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Using Prototyping to Teach the Design Thinking Process in an Asynchronous Online Course

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Abstract

Companies who use design thinking increase revenues and shareholder returns at almost double the rate of their industry peers, yet over 90% of companies do not employ design thinking, due to a lack of design skills in the workforce. Educators can address this skills gap by adding design thinking to the curriculum. Design thinking is a process where developers and users physically collaborate together to develop new products, so discovering whether online students who are never physically present together can successfully learn design thinking is critical to developing curriculum. This study examines whether students in "asynchronous online" courses can successfully apply design thinking to develop a prototype, as well as provide substantial feedback on classmates' prototypes during an iterative review process. The study employed an iterative model for the prototype design, review, and assessment. The results demonstrate that over two semesters an average of 77% of students successfully developed prototypes employing design thinking standards and 94% effectively provided feedback to peers on their prototypes during an iterative review process. The implication is faculty can confidently teach prototyping as a part of the design thinking process in asynchronous online courses, thereby helping to address the design thinking skills gap in the workforce.

Keywords: Design thinking, prototyping, iterative review, asynchronous online courses

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1. Introduction

Design thinking is an iterative process for creating prototypes of new products, gathering feedback from customers, and then redesigning the prototypes (Razzouk & Shute, 2012). The design thinking process and prototyping are effective business practices for developing new products because the product developers and customers work closely together, ensuring that the products meet the customers' needs (Dorst, 2011). Developing products that better meet customers' needs increases sales (Sheppard et al., 2018). Recent studies show companies using the design thinking process increase revenues and shareholder returns at almost double the rate of their industry peers, yet more than 90% of companies do not employ design thinking, because design thinking skills are largely missing from the workforce (Dalrymple et al., 2020; Sheppard et al., 2018). An example of how design thinking can improve revenues is IBM's implementation of the design thinking process for product development, which allowed IBM to cut costs by $20.6 million by accelerating projects and to increase portfolio profitability by $18.6 million by reducing risk (Brown, 2018). Design thinking increases revenue by improving customer experiences and by increasing product innovation (Gruber et al., 2015; Kolko, 2015; Mahmoud-Jouini et al., 2016).

Although design thinking skills are in demand, universities are still in a nascent stage of adding the design thinking process to the curriculum, and the majority have yet to even begin teaching it. A 2019 study of 99 business programs found two-thirds of universities have not started teaching design thinking using prototyping (Lande & Leifer, 2009; Razzouk & Shute, 2012; Sarooghi et al., 2019). At the same time more schools are offering online courses, with nearly all U.S. schools transitioning to online learning since the onset of the COVID-19 pandemic, but experts have long held that the iterative review employed by design thinking requires face-to-face communication (Garris & Fleck, 2020; Mishra et al., 2020; Turk et al., 2002; Williams, 2012).

This study examines whether students in an online asynchronous course can successfully apply the design thinking process through prototyping without ever being physically present together. Additionally, this study investigates whether students in an asynchronous online course can successfully complete an iterative review to provide feedback to their peers on their prototypes. The goal of this study is to determine whether faculty can feel confident employing the concepts of design thinking, including the practice of prototyping, in asynchronous online courses. If it is possible to teach the design thinking process successfully in asynchronous online courses, faculty in online programs can add design thinking to the curriculum, ultimately helping to address the shortage of design thinking skills in the workforce.

This paper begins with an overview of the related work, which supports the rationale for the study and the development of the research questions. After the presentation of the research questions, a description is provided of the course context and the course modifications that were made to add the design thinking process. The requirements for the prototype are defined, along with the International Organization for Standardization (ISO) guidelines that were used to judge whether the students' prototypes employed the standards of design thinking. Then the methodology is described, including the framework for implementing the design thinking process in the course and the rubric instrument used to measure whether students' prototypes met the standards for design thinking. Next the results of the study are presented and discussed in terms of how the findings supported the research questions. Finally, the conclusions and implications for the field of business are presented.

2. Related Work

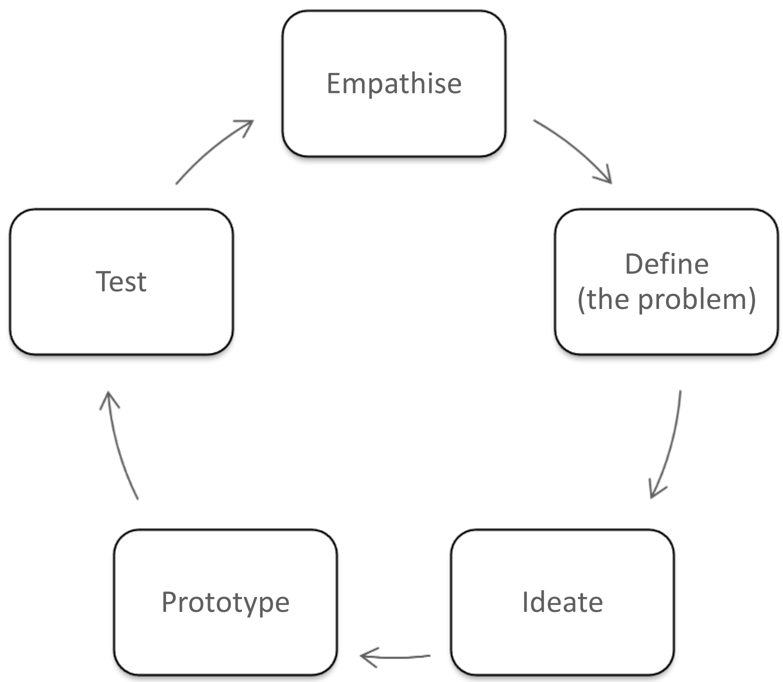
Stages in the Design Thinking Process

Design thinking is a process used in business and Information Technology (IT) to create products which solve specific problems (Dorst, 2011). As shown in Figure 1, the Hasso-Plattner Institute of Design at Stanford defines five stages in the process of design thinking: empathize, design, ideate, prototype, and test (Dam & Siang, 2021). During the first stage of design thinking, the developer is gaining an empathetic understanding of the problem by learning about it, which they then use to define the problem in the second stage of design thinking (Black et al., 2019). In the third stage of design thinking, the developer generates ideas about how to solve the problem (Dam & Siang, 2021). Then the developer models the solution to the problem using a prototype in the fourth stage (Dam & Siang, 2021). A prototype is a mockup of a new product that allows the user to interact with the product (Black et al., 2019).

Finally, in the last stage of the design thinking process, the developer presents the prototype to the user, and the user tests the prototype and provides feedback on how to improve it (Black et al., 2019). Prototyping allows the design team to create a visual mockup of the product to elicit feedback from the users, which the team then incorporates into the product design as a part of an iterative design process (Newman et al., 2015).The prototypes created during the design thinking process employ the standards of user-centered design, meaning that the product is developed with the users' needs in mind (Hartmann et al., 2006). The standards of user-centered design are defined by the ISO standard 9241-210:2019 Ergonomics of human-system interaction — Part 210: Human-centered design for interactive systems (ISO, 2019).

Figure 1

The Five Stages of the Design Thinking Process



Stages of the Systems Development Life Cycle (SDLC) and the Design Thinking Process

Table 1 shows how the stages of the design thinking process map to the phases of the SDLC. Stage 1 of the design thinking process maps to phase 1 of the SDLC, since this step involves observing, engaging with, and listening to users to understand their needs for the new product or system (Ragunath et al., 2010; Shanks, 2020). Stage 2 of the design thinking process roughly maps to phase 2 of the SDLC, since stage 2 involves defining the challenge or problem in design thinking, while phase 2 involves defining how the system will solve the problem, as well as defining the feasibility of the proposed system (Ragunath et al., 2010; Shanks, 2020). In the third stage of the design thinking process, ideation, the developer moves from identifying the problem to designing the solution, which maps to phase 3 of the SDLC, which is the design phase of the SDLC (Ragunath et al., 2010; Shanks, 2020).

During the fourth stage of the design thinking process, prototyping, the developer creates the prototype for the user to evaluate (Shanks, 2020). Stage 4 of the design thinking process approximately maps to the fourth phase of the SDLC. However, while the developer is creating a prototype in stage 4 of the design thinking process, they are coding the actual finished system in phase 4 of the SDLC (Ragunath et al., 2010). This is the point at which the design thinking process and the SDLC begin to diverge, as the waterfall nature of the SDLC means that the user does not interact with the system until it is finished, whereas the Agile approach of design thinking uses prototyping to elicit feedback from the user in an iterative fashion before the finished system is developed (Lichtenthaler, 2020).

Stage 5 of the design thinking process maps to phase 5 of the SDLC, since both involve testing (Ragunath et al., 2010; Shanks, 2020). However, stage 5 in design thinking consists of testing the prototype with the users, whereas phase 5 in the SDLC includes testing the finished system (Lichtenthaler, 2020; Shanks, 2020). There are no stages of the design thinking process which map to phases 6 and 7 of the SDLC, since the end product of the design thinking process is a prototype, not a finished system which requires installation, deployment, and maintenance (Ragunath et al., 2010; Shanks, 2020).

Table 1
Mapping the Stages of Design Thinking to the Phases of the Systems Development Life Cycle

Design Thinking	Systems Development Life Cycle
Stage 1: Emphasize	Phase 1: Requirement collection and analysis
Stage 2: Define	Phase 2: Feasibility study
Stage 3: Ideate	Phase 3: Design
Stage 4: Prototype	Phase 4: Coding
Stage 5: Test	Phase 5: Testing
No stage	Phase 6: Installation/Deployment
No stage	Phase 7: Maintenance

Rationale for Adding Design Thinking to the Curriculum

Design thinking has grown in popularity over the past two decades as method for incorporating the needs of users into products (Newman et al., 2015; Razzouk & Shute, 2012). However, educators are still in the beginning stages of adding design thinking concepts to technology-based degree programs, and the majority of programs do not yet incorporate design-thinking (Dym et al., 2005; Glen et al., 2014). Although prototyping is integral to the design thinking process, a 2019 survey of 99 business degree programs found only a third were currently using prototyping to teach design thinking (Sarooghi et al., 2019).

The rationale for integrating design thinking into the curriculum is that not only is it an in-demand skill, design thinking also provides students with myriad benefits, such as developing innovation, creativity, and emotional regulation (Dunne & Martin, 2006; Glen et al., 2015; Nielsen & Stovang, 2015). Integrating the design thinking process into the curriculum benefits students by increasing student learning, collaboration, and emotional development (Gerber & Carroll, 2012; Lande & Leifer, 2009; Rauth et al., 2010). The literature shows that although teaching design thinking using prototyping is a relatively new addition to the curriculum, it benefits students in a wide variety of ways (Huq & Gilbert, 2017; Kremel & Edman, 2019).

Employers increasingly expect graduates in technical fields to possess strong soft skills, which include innovation, creativity, and emotional regulation (Akman & Turhan, 2018; Wikle & Fagin, 2015). Integrating the design thinking process into the curriculum helps students develop the soft skills necessary to maneuver the innovation process, such as coping with ambiguity, and generating new ideas (Glen et al., 2015). Design thinking projects foster students' creativity and innovation because they encourage students to focus on "what might be?" in order to generate new solutions instead of narrowly focusing on a linear path to solving a fixed problem (Nielsen & Stovang, 2015). Students stretch their creativity during the design thinking process by generating new ideas for solving problems instead of relying on traditional business-school theories and models (Dunne & Martin, 2006).

Student learning increases when prototyping is integrated into college courses as a part of the design thinking process (Gerber & Carroll, 2012). A year-long Stanford University study on using prototyping to design products in an engineering course found students reported that they learned more and "worked better" when employing prototyping for their projects (Lande & Leifer, 2009). Professors in a research study conducted jointly at Stanford University and Potsdam University reported design thinking helped students develop prototyping skills as well as emotional skills, such as empathy (Rauth et al., 2010). A longitudinal study of 392 students in entrepreneurship courses at the Royal Melbourne Institute of Technology (RMIT) University in Australia showed teaching design thinking can significantly improve students' learning outcomes and experiences (Huq & Gilbert, 2017). Students in the RMIT study reflected positively on their experience with design thinking, commenting on how the learning environment is "highly interactive" and "more real" (Huq & Gilbert, 2017, p. 164). A 2020 study which introduced design thinking into an entrepreneurship course at Örebro University School of Business in Sweden discovered that design thinking increased student learning (Kremel & Edman, 2019). Students in this study showed a "high engagement in the learning process" (Kremel & Edman, 2019, p. 172). These findings demonstrate the benefits of teaching prototyping as a part of the design thinking process.

Adding Design Thinking to Asynchronous Online Courses

While the benefits to adding the design thinking process to the curriculum are clear, there are challenges with adding design thinking to college programs which contain courses offered in an asynchronous online format. In asynchronous online courses, there are no class sessions, so not only are students never present in the classroom physically together, and they are not even present online together. Since previous research on design thinking focuses on face-to-face courses, it is unknown whether students can use the Learning Management System (LMS) to successfully collaborate during the design thinking process the same way that designers and users typically interact face-to-face during the design thinking process (Huq & Gilbert, 2017; Kremel & Edman, 2019). The limitation of not being physically present together to share feedback on prototypes has the potential to hamper the process of using prototyping to learn design thinking skills, because prototyping is dependent on positive collaboration (Lachman & Rahnama, 2018). Since design thinking emphasizes the user and developer physically working together during the prototyping process, it is unclear if students who are unable to collaborate in real-time would be able to successfully develop prototypes using design thinking standards (Dantas de Figueiredo, 2021).

3. Rationale for Study

This study examines whether students in an asynchronous online undergraduate systems analysis and design course can use the design thinking process to successfully develop a system prototype and apply the standards of user-centered design to their prototype. The “asynchronous online” designation means that there are no class meetings and students are working on the course at any time of their choosing, 24 hours a day, seven days a week. The goals of the study are to determine if students are able to apply the process of design thinking through prototyping in this type of online course and to determine if students are able to provide substantive feedback to their peers on their prototypes while participating in an iterative review process. Most research on iterative development emphasizes that developers and users must physically work together, so it is significant to learn whether online students who are never physically present together in the classroom can successfully complete an iterative review as a part of the design thinking process (Turk et al. 2002; Williams 2012). The study was started prior to the onset of the COVID-19 pandemic in 2020, so there is also the opportunity to compare the results of prototyping using the design thinking process in sections of the course that were held pre-pandemic and post-pandemic.

Research Questions

R1: Are students in an asynchronous online undergraduate systems analysis and design course able to successfully develop a system prototype?

R2: Are students in an asynchronous online undergraduate systems analysis and design course able to successfully apply the standards of design thinking to a system prototype?

R3: Are students in an asynchronous online undergraduate systems analysis and design course able to participate in the iterative prototype review process to provide substantial feedback to their classmates to help them to improve their web prototypes?

R4: Are there differences in the results for developing prototypes using design thinking between the pre-pandemic and post-pandemic course sections?

4. Course Context

Background on Course Project

Students in the systems analysis course complete a substantial project based on an information systems business case. The project is individual, not team based. The project’s goal is modeling the information system described in the case using the design thinking process to develop a prototype. Students choose their own business cases. However, the case is subject to the approval of the professor to ensure that the chosen case includes an information system which can easily be modeled by a prototype as a part of the project. The professor provides a list of solid sources for cases, such as journals and software vendor sites which contain appropriate information systems cases.

Revisions to the Course Project

The course project was substantially revised for this study to include the design thinking process, so that students would have the opportunity to apply the design thinking concepts that they studied in the course materials to a prototype of the system. Previously the project required students to model a system using several types of diagrams, including Entity-Relationship Diagrams (ERDs) and use case diagrams. The appendix includes the instructions and the rubric used for grading the original version of the project. The revised project also included diagramming the system using ERDs and use cases in the project proposal, since diagramming is a key learning outcome for the course. However, the revised project was significantly expanded on the original by adding a new outcome. In addition to diagramming the system, the revised project requires students to use the design thinking process to develop a web prototype of the system. A detailed description of the revised project is included in the appendix, along with the instructions for the revised project. In addition, the timeline for the project along with a detailed task list is provided in the appendix.

Student Progress through the Design Thinking Process During the Course Project

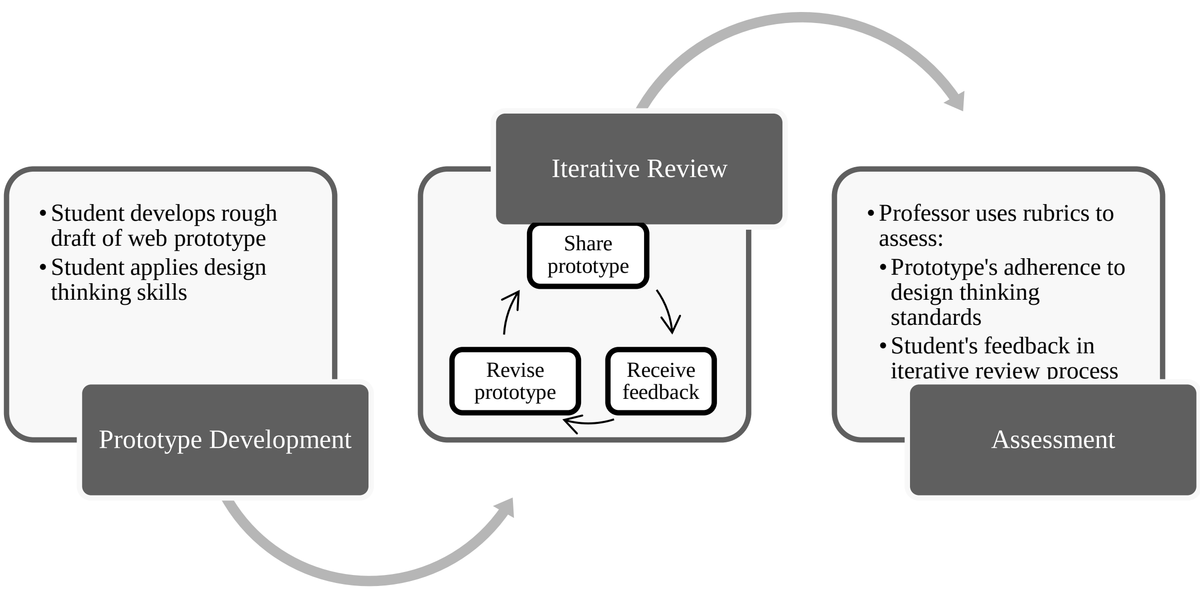
Students prepared for the course project by reading articles on the design thinking process, completing an online learning module on the stages in the design thinking process, and taking an interactive online quiz to test their knowledge of design thinking concepts. After the project kickoff, students engaged in the first three stages of the design thinking process (empathize, define, and ideate) by gathering observations on the system to emphasize with the user, defining the problem to be solved by improving the information system, and by generating ideas on how to solve the problem. The students researched the system in the case using vendor documentation, white papers, and technical articles to gather their observations on the system. Then students documented their observations, the problem definition, and their ideas on how to solve the problem in a project proposal. After writing the project proposal, students entered the fourth stage of the design thinking process: prototyping. The process modeled in Figure 2 was employed for developing, reviewing, and assessing the prototypes.

After developing prototypes, students entered the fifth and final stage of the design thinking process: testing the prototype. The students participated in an iterative review process to test the prototypes and give feedback on them, as modeled in Figure 2. Each student was assigned two classmates and provided feedback on those two classmates' prototypes, to ensure every student received feedback from their peers.

The students provided feedback using the feedback form shown in the appendix in Figure 4. The feedback form was based on the grading rubric for the web prototype as well as the standards of user-centered design, based on the ISO standard 9241-210:2019 (ISO, 2019). As students were evaluating the web prototypes, they were encouraged to refer to the standards for user-centered design as well as reflect on the reading on design thinking which had been previously assigned. The quality of the feedback that students provided to their peers was evaluated using a rubric, which is shown in Table 3 in the Procedure subsection of the Methodology section.

Figure 2

Model for Prototype Development, Iterative Review, and Assessment Process



Choosing a Development Platform for Prototyping

Students used the "Weebly" web development platform for creating the prototype of the system in their case. This platform was chosen based on four criteria which were established to ensure the development environment was appropriate for beginning students and to ensure equity by allowing all students to participate in the prototyping process regardless of income level or type of computer used at home. Weebly was selected as the web development platform because it met all four criteria. The criteria for determining the development platform included:

- Support for browser-based and cloud-based development.
- Free or low-cost pricing.
- Low-code/no-code environment.
- Reputation as a website provider.

While all of the students in the course are upper-division students enrolled in the Information Systems (IS) program, and IS students are required to have access to a computer to complete their coursework, the students' computers may have Windows or Mac OS, so using a browser-based, OS-independent platform was important. If students are unable to purchase a computer due to the cost, the school provides loaner PCs. Students who reside in a low-income household can also receive a free computer through a local non-profit which partners with the school. All students have internet access with reasonable speed and bandwidth, as the school provides hotspots to online students who are unable to come to campus to use the school Wi-Fi. Weebly is a low-bandwidth application and tolerates poor connectivity well. Since it auto-saves while the student is working and automatically reconnects, students will not lose work due to a spotty internet connection.

Prototype Requirements

As a part of the course project, the students were not only required to create a prototype of the system described in their case, they were also required to meet specific requirements to ensure they were applying design thinking standards. The prototype needed to employ the standards of user-centered design, based on the ISO standard 9241-210:2019 (ISO, 2019). There are five standards which are embodied by this standard:

1. The design is based on a clear comprehension of users, tasks, and environments.
2. Both the design and development involve users.
3. User-centered evaluation is employed to revise the design.
4. The design process is iterative.
5. The design addresses the entirety of the user experience.

Prior to embarking on the web prototype of the system, students met the first and fifth sub-standards in the ISO 9241-210 standard by creating a development proposal for the information system. To ensure students had a clear understanding of the users, tasks, and environments for the system, as well as a design that addressed the entirety of the user experience, students created the following artifacts as a part of their proposal:

- A list of the stakeholders and actors for the system.
- A list of the major use cases for the system.
- A diagram of the use case that is most critical to the functioning of the system.

Students met the second, third, and fourth sub-standards in the ISO 9241-210 standard by following an iterative review process. Since the actual users of the information system were not available for the project, students posed as users to test the web prototypes of their fellow classmates and then provide substantial feedback on the web prototypes. The Learning Management System (LMS) was used to facilitate the review process. The student developers followed an iterative process to use this feedback to revise the web prototypes and improve the usability of the web design.

5. Methodology

The course project included applying the design thinking process using prototyping. This project was used in two sections of an undergraduate systems analysis course at a public university in the upper Midwest area of the United States. The two asynchronous online course sections were held over summer semester 2019 and summer semester 2020. The semesters were a standard 15-week length.

Participants

A total of 41 students participated in the two course sections. The students were upper-division undergraduates who were Management Information Systems (MIS) majors. The students were roughly split between those identifying as females and those identifying as males. The university is a Federally designated minority serving institution, serving primarily non-traditional students with an average age of 29 years old.

Procedure

The project was implemented as an individual student project, so each student developed their own prototype. This was not implemented as a team project. However, students collaborated after developing their prototypes to give feedback to each other on the prototypes. After students developed their web prototypes, the students posted the links to their prototypes in the Learning Management System (LMS) to share them with their classmates. Then each student reviewed two of their classmates' prototypes and provided substantial feedback using a worksheet based on the rubric used to grade the prototype. The process modeled in Figure 2 was employed for developing, reviewing, and assessing the prototypes. The students' success in completing the web prototype portion of the project and employing the standards of user-centered design in their prototype was measured using the rubric shown in Table 2. After developing prototypes, students participated in an iterative review process, as modeled in Figure

2. Students' completion of the prototype review process and feedback to their classmates was measured using the rubric shown in Table 3.

In order to measure student performance on the prototyping discrete from other parts of the project, separate rubrics were used to evaluate the prototyping and iterative review process, as shown in Tables 2 and 3. Instead of using a traditional letter grade to evaluate the prototyping portion of the project, students were evaluated on how well their prototype met the standards of user-centered design, demonstrating that they applied the process of design thinking they learned in the course materials.

Table 2

Rubric for Web Prototype

Criterion	Professional Level	Amateur Level	Unsatisfactory Level
	The user interface for the web prototype was appropriate for the system, based on the description of the system given in the project proposal.	The user interface for the web prototype was mostly appropriate for the system, based on the description of the system given in the project proposal. One to two elements were missing or did not fit with the description in the proposal.	The web prototype was not uploaded to the dropbox by the due date or user interface for the web prototype was not appropriate for the system, based on the description of the system given in the project proposal. Multiple elements were missing or did not fit with the description in the proposal.
User-Centered Design	The web prototype employed the standards of user-centered design.	The web prototype mostly employed the standards of user-centered design. One or two elements were not user-friendly.	The link to the web prototype was not posted to the dropbox by the due date or the web prototype did not employ the standards of user-centered design. Multiple elements were not user-friendly.
Link Uploaded Correctly	The link to the web prototype was uploaded to the dropbox by the due date and the link worked correctly to open the website.	The link to the web prototype was uploaded to the dropbox after the due date and the link worked correctly to open the website.	The link to the web prototype was not uploaded to the dropbox by the due date and/or the link did not work correctly to open the website.

The students were graded on the feedback they provided on their classmates' web prototypes using a rubric, as shown in Table 3. This rubric provided an objective assessment of how well the students met the requirement for providing feedback which could be used to improve the prototype.

Table 3

Rubric for Feedback on Web Prototype

Criterion	Sufficient Feedback	Insufficient Feedback
Submitted feedback to the group discussion area prior to the deadline on the course schedule.	Feedback to the group discussion area submitted prior to the deadline.	Feedback to the group discussion area was submitted after the deadline.
Provided meaningful feedback on organization and clarity of points in assignment.	Comments include specific suggestions improving structure and order.	Comments do not include specific suggestions for improving structure and order.
Provided all comments in a positive, encouraging, and constructive manner.	Comments praise specific strengths of the presentation as well as constructively addressing weaknesses with alternatives that might be considered.	Comments might be interpreted as insulting.

6. Results

Students whose prototypes met all five sub-standards scored a level of professional, students whose prototypes met three to four of the sub-standards scored a level of amateur, and students whose prototypes met two to none of the standards scored a level of unsatisfactory. 100% of the students in both sections completed the prototype. As shown in Table 4, across the two sections over 78% of the students scored at the professional level and over 21% scored at the amateur level, meaning the majority of students employed all five standards of user-centered design in their prototypes. This finding indicates that the answer to research questions R1 and R2 is yes, since 100% of the students were able to successfully develop a system prototype, and over 78% of the students were able to successfully apply all five of the sub-standards of user-centered design to their prototype.

Table 4

Student Scores on "User-Centered Design" Criterion in Web Prototype Rubric

Semester	Professional Level	Amateur Level	Unsatisfactory Level	Percent of Students Meeting Professional Level
Summer 2019	12	5	0	70.58%
Summer 2020	21	4	0	84.00%
Total	33	9	0	78.57%

As shown in Table 5, of the nine students who scored amateur and did not meet all five of the design sub-standards, seven of them missed meeting only a single sub-standard, and that was sub-standard 1: "The design is based on a clear comprehension of users, tasks, and environments." The seven students who failed to meet this standard did not design a prototype which incorporated the system users, user tasks, and the system environment that was described in their project proposal. The two remaining students who scored amateur missed meeting two standards, standard 1 and standard 5: "The design addresses the entirety of the user experience." Both of these students created prototypes which failed to incorporate the system users, user tasks, and system environment, as well as did not address the entire user experience. One of these two prototypes failed to address the entire user experience because the web prototype was for an online store, yet it lacked a way for the user to check out and pay for their purchase. The other prototype that failed to address the entire user experience was developed for a manufacturing system, yet the inventory management web page was blank, meaning that users could not monitor the inventory of the raw production materials used to manufacture products.

As shown in Table 5, 100% of the students met the second, third, and fourth sub-standards for the development of the web prototypes. All of the web prototypes met sub-standard 2 by including user needs in the design. All of the student prototypes employed user-centered evaluation to revise the design and employed an iterative design process, as described in standards 3 and 4. Even the nine students that scored an amateur level, and were unsuccessful at meeting all of the user-centered standards, still incorporated the feedback provided by classmates to improve the prototype to some extent between the rough draft and the final draft. For example, the manufacturing system prototype that lacked the inventory page in the final draft had also been lacking other functionality in the rough draft which the student added based on feedback from their classmates. Since 100% of the students were successful at incorporating feedback from classmates on their prototypes, this supports an answer of "yes" to research question R3. Students were able to participate in the iterative prototype review process and provide substantial feedback to their classmates to help them to improve their web prototypes.

Table 5

Number of Students Who Did Not Meet Each of the User-Centered Design Sub-Standards

Semester	Sub-Standard 1	Sub-Standard 2	Sub-Standard 3	Sub-Standard 4	Sub-Standard 5
Summer 2019	5	0	0	0	2
Summer 2020	4	0	0	0	0
Total	9	0	0	0	2

During summer semester 2019, 17 students successfully completed the course. As shown in Table 6, of the 17 students who completed the course, 100% of them completed the web prototype portion of the project. This finding supports an answer of "yes" to research question R1 by demonstrating that students in an asynchronous online undergraduate systems analysis and design course are able to successfully develop a system prototype. Table 6 shows the percent of students who employed the user-centered design sub-standards, which includes students who met the professional level and excludes the students who met the amateur level. No students were at the unsatisfactory level, meaning none of the students met only zero to two of the sub-standards, failed to submit a prototype, or submitted a prototype past the due date listed on the course schedule.

As shown in Table 6, over 70% of students in the 2019 section successfully applied the sub-standards of user-centered design in their prototypes. No students were at the unsatisfactory level. This finding supports an answer of "yes" to research question R2 by demonstrating that the majority of students in an asynchronous online undergraduate systems analysis and design course were able to successfully apply the standards of user-centered design to a system prototype. Of the students who completed the course in the 2019 section, over 94% participated in the iterative prototype review process, and over 88% provided substantial feedback to their classmates to help them to improve their web prototypes, as shown in Table 7. This finding indicated that the answer to research question R3 is “yes” by showing that students in an asynchronous online undergraduate systems analysis and design course were able to participate in the iterative prototype review process to provide substantial feedback to their classmates to help them to improve their web prototypes.

During summer semester 2020, 25 students completed the course. 100% of the students who completed the course successfully completed the web prototype portion of the project, and 84% successfully applied the standards of design thinking to their prototypes, as shown in Table 6. This result provides support for an answer of “yes” for research questions R1 and R2 by demonstrating that students in an asynchronous online undergraduate systems analysis and design course are able to successfully develop a system prototype and to apply the standards of design thinking to the system prototype. Additionally, 100% of the students in the summer 2020 section participated in the iterative prototype review process and provided substantial feedback to their peers during the review process, as shown in Table 7. This finding indicates that the answer to research question R3 is “yes” by showing students in an asynchronous online undergraduate systems analysis and design course were able to participate in the iterative prototype review process to provide substantial feedback to their classmates to help them to improve their web prototypes.

Table 6

Completion of Prototypes which Employed User-Centered Design

Semester	Completed Course	Completed Prototype	Percent Prototype Completion	Employed User-Centered Design	Percent Employed User-Centered Design
Summer 2019	17	17	100%	12	70.58%
Summer 2020	25	25	100%	21	84.00%
Total	42	42	100%	33	77.29%

Table 7

Completion of Iterative Review and Providing Sufficient Feedback

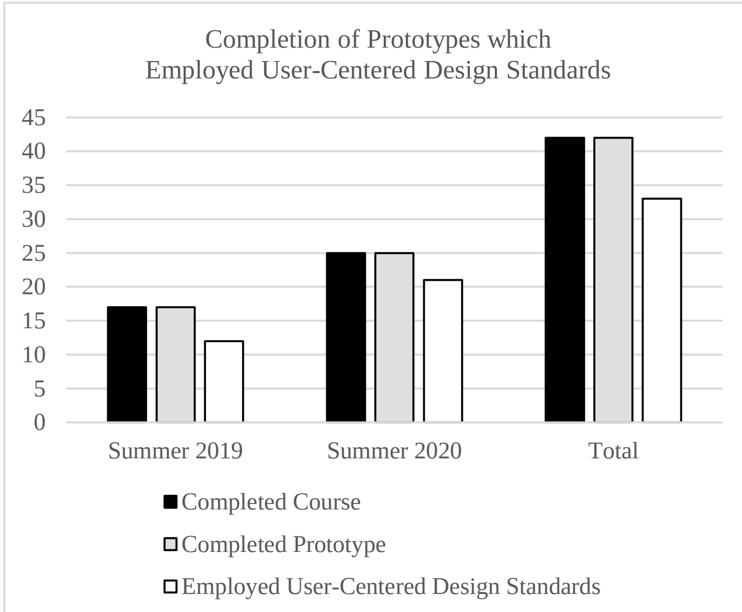
Semester	Completed Course	Completed Iterative Review	Percent Completed Iterative Review	Provided Sufficient Feedback	Percent Provided Sufficient Feedback
Summer 2019	17	16	94.11%	15	88.23%
Summer 2020	25	25	100%	25	100%
Total	42	41	97.06%	40	94.16%

Comparison of Summer Semester 2019 to Summer Semester 2020

Figure 3 compares the number of students who successfully completed the course, completed the prototype, and employed user-centered design standards during summer 2019 and summer 2020. Both course sections began with an initial enrollment of 27 students, but significantly more students completed the course during the summer 2020 semester than the summer 2019 semester. Only 17 students completed the course in 2019 versus 25 students in 2020. Additionally, more students in the 2020 section completed the prototype and employed user-centered design standards. These indicate an answer of “yes” to research question R4 by demonstrating that there were differences in the results for developing prototypes using design thinking between the pre-pandemic and post-pandemic course sections.

Figure 3

Completion of Prototypes which Employed User-Centered Design Standards



7. Discussion

In both sections of the systems analysis course, the majority of students demonstrated that they could employ the design thinking process in their projects. The vast majority of students completed the web prototype and successfully employed the standards of user-centered design in their prototype. The findings of this study demonstrate that the answers to research questions R1 and R2 are both yes, since students in the asynchronous online undergraduate systems analysis and design course were able to successfully develop a system prototype and to successfully apply the standards of design thinking to the system prototype. This is an extremely encouraging finding because it shows prototyping is a viable approach to applying the design thinking process in an asynchronous online course, despite the literature showing that face-to-face interaction between the user and the designer is required for the prototyping stage of the design thinking process.

In addition, all of the students in the 2020 section and all but one of the students in the 2019 section successfully performed as users during the iterative review process to provide substantial feedback to their peers on their prototypes. This finding shows that the answer to research question R3 is yes, since the vast majority of students in the asynchronous online undergraduate systems analysis and design course were able to participate in the iterative prototype review process to provide substantial feedback to their classmates to help them to improve their web prototypes. This is also an exceptionally encouraging finding, since most research on design thinking emphasizes that developers and users must physically work together during the prototyping stage of the design thinking process (Turk et al., 2002; Williams, 2012). Since the students in this online course could not even synchronously work together, much less physically work together, this finding provides great optimism that remote student teams can be successful in using an iterative approach for developing prototypes. Additionally, the students' high level of performance on providing substantive feedback and using it to improve their prototypes demonstrated that they gained benefits from the inclusion of the design thinking process into the curriculum, such as learning to refine the solution to the problem they identified.

An unexpected finding in this study was that not only were students able to apply the design thinking process through prototyping in an asynchronous online environment, the students in the 2020 section actually performed better at this task, despite the stressors wrought over the summer of 2020 by the COVID-19 pandemic and the civil unrest following George Floyd's murder in Minneapolis, MN, where the University is located (Hughes, 2020; Parks, 2020). This finding demonstrates that the answer to research question R4 is yes, since there were differences in the results for developing prototypes using design thinking between the pre-pandemic and post-pandemic course sections. This is thought-provoking because it seems counter-intuitive that students would be more successful at applying a challenging concept such as design thinking during a semester with extreme stressors outside the classroom. The students' high level of performance is especially surprising since a study by the American College

Health Association found college students were significantly stressed due to the COVID-19 pandemic in May 2020 when the summer semester started (The Healthy Minds Network and the American College Health Association, 2020). The same professor taught both sections using the same project instructions, course materials, and mode of delivery, so it is unknown why the summer 2020 cohort performed better at applying the concepts of design thinking through prototyping than the summer 2019 cohort. Although the systems analysis course which was the subject of this study is always taught in an online format, prior to the pandemic, students in the program could choose to register for face-to-face sections for several of the other courses in their major. Perhaps the students had more comfort in the online environment during 2020, because all of their courses were in an online format and their skills in the online learning environment improved as a result.

The results of this research demonstrate that faculty can confidently use the design thinking process, including the practice of prototyping, in asynchronous online courses to teach students design thinking skills. The wider implication is that providing evidence of student success in prototyping and the design thinking process will encourage faculty to implement these high-demand skills, thereby closing the skills gap. Since companies which employ the design thinking process increase revenue and shareholder returns at almost double the rate of their industry peers, closing the skills gap for design thinking will have a positive impact on the growth of organizations (Dalrymple et al., 2020; Sheppard et al., 2018).

Limitations and Further Research

A key limitation of this study was the sample size of 41 students. Since the study was designed to minimize course delivery variables by using the same course and professor, the population was limited to two course sections. Another limitation was student data prior to revising the course project was not available due to faculty turnover in the University, limiting comparison between the previous course project and revised course project in terms of student performance. This research will be continued with future sections to create a lengthier longitudinal study, providing a longer-term set of results as well as a larger sample size. An additional limitation of this study was the presence of the pandemic during the second section of the course, which may have inadvertently impacted student results due to the wide-ranging social effects of COVID-19. Further research is needed to show how students perform at using prototyping as a part of the design thinking process after the pandemic wanes. A limitation was created by the way in which the University scheduled this course, as the course is routinely scheduled in an asynchronous online format, so there is no data from a face-to-face section of the course to use as a comparison.

Further research is needed to compare the success of students in the asynchronous online course with students in other course formats, such as synchronous online courses with web-based class sessions and face-to-face course sessions. In addition, future research could be done on students' perceptions of using prototyping by incorporating an individual reflection on the design thinking process or by conducting class evaluations.

8. Conclusion

As the design thinking process and the accompanying practice of prototyping have become more commonplace in business, universities are slow at implementing these concepts in courses to prepare students for the workplace (Lande & Leifer, 2009; Sarooghi et al., 2019). This study demonstrates that students in an online asynchronous course can successfully apply the design thinking process, including prototyping. This finding is exceptionally promising since it shows prototyping is a viable approach to applying the design thinking process in an asynchronous online course. Additionally, this study establishes that students in an asynchronous online course can successfully complete an iterative review to provide feedback to their peers on their prototypes, despite never sharing a classroom with their peers. This finding is extremely encouraging, since the predominant view is that the iterative portion of the design thinking process must involve face-to-face communication (Turk et al., 2002; Williams, 2012). This study demonstrates that faculty can feel confident employing the design thinking process, including the practice of prototyping, in asynchronous online courses to teach their students the valuable 21st century skill of design thinking. The broader impact is that providing evidence of student success in prototyping and design thinking will inspire faculty to employ these two high-demand skills, thereby closing the skills gap and helping companies utilize design thinking to dramatically increase revenue and shareholder returns.

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10. Appendix

Original Project Instructions

Part 1: Develop an Entity Relationship Diagram (ERD) to depict the key data entities relevant to the system you have chosen. You should reverse engineer the tables and relationships for the ERD using the data-entry screens in the system. Write two to three paragraphs describing why the entities you depicted in your ERD are the most important entities for this system.

Part 2: Create a use case diagram for your chosen system. Write a paragraph describing the use case diagram.

Part 3: Create a Swimlane diagram to depict the activities, conditions and overall flow of the system you have chosen.

Part 4: Develop one additional requirements model of your choice to depict a process in the system you have chosen. You can choose from the following types of models: State Machine diagram, Data Flow Diagram (DFD), or Sequence diagram. For each model, write a paragraph describing the system process depicted by the model. In addition, for each model, write a paragraph describing why you chose this particular model.

Part 5: Write an executive summary of 1-2 pages that will introduce your models and summarize the case you chose that describes the system.

Original Project Rubric

The project will be graded on a scale of 0% to 100% based on an evaluation of the following criteria:

- Completeness – Was the project complete and did it meet the requirements described in the project instructions? Were the requirements models logically consistent with each other? Were assumptions and questions stated for each model?
- Precision – Was the project document presented clearly? Were the diagrams clear and easy to understand? Were the supporting descriptions for the models written clearly?
- Promptness - Was the project submitted on time?

Modified Project Instructions

Project Overview

- The aim of the project is to allow you to plan a system and then develop a web-based prototype for the system which can be added to your portfolio. Each student will develop a web prototype that can be added to the student's independent portfolio.

Project Proposal

- You are a consultant for TekMaxim Solutions. You are trying to secure a six-figure contract to build the systems solution that is described in the case. Your task is to create a project proposal and prototype for the new system that is so stellar that the company will hire you to build the system.

Structure of Proposal

1. Executive Summary
   - Describe the purpose of your system and the audience for your system. Imagine you are writing for top management, such as the CEO of your company. Be persuasive as to why this system is a worthwhile endeavor for your company to undertake.
2. Description of Users and Development Approach
   - Make a list of the users of the system.
   - Who will be using the system once it is implemented? Are all of the users described in the case? Are there potential users who are not mentioned in the case?
   - Recommend a development approach for the project, either using the traditional SDLC or an Agile methodology.
   - Justify why the approach you chose is optimal for this systems project.
3. System Requirements
   - Define the requirements for the system. What (in detail) do we need the system to do? Describe both the functional requirements for the system and the non-functional requirements (technical, performance, usability, reliability, and security requirements).
4. Budget and Cost-Benefits Analysis
   - Create a detailed budget for the project.
   - Use the budget to perform a cost-benefits analysis for the project. Calculate the Net Present Value (NPV) of the project as a part of your cost-benefits analysis.
5. Work Breakdown Structure (WBS)
   - Develop a detailed Work Breakdown Structure (WBS). Each task should be assigned a deadline.
   - Format your WBS like the one depicted in the textbook.

Modified Project Rubrics

The modified project rubrics were shown earlier in Tables 1 and 2. The rubrics were used to evaluate the prototyping and iterative review process, as shown in Table 1 and 2.

Feedback Form for Web Prototype

The feedback form that students used to evaluate their classmates' prototypes is shown in Figure 4 below.

Figure 4

Feedback Form for Web Prototype

Name of Reviewer: ___________________ Classmate Being Reviewed: _________________

Instructions:

1. Review your classmate's web prototype.
2. Answer the questions below to give written feedback to your classmate.
3. After answering the questions, circle the appropriate level for each criterion in the rubric. To circle the criterion in Word, click on the Insert tab, click on Shapes, and choose a circle, then select the circle and choose "no fill".
4. Upload the completed feedback form to share it with your classmate by the due date on the course schedule.

Background:

We will be using five standards of user-centered design to evaluate the web prototypes. These standards are a part of the broader of the ISO standard 9241-210:2019 "Ergonomics of human-system interaction — Part 210: Human-centered design for interactive systems".

Here are the five standards:

1. The design is based on a clear comprehension of users, tasks, and environments.
2. Both the design and development involve users.
3. User-centered evaluation is employed to revise the design.
4. The design process is iterative.
5. The design addresses the entirety of the user experience.

The questions below will prompt you to compare your classmate's web prototype to these standards. Please also refer to the previous reading on design thinking that was assigned. The links to the assigned articles are listed on the course schedule.

Questions:

1. Compare your classmate's web prototype to the project proposal that they previously uploaded. Does the web prototype address the needs of the system users that are described in the project proposal? Why or why not?
2. Does the web prototype allow the user to perform the tasks that are described in the project proposal? Why or why not? Which tasks (if any) are not supported by the prototype?
3. Does the prototype match the system environment that is described in the project proposal? What needs to be changed to make the prototype better fit with the system environment described in the proposal?
4. Are any of the design elements of the web prototype not user-friendly? (Refer to the articles that were previously assigned for reading on design thinking for examples of user-friendly design.) How can the design be improved to be more user-friendly?
5. Does the design of the prototype address the entirety of the user experience, as described in the proposal? If not, what can be changed to make sure the user's experience is better met by the web prototype of the system?

Rubric for Feedback:

Criterion	**Professional Level**	**Amateur Level**	**Unsatisfactory Level**
Web Prototype User Interface	The user interface for the web prototype was appropriate for the system, based on the description of the system given in the project proposal.	The user interface for the web prototype was mostly appropriate for the system, based on the description of the system given in the project proposal. One to two elements were missing or did not fit with the description in the proposal.	The web prototype was not uploaded to the dropbox by the due date or user interface for the web prototype was not appropriate for the system, based on the description of the system given in the project proposal. Multiple elements were missing or did not fit with the description in the proposal.
User-Centered Design	The web prototype employed the standards of user-centered design.	The web prototype mostly employed the standards of user-centered design. One or two elements were not user-friendly.	The link to the web prototype was not posted to the dropbox by the due date or the web prototype did not employ the standards of user-centered design. Multiple elements were not user-friendly.

Project Timeline

The course is structured as a 15-week course with 14 modules. The project is initiated during the second module and concludes in the fourteenth module, as shown in Table 8, so it spans around twelve weeks of the course. There may be a week of vacation (for 4th of July, spring break, or fall break) during the project, depending on the school calendar, which changes from year to year.

Table 8
Project Timeline

Module	Project Tasks
2	Project Kick-Off: Students choose the case for their project.
3	Students begin creating project proposal based on their case.
4	Students upload rough draft of project proposal to LMS.
5	Each student reviews a classmate's proposal and uses the Track Changes feature in Word to add feedback to the proposal. The student uploads the revised proposal containing feedback to the LMS.
6	Students use the feedback from their classmates to revise their proposals and submit the final draft.
7	Students begin working on the system diagrams for the system described in the case they chose for their project.
8	Students upload the rough draft of their system diagrams.
9	Students add feedback to their classmates' diagrams using Visio and upload the diagrams to the LMS.
10	Students revise the diagrams using the feedback from classmates and upload the final version to the LMS, then they begin working on the rough draft of the web prototype.
11	Students upload the link to the rough draft of the web prototype.
12	Students review their classmates web prototypes using the feedback form.
13	Students use the feedback to revise their web prototypes and upload the link to the final version to the LMS. Then they record a video presentation of the project.
14	Students upload the video of the project presentation and provide feedback to at least two other classmates on their presentations.

Author Biography

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