 100 course. The ethnographic method was adopted to capture details of student teachers' shared patterns of behavior, beliefs, and language observed in the course of project design. In the following sections, we describe the context of the course and study participants, followed by specific methods for data collection and analysis. This study was conducted in the C&I 100 course offered by the Liberal Studies major at a large public university in the United States. The university serves the linguistically and culturally diverse communities in Central California. The U.S. Department of Education designated the university as both a Hispanic-Serving Institution and an Asian American and Native American Pacific Islander-Serving Institution (details removed for review, 2021). The Liberal Studies major provided rigorous subject matter preparation for prospective elementary teachers and special education teachers. The C&I 100 was one of the required courses designed for juniors or seniors in which they explored emerging technologies used for teaching students core ideas and practices in disciplines.

Incorporating HCD in the C&I 100

The incorporation of HCD in the C&I 100 course design was an ongoing process that started in the fall of 2018 and evolved over time. The main goals of the course are to equip student teachers to (1) analyze social, ethical, and legal issues related to the use of technology (e.g., privacy, access, and intellectual property) and (2) integrate technology into the school curriculum for social justice or equity (e.g., assistive technologies). The major course assignment, Technological Leap Project (TLP), required student teachers to apply HCD to solving real-world problems with technologies. Course learning activities for the TLP were described in a design case study as follows:

> *Specifically, course learning activities involved exercises for the students to observe and identify problems in the K-12 teaching and learning environment. The students then were guided through HCD process exercises to further detect and analyze the problem, brainstorming possible solutions while attempting to understand the audience and refining their needs. The students were also tasked to get feedback from the audience, design, prototype the product to the audience and iterate based on the received feedback. As for the student's application, they followed the HCD process field guide with the understanding gained from the class activities on the TLP. Specifically, the students applied the HCD process and mindset to reach and build connection with the audience, to express their voice of concerns for them, to demonstrate choice making for tools and instrument to implement in the solution design, and to claim ownership of the artifacts they created. (Phan & Shin, 2021)*

Essentially, the employment of HCD in the TLP was centered around compassion and empathy for the beneficiaries for whom they designed. The human-centered mindset enabled student teachers to reflect their voices, choice, and ownership in the design process. The TLPs were done in groups to foster students' collaboration, leadership skills, as well as to join and refine ideas as a group. Through taking different design phases, student teachers manifested their project ideas with HCD as follows:

Inspiration: This phase started when a problem arose that motivated the search for solutions. Accordingly, the student teachers created a framework to define the problem, a benchmark to measure progress, and a set of objectives to be realized. According to the aforementioned DT process, understanding the audience (i.e., Empathize) and defining a problem(s) (i.e., Define) was key to a meaningful designing process. As a mindset, HCD reminded the student teachers to stay in the "Inspiration" phase and not rush to the execution stage. It also guided the students to converge with stakeholders to better understand their needs, assets, and opportunities to align around the problem. The students were expected to review the literature and present personal and professional connections to the topic emphasized on their projects in this phase.

Ideation: After observing and doing design research on the audience, the student teachers went through a synthesis process to distill what they saw and heard into insights that led to solutions or opportunities for change. In other words, the student teachers created an action plan based on synthesizing and analyzing the feedback from the audience in light of research and their own experience.

Implementation: The best ideas generated during ideation by the student teachers turned into a concrete action plan. Prototyping was at the core of this implementation process, turning ideas into actual products and services that were tested, iterated, and refined (Brown & Wyatt, 2010)

Table 1 shows the application of the HCD approach in the C&I 100 course in which the goals and learning outcomes were manifested by key assignments for the TLP and learning activities in each phase. The activities were completed by student teachers in the class through individual and group work (Phan & Shin, 2021).

Table 1

Application of HCD process in the C&I 100 course in full 2019

DT Phases	Goals	Key learning Activities for the TLP
Inspiration	• Enabled students to formulate an idea/problem in the K-12 environment that was rooted in their interests and past experiences • Allowed them to experience empathy by having their voices honored and ideas invested • Equipped them with technology tools to help solve the problems	• 30 circles to generate ideas • Identifying problems and forming groups based on mutual interests • Framing a challenge/problem with guided questions using a concept mapping tool Reviewing technology tools and making decisions on incorporating technology in the project • Application/software evaluation checklist allowed students to weigh multiple aspects of technology tools of their choice to mindfully and meaningfully implement technology into their project
Ideation	• Allowed students to approach, gather and process inputs from an actual audience for which the project was designed and to form an action plan • Encouraged students to practice empathy with the users by eliciting and honoring their inputs • Motivated students to exercise mindful and	• Survey and interview design that focused on empathy practice • User experience map (as a method of showing empathy) to visualize the learner's journey in the project from start to finish • Peer feedback on Inspiration phase to help groups fine-tune their ideas

	informed decision making by integrating technology to solve a problem	
Implementation	• Allowed students to design lesson plans that integrated technology as a problem solver • Enabled students to highlight the values of the project through digital storytelling • Allowed students to demonstrate their product to the whole class • Fine-tuned the work based on peer feedback	• Lesson plan design highlighted technology integration in the classroom • Promotional video to bring the TLP values to life • Peer feedback on Ideation phase to give groups input in order to revise their work • Peer feedback on the Implementation phase that focused on technology integration in the lesson plan • Final TLP Presentation • Revision of the entire TLP

Participants

Participants in this study consisted of 38 college students enrolled in the C&I 100 course in the fall 2018 or spring 2019 semester. All of the participants were juniors or seniors in the Liberal Studies major, 31 were female and seven were male students. Most students were planning to enroll in teaching credential programs after acquiring bachelor's degrees.

Purposeful sampling strategy (Creswell & Poth, 2017) was used to recruit the participants. To capture more details of students' projects, we employed three criteria to select the participants who: (1) signed consent forms, (2) completed all required coursework, and (3) participated in focus group interviews. There were 87 students enrolled in the course over the three sessions in two semesters who formed 32 project groups (i.e., each project group consisted of two to three students). All students were invited to this study at the beginning of each semester by the instructor. The participants of this study represented 10 project groups.

Data collection & analysis

This study employed qualitative research methods, including participant observations, focus group interviews, and artifact collection. The author conducted participant observations once a week from September 2018 to May 2019 in the classrooms (135 hours). The participant observations focused on: (1) the learning supports student teachers received from the instruction during their projects, and (2) how their engagement and learning in their projects changed. We videotaped the classes and created field notes to record the observations.

Focus group interviews were conducted with the participants at the end of each semester (10 hours). Each interview took place in a university classroom, and it lasted for 45 minutes to 1 hour. We used an interview protocol developed through biweekly research meetings (see Appendix 1). The interviews centered on (1) in what ways student teachers applied mindsets or process HCD to their projects, and (2) what knowledge, skills, or attitudes they developed from their utilization of HCD. Each interview was audio-recorded and transcribed for data analysis.

Besides, artifacts generated by students and instructor over the semester were collected for data analysis. The artifacts included TLP-related documents, blogs, lesson plans, class slides, and student handouts. The artifacts were primarily used to examine how student teachers visualized their engagement and learning in their projects and what learning opportunities facilitated their project development. Each artifact was saved in an electronic format.

Data analysis was guided by Creswell and Poth's (2017) framework of the data analysis spiral. The analytic procedures included: (1) organizing the data, (2) reading and memoing, (3) describing, classifying, and interpreting data into codes and themes, and (4) representing the data (Creswell & Poth, 2017). First, all qualitative data were converted into electronic files. The ATLAS.ti computer software (version 8.4.4) was used to manage the data and help researchers compare data analysis.

Second, the author checked all transcripts of interviews and artifacts and watched videos of the classes to get a sense of the data as a whole. In reading the data, analytic memos (Corbin & Strauss, 2008) were written to record the author's ideas on initial codes. To capture details of the projects, we created event maps representing the critical events of the projects (e.g., interviews with target users, brainstorming, & developing prototypes) in chronological order. We then wrote vignettes of the key events.

Third, the data were coded, drawing upon the constant comparative analysis (Corbin & Strauss, 2008). In open coding, we formed initial codes by extracting concepts from the data. Throughout biweekly research meetings, we compared and discussed the initial codes. Specifically, for the first round, the author coded a subset of the data (approximately 20%) to establish inter-rater reliability. For the next round of coding, the author aimed to reach over 85% of inter-rater reliability. The author then created a list of initial codes and analyzed the rest of the data accordingly. The total number of initial codes was 57 (e.g., integration, empathy, creativity, collaboration, and horizontal learning). In axial coding, we identified the relationships between the initial codes (e.g., causal conditions or central-peripheral phenomena) and merged the related codes. In selective coding, key codes observed across all cases of student projects were collected and transformed into three key themes. The key themes included (1) critical uses of technology benefit learning, (2) designing with empathy unlocks new insights, and (3) embracing human-centeredness promotes expanded learning.

Last, a table with detailed information about student groups' projects to highlight how students applied the HCD in the C&I 100 course was created (see Table 2). The three key themes regarding the impact of HCD on student engagement and learning are provided below with the representative cases of projects.

Findings

This section includes a description of course design that incorporates DT&HCD and is followed by a summary of the student teachers' projects.

Student teachers' application of DT&HCD in the technology integration course

The students were engaged in a number of class activities that were attributed to their TLP since the establishment of the group at week two of the semester. For example, one of the class activities was tool review in which student groups would present their tool evaluation in class and seek feedback from their classmates. There were over 100 tools provided by the instructor that were categorized into six different functions (i.e., communication, creativity, presentation, delivery, collaboration, and engagement). As part of the homework, each group would sign up for three tools from three different categories and perform a detailed evaluation for each one. In class, the group would present their tool evaluation and demonstrate its use by incorporating it into a teaching activity. With support from the instructor, they would also monitor and facilitate an extended discussion of pedagogical uses of the tool.

Another series of class activities involved discussion on scholarly readings and webinars on contemporary issues on teaching and learning. An example of a reading activity included group reading, interpreting, and aspects of applying the ISTE Standards for educators, students, and when designing a product that involves them. Yet another example related to students participating in an expert panel discussion series on aspects of teaching and applying the insights and research findings from these discussions to their TLP. As part of the TLP assignment, students were required to report 3-5 research resources related to their problem in the format of a Literature Review. This gateway to expert view and perspective-taking was intended to not only help students establish a scholarly foundation of their work but also situate their work and problem-solving practice around real-life problems.

Table 2 presents 10 sample projects with identified design challenges, project descriptions, the target audience, key technology use, and themes that the project covered (Phan & Shin, 2021).

Table 2

Summary of students' projects that applied the HCD Process

Project	Design Challenge	Project Description

Replacing traditional tests and quizzes with Kahoot!	Test anxiety	• Target audience: 4th graders • Tech tool: Kahoot! • Goal: Reduce students' test anxiety in Math and science class using Kahoot application • Behaviors: Students will take and design quiz items on Kahoot!
Habitz creates Healthy Students	Children facing the risk of not having a healthy lifestyle	• Target audience: 3rd graders • Tech tool: Habitz • Goal: Promote exercise and healthy eating and an active lifestyle using the Habitz application • Behaviors: Teachers and parents can access, guide, and co-manage the students' progress on healthy eating and exercise on Habitz
Facilitating Music Learning With Music Tech Teacher	Music being given less attention than other subjects	• Target audience: 4th graders and teachers • Tech tool: Music Tech Teacher.com • Goal: Motivate students' learning and exploring their musical potentials with resources and practice • Behaviors: Teachers can access different programs, activities, lesson plans, videos, and collaborate with other music teachers using the resources on the website
QR Classroom	Parents unable to assist their children with math homework	• Target audience: 4th graders • Tech tool: QR code generator • Goal: Reinforce classroom learning at home and support parents who want to support their children's learning • Behaviors: A scannable QR code is embedded to the homework sheet which links to a video tutorial that allows students to complete their homework and parents to access and assist their kids if needed

Imagine Learning	Children with pronunciation and reading problems	• Target audience: 6th graders • Tech tool: Imagine Learning software • Goal: assist students with pronunciation and reading skills with Imagine Language and Literacy (an area of focus of Imagine Learning) tool • Behaviors: Teachers guide students through learning activities on Imagine Language and Literacy site
Time to Relax	TK-2nd grade teachers and students with stress and anxiety	• Target audience: TK-2nd graders and teachers • Tech Tool: student-built website • Goal: Help reduce stress levels in the classroom • Behaviors: Teachers can access and have students do music, yoga, and meditation exercises using the resources from the website
Limiting Creativity Led to Life-Long Challenges	Students' lack of critical thinking and flexible problem-solving skills	• Target audience: 1st – 3rd graders • Tech Tool: Cognitive Guided Instruction (CGI) Mathematics, DYI.org • Goal: Help students develop critical thinking and flexible problem-solving skills using resources from CGI and DIY.org • Behaviors: Teachers use CGI Inventory Database to plan the lessons and track students. Students showcase their Math problem-solving skills on DIY.org.
Get Outside	Kids not getting enough exposure to the outdoors	• Target audience: 4-6th graders and teachers • Tech Tool: student-built website • Goal: Educate children on local wildlife and national parks and spark interests to obtain first-hand experience • Behaviors: Teachers organize field trips using resources and guidance from the website. Students will write a report of what they learn from the field trip

Skills for Life	High school students lacking survival skills	• Target audience: High school seniors • Tech tool: Skills for Life app • Goal: Equip students with life skills (i.e. cooking, laws, directions, paying bills, filing tax, etc.) to prepare them for the real world after high school • Behaviors: Students will take a quiz about their performance on the skills they learn on the app
Motivating with Monster	Students lack the motivation for academic success	• Target audience: K-5 teachers • Tech Tool: Class Dojo • Goals: Improve teacher-parent communication and kids' behaviors in the classroom. Parents can connect to their child and help them academically. • Behaviors: Teachers collaborate with parents in co-managing kids' behaviors. Kids enjoy extrinsic rewards with Class Dojo.

Impact of DT&HCD application on student engagement and learning

The impact of DT&HCD on student engagement and learning were categorized into three key themes in which pedagogical practice was highlighted and students' guided experiences were captured. These themes are: (a) critical uses of technology benefit learning, (b) designing with empathy unlocks new insights, and (c) embracing human-centeredness promotes expanded learning. In each theme, different ways in which the students experienced the DT&HCD process within the technology integration context and how that shaped their learning in the course were presented.

Critical uses of technology benefit learning

Explain/define each theme and what sources of data used to illustrate it.

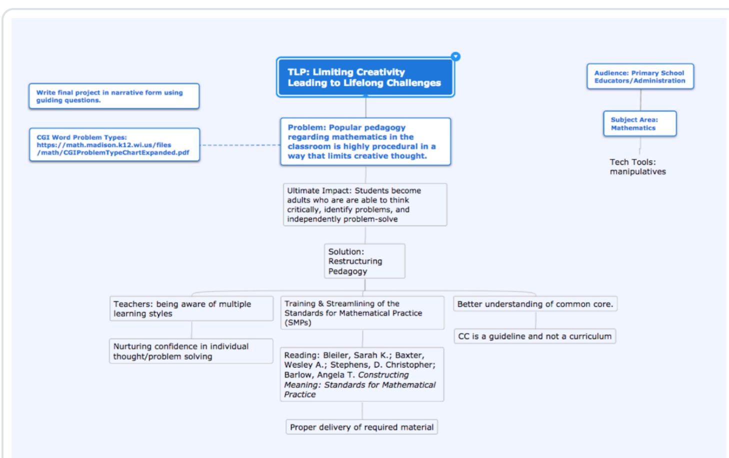
The data indicate that students used diverse technological resources in ways that directly benefited their group projects. Since one of the requirements of the TLP assignment is to integrate technology in the design of a solution, the project design was technological oriented at almost every phase of the process. Specifically, each group of students reviewed technological applications viable to solve the problem they identified in the Inspiration phase, demonstrated the use of the tools in the class and sought feedback, and integrated them into the lesson plan design in the Implementation phase. In selecting the best tool(s) to apply in their project, each group would choose three potential tools and run each of them through a provided evaluation checklist to determine the (1) appropriate cost, (2) suitability and relevance to the audience's age, technological levels, and needs, (3) ease of use, and (4) credibility. Decisions on which tool(s) to apply for their TLP would be made in a consolidation fashion based on the evaluation checklist and the aforementioned tool demonstration and discussion activity in class.

For example, in the project Limiting Creativity Led to Life-Long Challenges (See table 3), Jason and his group developed a solution that employed the Cognitive Guided Instruction (CGI) Inventory (Fennema et al., 1999) and Database in Conjunction with DIY.org to help promote students' critical thinking and flexible problem solving. In the Inspiration phase when the group detected problems of Math being taught in a mainstream classroom, they chose to use Mindomo (see Figure 3) to frame the challenge. Jason described his experience using the tool as follows:

> *I found this software particularly helpful as someone who does not organize things well. Mindomo is relatively easy to use and allowed me to keep my drafting ideas for the TLP in order. By laying everything out in a sequence, Mindomo helped me to keep my ideas focused during the Inspiration phase of the TLP (Jason's blog).*

Figure 3

Concept Map of Project "Limiting Creativity Leading to Lifelong Challenges"



Next, the group decided to use Buildfire to develop their CGI Inventory Database app after weighing the pros and cons of each of the three tools in their tool review. Jason explained the tool use as follows:

> *Buildfire is an app-building website that allows you to select from a series of templates to develop your own app. You can freely adjust the functions, attach links and videos into the app itself. One major downside to Buildfire is the learning curve.*

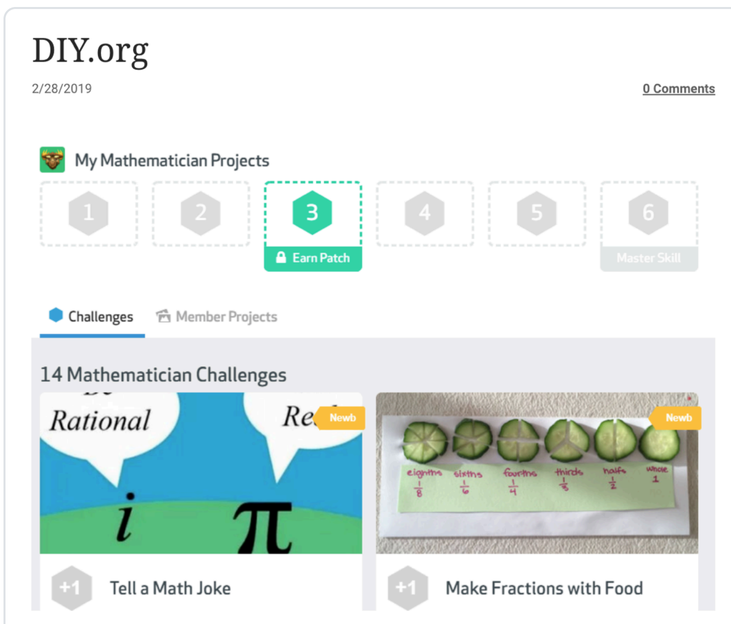
> *Because the program allows for so much customization, the user interface can sometimes be overwhelming. I spent several hours simply learning how to add and adjust features on the app I was designing (Jason's e-Portfolio).*

Similarly, based on the tool reviews, the group also decided to employ DIY.org, a project-oriented educational website specifically designed for children under the age of 16, to increase student interaction in their TLP. Moreover, they mentioned planning to use DIY.org in their future classrooms in order to encourage students to stay in touch with their homework assignments.

> *Students can find new challenges and achieve goals based on their personal interests, making DIY.org a perfect site for self-guided learning. DIY.org incentivizes student learning by allowing them to earn badges based on specific goals and challenges. These challenges are designed around specific student interests. When students earn enough badges in a category, they gain a mastery achievement on their profile (Maria's blog).*

Figure 4

DIY.org tool demonstration



As part of the TLP, the group created a promotional video (i.e., digital story) that highlighted their TLP practical values. The group chose to use Animaker to create their digital story once again based on their hands-on experience with the tool. Below is the group's reported tool review:

> *Animaker is a do-it-yourself video designer. Users can design their own cartoons, videos, and presentations using a variety of scenes, props, and character designs. Animaker is easy to use and highly customizable, making it a fun way to design a*

> *video relatively stress-free. However, users should be aware that they can quickly find themselves restricted by pay-gates and subscription fees. Animaker can also be difficult to use on older computers due to the large amount of processing power that videos-even those made in flash-demand when being created (Patricia's e-Portfolio).*

Given the opportunity to explore and choose the type of technology to implement in their TLP, Jason's group demonstrated strong engagement and critical thinking skills at every phase of the project in regards to evaluating and applying the technological resources. Jason's group and other groups who went through the same phases of TLP benefited from the hands-on experience of reviewing the tools to use in their project. Their approach to technological uses in their TLP was problem-solving, mindful, self-reflective and dynamic in nature, which exemplified the problem that they were aiming to solve in their TLP.

Designing with empathy unlocks new insights

Analysis of data indicates that student teachers centered empathy on designing their projects and developed their multifaceted understanding of the people whom they were designing for and the contexts where the projects were undertaken. Stepping into other people's shoes created a space in which the student teachers dismantled their preconceived ideas or assumptions regarding their target population and developed more nuanced views of their communities. The breadth and depth of understanding of the people and the contexts unlocked new insights and possibilities for their projects.

According to Davis (1983), there are two main types of empathy based on its role in interpersonal understanding and in driving prosocial behaviors (i.e. Davis, 1994; Eisenberg & Strayer, 1987; and Batson, 2009): (1) Affective Empathy (i.e., the capacity to respond with an appropriate emotion to another's mental state), and (2) Cognitive empathy (i.e., the ability to know and understand another's perspective). Both types of empathy were shown in the students' TLPs. Specifically, the Imagine Learning project is a typical example of student design with strong Affective Empathy starting from choosing a topic to executing the plan. One of the group members, Emily, an instructor at an intervention literacy program for seven years, decided to implement Imagine Learning as a supplemental tool to support students' English Language Acquisition (ELA). Emily observed students using it for independent work and commented on how it supported students who struggle with literacy. She recalled:

> *I wanted to solve the problems with students struggling with literacy, whether they are struggling with phonetics, or decoding, or comprehension, and this would help support them in those areas. It's so sad to see students not being able to read at the grade level. I worked with special education students and I saw that they were struggling, they were 5th or 6th graders but their reading levels were at 1st or 2nd grade and that really broke my heart. So, anything at all that would come to support these students to enable them to read and live their lives I am all for it (Emily, focus group interview).*

Having spoken no English when her family moved to the U.S. from Cambodia, Emily struggled a great deal to pick up the language and culture as she attended schools in America. Her strong sense of empathy for the students who struggled with different aspects of the language in her class derived from (but not limited to) her own experience being a non-native speaker of English. Her heart grew to feel for the students who are going through what she went through.

Cognitively, design with empathy also means identifying, understanding, and attempting to solve the problem for someone else. Importantly, this is evidenced in the TLPs where students demonstrated understanding of the problem by making personal and professional connections with the audience. As in the case of Limiting Creativity Leading to Lifelong Challenges, the author identified one of the problems that hindered the students' creativity, which in turn aspired his group to design the solution, based on their classroom observations and analysis as follows:

> *I am a first-year Special Education teacher teaching in a middle school, and I am responsible for teaching both Math and ELA to my students. Students who are placed in my class are often working far below grade level across all subjects. This occurs most frequently due to a combination of two factors. First, the student's behavior is so intense that it severely inhibits his/her ability to master new concepts. Second, the student was taught that there was only one way to solve a problem and express its solution, and he/she was never encouraged to think flexibly about a problem (Jason's blog).*

The author mentioned that they chose the topic because they understood the value of flexible thinking and creative freedom in helping students to regain confidence and promote breakthroughs in academic success:

> *If I better understand the ways students think and have a better grasp of the strategies available to problem solve, I can better empower students to become creative problem-solvers." (Jason's blog)*

Embracing human-centeredness promotes expanded learning

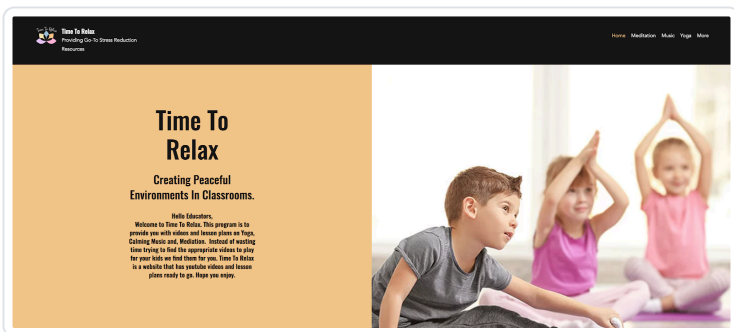
The data revealed that embracing human-centeredness (i.e., keeping the users' needs in mind when designing) facilitated the creation of expanded and sustained learning opportunities. Through acknowledging the inherent uncertainty in the DT&HCD projects (i.e., not knowing the answer to a problem in advance) and exploring different options for solutions to identified problems, the student teachers continued to navigate new ideas, tools, or resources to advance their technological project to unknown territories. In the case of Time to Relax, Mary, one of the authors, shared:

> *I feel like student behavior is a big issue and can be narrowed down to real-life situations that teachers go through every single day: stress level in the classroom. Finding free, accessible resources that can potentially lower the stress levels and behavioral issues in the classroom is something that we were focusing on. To come up with a solution to this problem I think was a little difficult because we were thinking of the problem realistically versus hypothetically, something that the teachers and students face every day (Mary, focus group interview).*

The group started with reviewing the literature on the negative impact of stress on teachers and students, including causing teachers to leave their jobs and preventing students from engaging in the lessons (Raschke et al., 1985). Next, they documented the benefits of music, yoga, and meditation in (1) reducing aggressive behaviors and mood regulation (EOC, n.d.), (2) improving students' mindfulness, self-esteem, and physical condition (Hagins & Wang, 2015), and (3) creating a more peaceful classroom with more compassionate and caring students towards one another. From a professional perspective, Mary reported witnessing teachers who struggled with students' distracting behaviors in the elementary classroom in Central California. On the other hand, on a personal level, Vickie, another group member, described being a victim of disruptive behaviors from her counterpart students in the classroom she attended in her home country of India. Driven by a strong sense of affective and cognitive empathy for the audience (i.e., students and teachers), the group decided to gather stress reduction resources and develop activities to incorporate them in the classroom. They also suggested methods of measuring students' progress over time with the treatment.

Figure 5

Website of Time to relax



After observing and doing design research on the audience, the team went through a synthesis process to distill what they saw and heard into insights that led to solutions or opportunities for change. In other words, they created an action plan by brainstorming solutions based on synthesizing and analyzing the feedback from the audience in light of research and their own experience as shown in Figure 6.

Figure 6

User experience map for Time to relax

The group then prototyped the idea of incorporating the TtR website into 5 sample lesson plans, and a measurement of student learning outcomes, which was formed in the ideation phase. The five lesson plans would serve as a guide for the Tk-2nd grade teachers to follow in conjunction with the resources on the TtR website. The teachers could choose to incorporate any portion of the videos and/or sample lesson plans on music, yoga, and meditation within and among lessons in their classroom. Measurement of student learning outcomes included submission of "How I feel" daily journal and Friday reflections. The teachers could review the students' journals using a provided rubric and adjust the class activities based on the student feedback. Measurement of teaching effectiveness included the teacher's self-assessment of incorporating TtR in the classroom and their reflection on possible improvement plans (see Appendices A, B, C, and D for examples of the first lesson plan, student's learning outcome "How I feel" journey, a rubric, and the questionnaire for the teachers).

Finally, the group reported some possible issues and barriers for using TtR, such as space availability for monitoring student participation in the activity, access to the website at the school site, etc. The groups provided suggested solutions for each potential problem identified. The group performed collaboration among the group members with the facilitation of the course instructor at every stage of the DT&HCD process.

In short, embracing ambiguity over the course of their TLP encouraged Vicky and Mary to actively pursue new learning opportunities not only in technology but more importantly an opportunity to test the effect their product had on young students in reality - what they set out to do from the beginning. In looking back, Mary stated: "I think that the risks that we took ended up to be something so beautiful that it can actually be used in real life." (Mary, focus group interview).

Discussion and implications

It can be said that the participant's active engagement in the course activities and assignments, particularly the TLP, reflects their positive responses to the constructivist learning embedded in the course design. Demonstrations of students integrating their knowledge and observations to design a solution to a real-world problem in a collaborative manner indicated some success of the DT approach, which was set in the course design stage, outlined in the course goals and objectives and manifested by the class activities and assignments. In other words, the course vision to focus on inquiry-based learning with a connection to real-world problems and scholarly research involvement was somewhat achieved. Going hand in hand with DT, HCD was intended as a mindset for the students to apply and focus on human beings as they go through the process of designing a solution.

The student teachers have demonstrated various levels of understanding the audience while developing their technological hands-on skills and experience, synthesizing different resources and applying the understanding and skills holistically in different phases of their solution design. The search for a solution was driven by a sense of empathy the group had for the audience and their problem(s) in the first place. The group then went through different steps of defining, iterating, prototyping, and testing the idea when constantly and tirelessly attempting to better understand the audience. Technology was used in the project as a tool, as well as a skill and a gateway to problem solving.

The way the student teachers applied the DT&HCD approach and mindset when going through different design phases of the project revealed positive evidence of engagement, both in individual phases and in a consolidated manner. First, most groups focused on understanding the audience and it context at every phase of the project. This is aligned with the DT process developed by the Stanford d. school and aforementioned findings by Brown and Katz's study (2011). This is also consistent with Zoltowski, et. al's (2012) findings that in order to make products and services useful, usable and desirable, it is important to seek understanding of the target audience holistically. IDEO (2011) also embraces human-centeredness and creative ways to approach the audience, to dive in to make and prototype different ideas.

Students demonstrated deep interest in the topic and when framing the challenge, they drew connections from their personal experience and observations while backing up their idea and argument with research findings. To further understand the users, each group reached out to the target audience for authentic feedback. In analyzing the received feedback, they factored the audience's comments or concerns into visioning their product design. They also drew a user experience map to showcase the journey an actual user would experience with the learning process. As the tasks were built on each other, the student teachers matured and became increasingly capable of incorporating more complex information about the stakeholders (i.e., the student and teacher audience) as well as aspects related to the feasibility and viability of their ideas.

In sum, critical attributes of student teachers' application and experiences of DT&HCD include: framing the problem, investigating multiple possible solutions and using data and resources to make decisions, testing different solution options, and focusing on finding the best solution to the specific design problem identified in the K-12 classroom environment. Such conclusions were aligned with the study findings by Henriksen et al. (2017) that graduate students found themselves as designers who utilized DT practices to transform educational problems of practice. It also strengthened Oehlberg et al.'s findings (2012) that the HCD approach in design promoted multidisciplinary conversation about design among students and broadened perspectives of design. The process employs logic, evidence, and rationality, which are consistent with the themes that define DT approach (Brown & Wyatt, 2010; IDEO, 2015a).

Findings from the three themes (i.e., critical uses of technology, designing with empathy, and embracing human-centeredness) with excerpts of students' project design and development once again highlighted the students' alignment with the core values of DT&HCD. First, the students have demonstrated a wealth of evidence of critical use of technology in different stages of the project throughout the semester. This is aligned with the course design and focus of a technology integration course. The students not only used technology, but also developed critical technology review skills and weighed various factors in ways that the tool can best serve their project. In other words, students' use of technology in the context of the course did not immediately start with using the tool per se, but from critically assessing the tool, understanding the audience and process, and applying the tool to solve the problem in light of understanding the condition and circumstances of the audience.

Secondly, the students approached the problem with a strong sense of empathy with the identified audience that guided their actions and sustained their interest. Maneuvering the project with the audience in mind, they developed a critical mindset towards using technology and applied technological tools in ways that best benefited their projects. This community-driven design foundation serves a number of benefits. The depth of understanding of the people provided new insights and possibilities for their designs. It enabled groups of students to understand the strength of the audience and assets they brought to the table, which presented a positive counterpoint and energy to the team effort, and revealed resources and opportunities for innovative intervention.

Thirdly, embracing human-centeredness in designing a solution allowed the students to explore different options and territories to the identified problems, including navigating new ideas, tools, and resources. Students were guided to maneuver through ambiguity by bite-size assignments and activities in class, including conducting secondary research or consulting experts in the field on existing solutions to the problem. While consulting the scholars and experts in the area, the student teachers practiced decision making and problem-solving skills as they built the design solution during the course. This sense of proactivity and ownership has boosted their self-confidence and helped them confront and conquer the ambiguous state of the project.

The unique part of this study lies in the application of the DT&HCD at the same time. Unlike previous studies that employed either DT or HCD, this study employs the best of both worlds by applying both DT and HCD at different stages in the course design and delivery process. The DT approach is proposed in the course design stage to ensure inquiry-based learning while HCD is applied as a mindset that gears towards improving the usability and user experience of the products or services for a specific group of audience. The combination of DT&HCD provides a structured and inclusive approach and process that does not rely on a visionary leader. Instead, it leverages the strengths and insights of the group and the audience community to increase the viability and likelihood that the solution will be successful. Each individual brought relevant background experience and skills to contribute to the group, including members of the audience community. In the process of constructing learning experience through a group project, students: (a) experience ambiguity when maneuvering through different stages of the project, (b) accept constructive criticism from fellow students while exploring and testing multiple possibilities to a single challenge and confronting the risks of failure of a solution, (c) ask the right questions, and (d) develop a sense of empathy for the users when designing a product for them.

- Student performance using DT&HCD: How do the students perform individually and collaboratively in a group project that employs DT&HCD?
- Students' sense of ownership and accountability and choice making in the group work: How do they maneuver these through different steps when applying DT&HCD?
- What are the perceived rewards and challenges of applying DT&HCD by the students and the instructor?
- How to identify quality DT&HCD projects? For instance, what are the pedagogical elements in a quality design project by the students?
- Inquiry-based learning and students' uses of technology: To what extent does focusing on problem-solving help students with technological skill development? Students' self-efficacy and interpersonal skill development as they apply DT&HCD.

There are a number of limitations during the first two iterations of the course. First, there were difficulties in teaching the course for the first time and adjusting to the students' responses whose design backgrounds varied and who encountered design thinking in this fashion for the first time. A second challenge was that although most of the participants were juniors, seniors or post-bachelors, this was the first time they had to read, synthesize scholarly resources and write a literature review. Thirdly, given the time constraint of one semester (i.e., 14 weeks), the students could not afford to fully develop and test the products. This limitation is inherent in the course design and not easily modified.

The results of this study on students' application of DT&HCD must be regarded within the context of this study. Although the student teachers described a variety of experiences through their design projects, most of them are within the academic context, specifically K-12 and were subject to the real and perceived barriers. Therefore, it is not expected that the results would necessarily be generalized to the experiences of students working exclusively in a more professional context where the designers were professional designers.

In addition, the exploration of DT&HCD is contextualized in designing for others. Despite the intent and endeavor put in the course design and delivery by the instructor (i.e. subject matter expert) to introduce and apply the concept, this prompt could limit the students' responses if they did not view their design experience fitting to the context. Furthermore, using the terms "DT&HCD" may cause some limitation and bias against the students' responses if they were unfamiliar with the terms.

Conclusion

Understanding the ways that students experience DT&HCD through the design process serves as the first step for course designers to determine what skills need developing for using the DT&HCD method and what DT&HCD experiences contribute the most to the students' learning and development of understanding, empathy, and caring for the audience, which is at the heart of teacher education.

Among the contributions of this study to the field of technology and design education are the insights into ways to prepare student teachers' technology and assessment of their technological competence, and their adoption of DT&HCD approach and mindset where the student teachers' feelings, intuition and inspiration with rationales and analysis skills are employed. In the project-based learning model, the students' concerns, interests, and experiences are not only taken into consideration but also the catalyst that forms the challenges and drives the solutions.

Although the students described a variety of experiences, most of the experiences were within the academic teaching and learning contexts, in which time constraints and students' young apprenticeship to DT&HCD may have presented some barriers to the design process. Nonetheless, the results may be generalizable to the experiences of a similar student teacher population group in technology education courses. Importantly, this work lays a solid foundation for future studies that involve course design that maximize student experiences with the DT&HCD method.

Availability of data and material

The data for this study is not made public. However, they are available for the reviewers on request.

Competing interests

There is no conflict of interest found in the research study.

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Appendix

Interview Protocol

Background

- Can you please introduce yourself? (Name, major, years at Fresno State, etc.)
- Why did you take the course? Or What is your purpose of/reason for taking this course?
- How do you describe your tech skills and/or funds of knowledge prior to the class?

HCD Project Overview

(Could you describe your (TLP) project?

- What was the problem you wanted to solve with your project?
- What was your solution to the problem?
- What is the significance/uniqueness of the project? And their sense of ownership.

(In paper: We will describe the phases, and the activities intended for the students to build up the skills for the phase)

Participant and Engagement

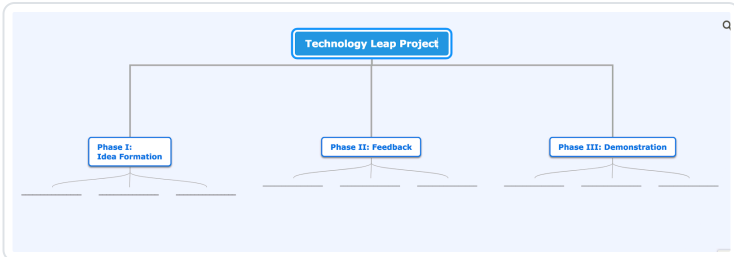
Fill in the form key activities you participated (They can use their note/blog) 15-20 mins.

- Phase I, II, & III: What's your most highlighted experience in this phase? (i.e. have them focus and describe in great detail that activity. As we move around the circle, the other member(s) will add some additional info, or describe another activity)
- Were you engaged in the activity? Did you like the activity?
- How do you think engaging in the activity supported your project?

Benefit/Challenges/ Struggles

- **Micro Level:** Phase I, II, & III: What's your most rewarding/challenging moment in this phase? (If they already answer part of the question on the Participation part, we can ask for further details/additional info)
- **Macro Level:**
- What's your take away from this project? Professionally as a future educator and/or personally.

- Are there any suggestions, if any, you have to improve this course? Or is there anything you would have liked to see differently?



Effects of the Project's Usefulness on Students' Initial Motivation

- How was your idea/interest for the TLP developed? Did you encounter any difficulty narrowing/framing the problem that you're trying to tackle?
- How do you describe the values/significance/usefulness of your TLP? (i.e. How relevant?
- How did it connect to the world?) In what way did your background knowledge and experience affect the formation and development of the idea (support and limit it?)
- In what way were you motivated and sustained by it over time? How do you feel about building a project that is useful vs. finishing it as an assignment for grade?
- How do you describe your experience applying the HCD approach into your TLP? What's your take away from the TLP?
- How did it help/engage/inspire you professionally and personally?
- Do you have any plans to continue/sustain/implement the project into the real world?

Effect of Peer Feedback on Students' Views of Their Works

- Were you able to see the users' point of view when you began the TLP?
- Did the peer feedback influence shape the view of your TLP work? If so, in what way?
- In what way did the peer feedback help you to revise/improve your TLP work?
- Pointed out possible problems with your design
- Asked questions/suggested ideas that you did not think about
- Helped you see/develop an objective point of view
- Provided good suggestions on direction for improvement for your TLP.