A Conceptual Model for Educating Design Thinking Dispositions

Nguyen Hoang Thuan
The Business School, RMIT University, Ho Chi Minh city, Vietnam
OCID: 0000-0002-6241-8205
Email: Thuan.NguyenHoang@rmit.edu.vn

Pedro Antunes
Department of Informatics, Faculty of Sciences, University of Lisbon, Lisbon, Portugal
OCID: 0000-0002-5411-8798
Email: padantunes@fc.ul.pt

Abstract
Design thinking dispositions are essential for students to understand why design thinking knowledge should be applied to perform specific tasks. However, few studies are focused on teaching design thinking dispositions. This study proposes a conceptual model that supports teaching design thinking dispositions to address this gap. The model was instantiated in an undergraduate course. Students' reflections about the course were collected to evaluate the model. The use of the model is also demonstrated by considering different teaching scenarios. This study contributes to better teaching and learning design thinking dispositions based on a unique model that helps educators organize their design thinking courses. The study also derives some implications for educators. While teaching design thinking knowledge and skills is essential, developing students' design thinking dispositions is equally essential.

Keywords: Design Thinking, Design Thinking Dispositions, Teaching Design Thinking Dispositions.

Paper type: Research paper

Thuan, N., and Antunes, P. 2024. "A Conceptual Model for Educating Design Thinking Dispositions." International Journal of Technology and Design Education. ISSN: 1573-1804. DOI: https://doi.org/10.1007/s10798-024-09881-x.

1 Introduction

It has been widely recognized that the design concept extends beyond professional-design domains (e.g., industrial, interior, and architectural design) towards other professions such as engineering, law, and management (Brenner and Uebernickel, 2016; Johansson-Sköldberg et al., 2013; Kimbell, 2011; Pande and Bharathi, 2020). In management, the design concept is often associated with innovations in organization, services, technology support, and customer orientation, developed by managers rather than brought by expert designers (Verganti et al., 2021). This managerial adoption of the design concept, where management practitioners apply design principles, methods, and practices, is often coined "design thinking"[1] (e.g., Brenner et al., 2016; Dorst, 2011; Panke, 2019). In this study, we adopt this particular contextualization of design thinking.

As design thinking gained significant interest and popularity, it became an essential subject in business schools (Dunne and Martin, 2006; Glen et al., 2015; Pande and Bharathi, 2020). For instance, case studies from the influential firm IDEO have become the centerpiece of classes and courses on design thinking (Verganti et al., 2021). Institutions like the d.School at Stanford University and the University of St. Gallen have been conducting design thinking teaching for many years (Brenner et al., 2016). Essentially, there has been a significant focus on how to make a pedagogical sense of design thinking and educating design thinking competencies (Beligatamulla et al., 2019).

We adopt the competency construct from IS2020, the competency model for undergraduate programs in the information systems (The Joint ACM/AIS IS2020 Task Force, 2021). IS2020 defines competency as knowledge plus skills and dispositions in a task situation. The current study focuses on dispositions because "disposition is that affective component which puts skill and knowledge into correct action in a specific context" (Frezza et al., 2020). Dispositions provide know-why, which complements know-what and know-how (Garud, 1997). Dispositions also feed the know-yourself, i.e., the personal journey that brings an individual to undertake a specific task in a certain way (Billett, 2009; Frezza et al., 2020). Adopting this viewpoint, we characterize design thinking competency as combining design thinking knowledge, skills, and dispositions in addressing managerial goals.

There is already extensive literature addressing design thinking knowledge, considering a variety of topics such as creativity (Dorst and Cross, 2001), abductive thinking (Dorst, 2010), STEM activities (Hsiao et al., 2023; Öztürk and Korkut, 2023), framing (Antunes et al., 2014; Dorst, 2011; Schön, 1983), modes (Lattemann et al., 2020), and evaluation (So, 2019), to mention a few. There is also an increasing body of knowledge addressing design thinking skills. For instance, the literature highlights need-finding (Patnaik and Becker, 1999), empathizing (Vignoli et al., 2023), brainstorming (Glen et al., 2015), idea-

[1] It should be noted that others characterize "design thinking" as a process that starts with problem definition and goes through need finding, ideation, prototyping, and testing (e.g., Brown, 2008). Johansson-Sköldberg et al. (2013) suggest using the term "designerly thinking" to characterize management practitioners' use of design principles and methods. Nevertheless, "design thinking" has gained more traction in research and practice.

testing (Panke, 2019), problem-solving (Cross, 2004), representation (Dorst, 2010), prototyping, and co-design skills (Sanders and Stappers, 2014), to mention a few. However, the literature on design thinking dispositions is much scarcer. In particular, few studies discuss building design thinking dispositions from a teacher's perspective, where a vision and appropriate educational experiences must be created and refined to allow students to understand why design thinking knowledge and skills should be applied to perform well in a specific task (Koh et al., 2015).

This study discusses how to organize learning experiences that effectively cultivate design thinking dispositions. We develop a conceptual model for educating design thinking dispositions, which is evaluated in a design thinking course. The study contributes to a better understanding of building design thinking dispositions in higher education.

The paper is organized as follows. Section 2 provides a background of the research. Then, the chosen research methodology is justified and detailed. Section 4 develops a model for teaching design thinking dispositions. Section 5 presents the model evaluation. Subsequently, Section 6 discusses how the model can be applied through three educational scenarios. The final section presents some concluding remarks.

2 Background

2.1 Teaching competencies and the relevance of dispositions

Competency-based learning has been a successful pedagogical approach (Billett, 2009). It focuses on the learners' acquisition of knowledge, skills, and dispositions rather than getting credits. Furthermore, competency has also been used as a measure of success in learning (Raj et al., 2021), where learners demonstrate they have mastered specific knowledge and skills and the disposition to perform well in their career (Raj et al., 2021).

An essential aspect of professional education is the capacity to encourage, guide, assess, and certify that a student gained a set of competencies, which should naturally include dispositions. The expectation is both retrospective and predictive: the expectation is that students would have accrued a particular behavior by performing in a specific context and are expected to repeatedly and consistently exhibit the same performance across similar contexts in the future (Duplass and Cruz, 2010).

Arguably, dispositions are essential for good professional practice, as they reflect the professional milieu, which complements technical knowledge and skills (Frezza et al., 2020). A wide range of managerial dispositions have been discussed in the literature, e.g., critical thinking, time management, collaboration, entrepreneurship, and leadership (Duan et al., 2022; Dwyer et al., 2017, 2017; Shet and Pereira, 2021). More general dispositions like creativity and communication are often considered soft skills (Glen et al., 2015).

The relationships between developing professional competency and cultivating dispositions have been a significant concern in educational research (Dwyer et al., 2017). Curriculum designs, educational

resources, learning journeys, and case studies can increase students' chances to develop curiosity, enthusiasm, and confidence with specific dispositions (Dwyer et al., 2017). In particular, defined tasks can encapsulate the goals and means by which students experience and reflect on dispositions (Lehrer, 2009). Working end-to-end on realistic tasks, recognizing problems, exploring solution opportunities, and building and evaluating solutions creates an adequate backdrop for cultivating dispositions (Lynch et al., 2021; Novak and Mulvey, 2021; Termeer and Dewulf, 2019).

2.2 Teaching design thinking

There has been a rising call to teach design thinking to students in higher education (Goldkuhl et al., 2017; Keskin and Romme, 2020; Lynch et al., 2021). Recent research indicates that design thinking enables students to gain experience with complex and wicked organizational problems, which demand creativity, value creation, innovation, trial-and-error, and design-driven approaches (Leavy, 2010; Lynch et al., 2021). Other research highlights the potential of design thinking in project-based learning, where students work on end-to-end solutions to defined problems, identifying wicked problems, exploring solution opportunities, and building and evaluating solution propositions and prototypes (Lynch et al., 2021; Novak and Mulvey, 2021; Termeer and Dewulf, 2019). At a more philosophical level, design thinking allows professionals to deal with problems that challenge the traditional view of knowledge as objective and verified truth, offering a constructivist framework that accommodates unique, creative, spontaneous, and ambiguous problem-solving processes (Cross, 2001; Koh et al., 2015; Pande and Bharathi, 2020).

Design thinking has been widely taught in business schools (Foster, 2021; Lynch et al., 2021; Novak and Mulvey, 2021). Lynch et al. (2021) examined students' reflections on a learning process that combined technology and entrepreneurship and found that "the students highlighted their development of knowledge and skill as an important part of the experience" (p. 9). Similarly, Novak and Mulvey (2021) analyzed data from an online course that applied design thinking and reported "higher levels of design thinking skills" (p. 87). Foster (2021) recommended teaching design thinking in business schools to develop students' "creative thinking and critical thinking skills" (p. 129). These studies have shown that design thinking has enhanced students' knowledge and skills.

2.3 Teaching design thinking dispositions

Since competency-based learning includes knowledge, skills, and dispositions (The Joint ACM/AIS IS2020 Task Force, 2021), we expected to find consolidated knowledge on how educators can organize learning experiences that encourage, guide, and assess design thinking dispositions. However, not much research has been conducted regarding this topic. Prior research has mainly focused on knowledge and skills (Foster, 2021; Lynch et al., 2021). Such a gap may frustrate educators who want to focus on dispositions. Design thinking dispositions concern a particular subset of managerial competencies. As

noted in the introduction, dispositions articulate know-why. They have a cognitive nature, which reveals perspective, empathy, intentionality, self-awareness, and autonomy (Frezza et al., 2020; Raj et al., 2021). This cognitive nature is expected to be exhibited frequently as an attitude, tendency, or habit of mind (Thornton, 2006). Dispositions also have a meta-knowledge dimension, revealing knowledge about developing capacities to use knowledge effectively and strategically (Billett, 2009).

Research has suggested generic approaches toward cultivating design thinking dispositions. For instance, the design studio method, which is common in the education of design professionals, can promote design thinking dispositions (Koh et al., 2015). However, the design studio's focus on tacit knowledge, techniques, and instruments makes it difficult to apply the approach to management, which requires a larger, systemic thinking (Meyer and Norman, 2020). Considering these research gaps, we develop a model for teaching design thinking dispositions, which helps to organize learning experiences that effectively cultivate dispositions. Such a model is further important if we consider design thinking dispositions as "one of the main focuses for improving students' 21st century competencies" (Tsai and Wang, 2021).

3 Research methodology

The current research adopts the design science method (Hevner et al., 2004), which has been increasingly applied in education for developing educational artifacts (Hevner and vom Brocke, 2023; Thuan et al., 2023). It does so by addressing real-life education problems, similar to the research problem being addressed in the current study. Further, design science balances two research goals (Baskerville et al., 2018). On the one hand, it contributes innovative artifacts that resolve identified problems. On the other hand, it generates knowledge contributions related to artifact construction and evaluation. This balancing act is strongly aligned with the objectives of the current study: 1) propose a model addressing a real-life education problem, and 2) contribute knowledge in the field of design thinking dispositions.

Adopting the design science method, our research is divided into two main activities: build and evaluate (Hevner et al., 2004). The building activity seeks to create an innovative model for teaching and learning design thinking dispositions. The build activity is detailed in Section 4. The evaluation activity assesses how the model supports learning design thinking dispositions. We evaluate the model by implementing it in a course and collecting students' reflections on the learning experience. An open-ended survey is used for data collection. The evaluation activity is detailed in Section 5.

4 Building the Model

4.1 Knowledge sets used to build the model

We build the model based on two knowledge sets (Table 1). The first set comprises foundational studies on design thinking, which provide background and insights into the topic. The second set considers literature searches for design thinking dispositions and related concepts in Google Scholar (in 2023).

Table 1 – Foundational studies and literature searches on design thinking dispositions

Knowledge sets	References and notes
Foundational studies	
Foundational studies on design thinking	(Brown, 2008; Buchanan, 1992; Dorst, 2011, 2010; Kimbell, 2012; Owen, 2007)
Literature searches	
"Design thinking" AND "Dispositions"	(Koh et al., 2015; Michlewski, 2008; Royalty et al., 2019; Vanada, 2013)
"Design thinking" AND "Wisdom"	(Denning, 2013; Koh et al., 2015)
"Design thinking" AND ("Confidence" OR "Motivation")	(Jobst et al., 2012)
"Design thinking" AND "Know why"	Most identified papers focus on knowledge and skills. For instance, Lin et al. (2020) develop a design thinking framework for an IT course that considers three main skills: inspiration, ideation, and implementation. Nevertheless, a small number of papers discuss dispositions (Dym et al., 2005; Haskamp et al., 2020; Huq and Gilbert, 2017).
"Design thinking" AND "Mindset"	(Brenner et al., 2016; Dosi et al., 2018; Groeger and Schweitzer, 2020; Howard et al., 2015; Lattemann et al., 2020; Panke, 2019; Schweitzer et al., 2016; Sobel et al., 2019; Vignoli et al., 2023)
"Design thinking" AND "Culture"	No selected papers, as most references concern corporate culture (e.g., Dong, 2015) while the current study is focused on individual learners.
"Design thinking" AND "Analysis of factors"	No selected papers, as most references focus on organizational drivers and enablers of design thinking, such as organizational strategy and work environment (Badding et al., 2014).
"Design thinking" AND "Self-efficacy"	No selected papers, as most references focus on skills rather than dispositions (e.g., Ohly et al., 2017; Sadler et al., 2016; Tsai and Wang, 2021).

We used keywords search to identify articles related to design thinking dispositions. The research query consisted of "design thinking" and keywords related to dispositions (e.g. dispositions, know why, wisdom, confidence…). We note that the search related to the design thinking mindset emerged as particularly relevant to this research. Mindset theory has been developed in the field of psychology, it seeks to explain how people take certain courses of action for tasks that are to be solved by activating mental frameworks (mindsets), which can be characterized by a set of principles (Gollwitzer, 2012; Hastings and Schwarz, 2022). The construct can be expressed as [mindset] *is explained by* [principles]. The educational field discusses a different construct. It discusses how educators can encourage and cultivate a set of dispositions to produce a certain mindset (Duplass and Cruz, 2010). The construct can be expressed as [dispositions] *produce* [mindset]. Taking the two constructs together suggests that

design thinking principles can be aligned with design thinking dispositions, as dispositions contribute to acquiring principles.

4.2 Identification of design thinking dispositions

We reviewed the two knowledge sets to identify design thinking dispositions. Table 2 synthesizes the design thinking dispositions identified in the selected literature. Besides integrating a set of name variations, the selection is parsimonious, combining several concepts that could be further organized into classes and subclasses (e.g., problem reframing could be defined as a subclass of critical questioning). All identified dispositions have significant support in the literature (albeit the name variations).

Table 2 – Design thinking dispositions identified in the related literature

Dispositions (including name variations and sub-topics)	**Key references**	**Definition**
Empathy with users (user-centeredness, human-centeredness)	(Brown, 2008; Lahiri et al., 2021; Schweitzer et al., 2016)	Taking a people-first approach to design, imagining solutions that are inherently desirable. Recognizing human behaviors, needs, values, and contexts
Critical questioning (critical thinking, searching and tackling paradoxes, problem reframing, openness, inquisitiveness)	(Brown, 2008; Buchanan, 1992; Carlgren et al., 2016; Dorst, 2011; Lahiri et al., 2021; Schweitzer et al., 2016; Vignoli et al., 2023)	Positioning and repositioning problems and issues. Dealing with conflicting statements, which cannot be combined. Transforming problems and issues in working hypotheses. Exploring constraints in creative ways. Ability to question everything
Resilience in problem solving (optimism, tolerance for ambiguity, tolerance for risk)	(Brown, 2008; Carlgren et al., 2016; Fraser, 2011; Micheli et al., 2019; Vignoli et al., 2023)	An understanding that things will not always go right, keeping a positive attitude, and being able to correct things as and when required. Feel confident with complex problems and accept ambiguity
Integrative thinking (holistic view, social-reality view, consolidating multidimensional meanings)	(Brown, 2008; Buchanan, 1992; Michlewski, 2008)	Ability to look at a situation from a wide variety of perspectives, seeing all of salient aspects, and consolidating and reconciling contradicting objectives. Understanding that problems are wicked, and the subject matter is potentially universal in scope
Attentiveness to practice (mindfulness, mindful of process and thinking modes)	(Fraser, 2011; Kimbell, 2012; Schweitzer et al., 2016; Vignoli et al., 2023)	Awareness of the process of design. Consideration for the situatedness, contextualization and contingencies involved in the design practice. In the design process, everything is important

Pursuit of novelty and progress (creativity, creative agency, creative confidence, openness, abductive way of thinking, consciously creative)	(Carlgren et al., 2016; Dorst, 2010; Fraser, 2011; Kimbell, 2023; Lahiri et al., 2021; Royalty et al., 2019; Schweitzer et al., 2016)	Sustained effort to create, exploring many ways to get to a solution instead of being limited to a single solution. Being open to different perspectives, thinking in a different manner, support new ideas, and challenging conventional processes and styles
Orientation towards action (action orientation, experimentalism, experiential intelligence)	(Carlgren et al., 2016; Fraser, 2011; Schweitzer et al., 2016; Sobel et al., 2019; Vignoli et al., 2023)	Preferring action over discussion and conceptual or analytical behaviors
Enthusiastic collaboration (teamwork, be collaborative, collaboration in diverse teams, collaboratively geared, democratic spirit)	(Brown, 2008; Carlgren et al., 2016; Lahiri et al., 2021; Sobel et al., 2019; Vignoli et al., 2023)	Work alongside with others. The adoption of interdisciplinary collaboration replaces individual creativity

4.3 Model's underlying structure

Design thinking dispositions are often presented as a list, as presented in Table 1 (Brown, 2008; Groeger and Schweitzer, 2020; Vignoli et al., 2023). The list presentation is useful to raise attention and identify what educators should consider when building educational experiences related to design thinking. However, the list presentation does not provide much guidance, as it lacks structure. Therefore, our next step in building the model was to define an underlying structure on which the design thinking dispositions could be anchored.

From the related literature, we identified three sets of structural concepts. The first set includes three related concepts: problem, process, and solution. These concepts resonate with the well-known input-process-output perspective from the information systems domain (Green et al., 2014). The (design thinking) process takes a problem as input, which captures needs, values, constraints, and other factors that may be considered relevant inputs. The process involves a series of steps, which confer structure to design thinking activities such as ideation and prototyping (Brenner et al., 2016). Finally, the process generates a solution, which captures innovation, impact, and other elements that may be considered relevant outputs.

The second set includes two concepts: users and environment. Arguably, there is no design thinking without a significant focus on the users and the environment. "Great design thinkers observe the world in minute detail" (Brown, 2008). "[D]esigners are perceived as being willing and able to understand and interpret the perspectives of end users and the problems they face" (Kimbell, 2011). The environment provides the situations and "set of scenarios of value creation" (Dorst, 2010).

The third and last set includes one single concept: prototype. Prototypes that can be experienced are essential to experiment, communicate, and validate creative solutions with specific users in particular environments (Brenner et al., 2016; Brown, 2008; Kimbell, 2011; Pande and Bharathi, 2020). As such, even though this set includes one single concept, it links to concepts in the other sets (solution, users, and environment).

Figure 1 (inner circle) shows how the identified concepts are connected to confer structure to the model. The problem links to the process, and the process to the solution, establishing the input-process-output design perspective. The users and environment link to the problem, establishing the design focus. Finally, the solution links to the prototype, which in turn links to the users and environment, thus supporting design communication and validation.

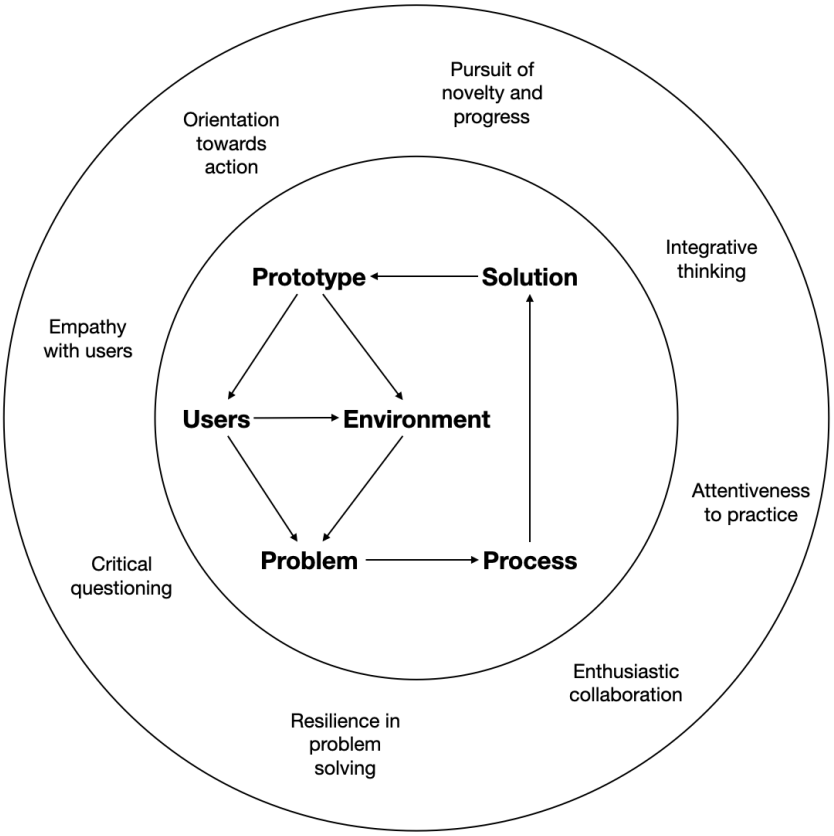


Figure 1. Model for teaching design thinking dispositions

Enter the design thinking dispositions

We regard the design thinking dispositions as a backdrop for the identified structural concepts (Figure 1, outer circle). The dispositions influence how users and operating environments are analyzed, how problems and solutions are framed, the process of articulating problems and solutions, and the role played by prototypes in design. Together, the integration of structural concepts and design thinking dispositions present a model for teaching design thinking dispositions (Figure 1).

We highlight that the model in Figure 1 is not intended to propose a set of constructs describing or explaining the effects of dispositions in design thinking. Instead, it is intended to help educators organize

design thinking projects and tasks. Therefore, with the purpose to accomplish these specific goals, next, we further discuss how to mix and match certain dispositions and structural concepts.

4.4 Mixing and matching dispositions and structural concepts to suit pedagogic purposes

Dispositions can be mixed and matched with structural concepts in different ways to suit specific pedagogic purposes. Based on the above model, we now suggest important anchors mixing and matching dispositions and structural concepts. In particular, educators can promote empathy with users by asking students to carefully identify and analyze users in their specific operating environments. Even though critical questioning concerns the whole design, educators can focus on the problem as an anchor for building critical questioning, e.g., asking students to identify and discuss conflicting viewpoints.

Resilience in problem-solving is a reflection of being comfortable with iterative, fail-fast processes (Dosi et al., 2018). Therefore, educators can propose tasks that require multiple attempts at problem solving. Even though enthusiastic collaboration encompasses the whole design, educators can also focus on the process as an anchor for building enthusiastic collaboration, e.g., through processes that require communication and participation. Still regarding the process, educators can also anchor attentiveness to practice on processes that require significant reflection on the way the process is approached and implemented (Schweitzer et al., 2016). For instance, this can be done by giving options and asking students to reflect on their choices.

Educators can utilize the solution as an anchor for developing integrative thinking. This can be done, for example, by asking students to analyze not only the achievable solutions but also the potential contradictions and omissions in such solutions (Brown, 2008). By asking students to propose inventive solutions, educators can promote the pursuit of novelty and progress.

Finally, educators can anchor orientation towards action onto prototypes. Prototype development offers an action-oriented approach to test solutions and their underlying assumptions (Carlgren et al., 2016).

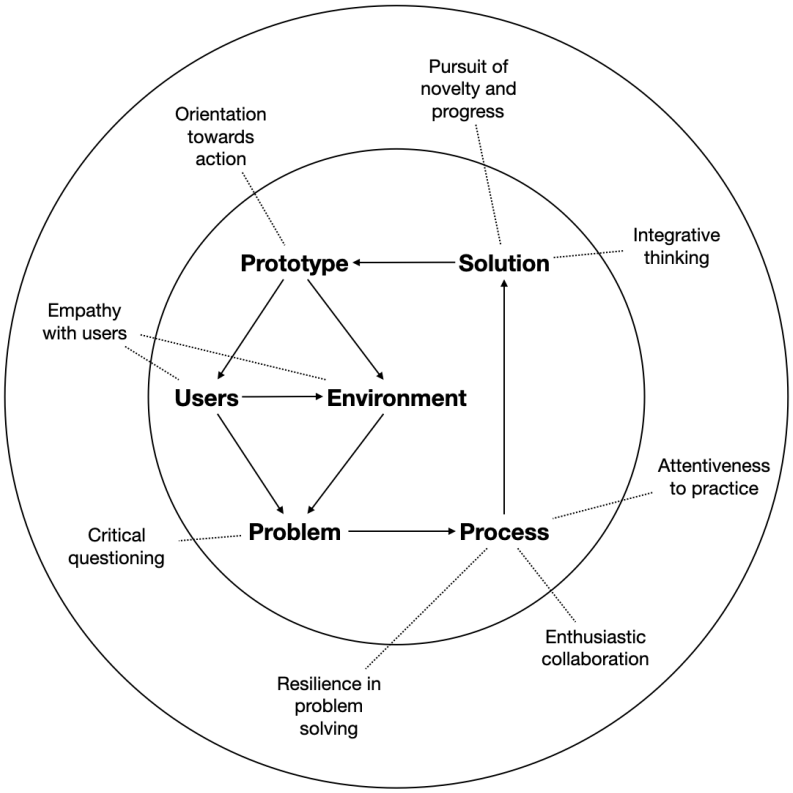


Figure 2. Model with suggested anchors for design thinking dispositions

Figure 2 shows the model with the suggested anchors for design thinking dispositions. Its purpose is to help educators strategize how to build educational experiences that foster design thinking dispositions, giving more directedness to specific requirements and clarifying specific tasks. For instance, using the model with anchors, educators can create an experience that leads student to discover the users and operating environment, followed by an experience that critically questions an initial problem formulation. Next, we discuss the model evaluation.

5 Model Evaluation

The model described above (including anchors) has been instantiated twice in an undergraduate course, in 2022 and 2023. The course has a 12-week structure and teaches students how to apply design thinking for digital start-ups. The course was structured around the structural concepts (inner circle of Figure 1) and related dispositions (outer circle of Figure 1).

In particular, we taught students how to analyze users' problems while taking into account the surrounding environments. Students were free to select the problems they would like to address. With the selected problem, they explored business ideas and digital solutions. The next topics involved prototyping through an iterative process of development and feedback from peers and lecturers. At the end of the course, students consolidated their business idea, prototypes, and digital solutions for class presentation.

The assignments developed for the course asked students to apply design thinking. Students worked in groups of four or five. The assignments required students to accomplish a variety of tasks indirectly promoting design thinking dispositions. One task required students to frame a real-work problem and ideate a business idea (with a constraint, where the business idea had to involve a digital solution). Another task required students to conduct 30-minute interviews with users to understand the problem and empathize with the users. Another task asked students to rapidly prototype a solution using tools like Figma and Visily. In this task, students were encouraged to explore, trial-and-error, learn-by-doing, and reflect on what could work or not work for the users. The final task asked students to present the solution. All tasks had a collaborative nature, where students work and learn from each other.

5.1 Data collection

After the course assignments were completed, data collection took place using an open-ended survey. The questions fostered students to reflect on design thinking dispositions and reveal their personal learning journeys. The adoption of open-ended surveys, rather than interviews, promotes anonymous, open expression of thoughts. Open-ended surveys have been shown to effectively promote students' reflections on learning experiences and have been used in similar studies (Lynch et al., 2021).

The survey was organized according to the dispositions listed in Table 2. It included questions related to: empathy with users, critical questioning, problem solving, integrative thinking, attentiveness to practice, pursuit of novelty, action orientation, and teamwork. It also included additional questions about the learning experience and the likely adoption of design thinking in the future.

The participants were recruited online, after completing the course. The course offerings included 76 students. We announced the open-ended survey link through the course's website. Eighteen respondents voluntarily participated in the evaluation. After removing four respondents who skipped most of the survey, the sample consisted of 14 respondents. The response rate is 18.4%, which is consistent with the common practice of using open-ended surveys: "open-ended questions tended to suffer higher rates of item noncompletion" (Denscombe, 2008, p. 360). Nevertheless, as the participants provide qualitative data, this sample size aligns with Creswell's (2009) recommendation that the qualitative sample size can be between 5 and 25 participants. Table 3 profiles the participants.

Table 3 – Participants' profile

ID	Project assignments	Age	Learning experience
A	Website for designing packaging online	21	1 to 3 semesters
B	Pade is a packaging and logo design platform targeted to small businesses, which helps them use AI to create green, sustainable packages	20	>9 semesters
C	SeekAR - a dating application that uses augmented reality	20	7 to 9 semesters

D	Charidi - an application that provides transparent charity services using blockchain	21	4 to 6 semesters
E	No project description was provided by the student	20	4 to 6 semesters
F	An application dedicated to solving a particular problem in society nowadays	20	4 to 6 semesters
G	No project description was provided by the student	22	>9 semesters
H	An application that helps students look for roommates and soulmates	19	1 to 3 semesters
I	An application similar to a mobile social environment. The application is targeted to university students and alumni	23	>9 semesters
J	MATECH - a highly secure and safe place for fresh-graduate university students and alumni to find compatible roommates	21	7 to 9 semesters
K	Helus - Helps people find helpers	22	1 to 3 semesters
L	An application that uses blockchain to track the origin of products	20	4 to 6 semesters
M	Clothink - An application that allows users to sell second-hand clothes for extra cash	21	7 to 9 semesters
N	An application that helps users easily create daily outfits using AI-generated suggestions	21	7 to 9 semesters

5.2 Data analysis

The collected data were analyzed using structural coding, following the procedure suggested by Saldaña (2015). Structural coding enabled us to compare commonalities and differences between the participants' answers and the model presented in Figure 1 (Saldaña, 2015). The students' descriptions of their know-why and know-themselves were identified, and relevant quotes were extracted. Then, we added codes to these quotes. Finally, the codes were aggregated into higher themes and compared across the participants' answers. This enabled us to find patterns shared by the students.

We checked reliability through triangulation. First, we performed investigator triangulation, where the two researchers independently coded the data. The outcomes were compared and discussed for any differences. Second, we triangulated the outcomes across students' answers, quotes, codes, and emergent themes. Third, data interpretations and findings were cross-checked with the raw data for reliability (Shenton, 2004).

5.3 Results

The results are summarized in Table 4 and Table 5. Table 4 presents the statistics of the model's structural concepts that appeared in the participants' reflections. Overall, the results indicate that all structural concepts (including name variations) have been mentioned multiple times by the participants, which supports their key roles in the proposed model. Four structural concepts (solution, user, prototype,

and problem) were mentioned by more than 10 participants (out of 14), which strongly supports their role in structuring design thinking dispositions. Two concepts (environment and process) have less support. Nevertheless, these concepts are important because they are mentioned by at least five participants. Also, they link to design thinking dispositions reflected by the participants. All structural concepts are further highlighted in the qualitative results presented next.

Table 4 – Statistics of the model's structural concepts

Model's structural concepts (including name variations)	**Appeared in participants' reflections**	
	N=14	**%**
Solution (product, solve, application)	13	93%
User (customer, people)	11	79%
Prototype (prototyping, app on Figma)	10	71%
Problem (struggle, issue)	10	71%
Environment (context, society, real life/scenario)	7	50%
Process (procedure, step)	5	36%

Table 5 presents the list of dispositions identified in the dataset, along with selected quotes from the student's reflections. Overall, the results support the claim that students cultivated the set of design thinking dispositions identified in this study. Regarding the relationships between dispositions and structural elements (Figure 1), we also found some supporting evidence (noted in bold on the selected quotes), where the dispositions link to a structural concept or a group of structural concepts for pedagogic purposes. Next, we discuss the results in more detail.

Table 5 – Students' reflections on design thinking dispositions

Dispositions	**Selected quotes from the open-ended survey**
Empathy with users	"Empathy with [the] **customers**' perspective defines the core problem and leads [our] initiative" "[Helps] **understanding** what we are doing and what **customers** need and want" "**User**-centered design creates intuitive and easy-to-use interfaces and functions" "**User**-centered design is a key standard for building our **prototype**, especially in the process of button placement and content creation"
Critical questioning	"This course has helped me have innovative thinking, which turns **problem** into question. When facing **problems**, resist to come up with a solution straight away. Instead, I've changed my mindset into asking a question, which will help me get closer to the **problem**'s root and contribute to the overall improvement [of the situation]" "I'm curious how quick/how efficient the business would generate profit and how it contributes to the **society** as a whole"

Resilience in problem solving	"It works out the most when issues happen, the design thinking **process** guides us as a 'procedure' to solve the **problems**" "During my time working for Pade, design thinking helped me tackle vague **problems**, […] and disregard unimportant issues and feature prioritization" "[The] 5-step solution [**process**] of problem-solving helps me visualize the **problems** thoroughly and implement the solution effectively"
Integrative thinking	"Design thinking is a work of social technology involving numerous stakeholders in every stage of development from **problem** defining to **solution** brainstorming for changes. My team was motivated by applying [the] design thinking structure into our workflow with collaboration for agreement on the essential outcome at every phase, which breaks the ice between departments and eliminates workplace politics by experience sharing at every step" "Holistic design allows us to define the **target audience** and be in their shoes to understand what their needs are and narrow down or modify the existing features to meet up the demand"
Attentiveness to practice	"The **process** and the value of applying it in practical scenarios" "I find that design thinking can be applied in other aspects of our life in **solving** problems" "Yes, because it was useful and insightful. Yes, because I find it is useful not only to apply in coursework but also in other aspects of life" "By exploring new functions […], our team was able to illustrate our application idea using a **prototype**" "[At] the time we make a **prototype**, it actually works well"
Pursuit of novelty and progress	"To come up with new ideas and bring out the optimal **solution**, to eliminate unnecessary factors that distract the outcome" "How to generate ideas when starting up a business and manage possible risks" "I was able to know how to properly arrange and innovate in a structured manner and develop myself more" "We need to try and research on new ideas to evaluate if it is possible for applying to the whole project"
Orientation towards action	"I was motivated as it is my first time **experimenting** and trying out design thinking in a real scenario" "We **experimented** with the sprint backlog to properly divide and track the progress of our teams. Though struggling in the beginning, we were able to utilize it well" "The BMP ensures our website **flow of features** and **customer journeys** are clear and simplified for the best experience, which also layout the foundation for front-end developing of our web application"
Enthusiastic collaboration	"Working in a team, and each member has their own specified tasks, could make the **process** of planning and solving problems easier" "Team working, pitching, designing, tools, using skills" "We can learn from each other as a team, and understand others' perspectives"

Note: Certain quotes may illustrate multiple design thinking dispositions. In these cases, Table 5 links them with the most relevant dispositions.

Empathy with users

Several students asserted the importance of empathy with users in design thinking (participants B, D, F, H, I, & M). For instance, a student noted, “it is about understanding and empathizing with the target customers” (participant H). They also suggested that empathy is essential for user-centered design. More importantly, students elucidated why empathy is so important, asserting three main reasons. The first reason is that empathy with users helps to define the problem being addressed: “Empathy with [the] customers’ perspective defines the core problem and leads [our] initiative” (participant D). Second, empathy enables innovation: “The innovations have to be user-centric, which means we have to gain insights about what the users really need, and we will develop the innovations based on them” (participant F). Third, empathy guides prototype development. The functionality delivered by the prototype needs to address the user needs: “User-centered design is a key standard for building our prototype, especially in the process of button placement and content creation” (participant B). These reasons led students to perform multiple empathy-inducing activities, both within and outside the class. Some interviewed their peers playing the role of users, while others surveyed real users in their working environments to understand their pain points.

All in all, the students’ reflections highlight the importance and rationale behind this disposition. Further, the results also support the relationship between this disposition and one model element: users. No evidence was found in relation to the environment element. Interestingly, we further found a strong relationship between this disposition and another model element: prototype.

Critical questioning

Another important result was the students’ ease with critical questioning. For instance, one student noticed that “this course has helped me have an innovative thinking, which turns a problem into a question. When facing problems, resist to come up with a solution straight away. Instead, I’ve changed my mindset into asking a question, which will help me get closer to the problem's root and contribute to the overall improvement [of the situation]” (participant F). We further note that critical questioning in design thinking is not only about rational thinking, but it also integrates critical thinking and creativity. Students have done critical questioning in their weekly meetings: “Our weekly meetings also play a role in exploring new ideas and reviewing old ones for clarification and expansion” (participant B).

Besides weekly meetings, students have done other activities related to critical questioning during the course. For instance, when students interviewed users or discussed problems with their peers, they were motivated to ask multiple ‘why’ questions to understand what was at the heart of the problem. One student asserted that they would know more about the problem by asking many questions: “I gain more of this knowledge by doing research and asking many people” (participant F). Consequently, the results support the relationship between this disposition and one model element: the problem. In this relationship, critical questioning is essentially related to problem framing and reframing.

Resilience in problem-solving

Regarding problem-solving, eleven out of fourteen students suggested that design thinking provides them with a problem-solving approach. This is consistent with the existing design thinking literature (Foster, 2021). However, students developed their own personal journeys to problem-solving. For instance, one student reflected on problem-solving as a systematic process: [The] 5-step solution [process] of problem-solving helps me visualize the problems thoroughly and implement the solution effectively" (participant A). Another student emphasized divide-and-conquer: "After this project, I have learned a lot about solving problems while working as a team. We need every time to sit down and specify all the issues we have. Then gradually solving one by one" (participant J). Other students reflected on problem-solving as innovating: "We have to come up with ideas to solve the problems and bring those ideas to real life through innovation" (participant F). These results show that problem-solving has been internalized as an important aspect of design thinking but not as a one-size-fits-all approach.

Regarding the resilience aspect, students asserted they were comfortable with addressing vague problems: "During my time working for Pade, design thinking helped me tackle vague problems, […] disregard unimportant issues, and feature prioritization" (participant A). Further, students expect problems to emerge at different project stages: "It works out the most when issues happen, the design thinking process guides us as a 'procedure' to solve the problems" (participant C). Students also asserted their confidence in addressing a variety of problems: "I find that design thinking can be applied in other aspects of our life in solving problems" (participant D); and "Somehow, somewhat I can address problems comprehensively" (participant L). The results indicate that resilience in problem-solving relates to the problem and process elements of the proposed model.

Integrative thinking

Two patterns related to integrative thinking were identified. First, most students moved from a narrow, essentially vertical (problem-solving) view of design thinking towards a more horizontal, holistic, and integrative view. One student asserted such a holistic view this way: "The innovations have to be user-centric, which means we have to gain insights about what the users really need […]. Then we have to come up with the ideas to solve the problems and bring those ideas to real life through an innovation. We keep developing the innovation by receiving users' feedback and make needed changes" (participant F).

The second pattern emphasizes a social-reality view over problems and solutions. It considers that multiple stakeholders, perspectives, and meanings may be involved in problem-solving: "Design thinking is a work of social technology involving numerous stakeholders in every stage of development from problem defining to solution brainstorming for changes. My team was motivated by applying design thinking structure into our workflow with collaboration for agreement on the essential outcomes

at every phase, breaking the ice between departments and eliminating workplace politics by experience-sharing at every step" (participant B); and "Holistic design allows us to define the target audience and be in their shoes to understand what their needs are and narrow down or modify the existing features to meet up the demand" (participant M).

The results support the relationships between integrative thinking and the problem and solution as in the proposed model. Nevertheless, they highlight that integrative thinking also concerns users/user-centric view.

Attentiveness to practice

The results highlight three aspects in relation to attentiveness to practice. The first aspect links the process to the problem and environment, where students appreciated working on a problem in a real-world, practical environment: "I was motivated as this was my first time experimenting and trying out design thinking in a real scenario" (participant B); and "I want our project to be launched in real life" (participant J).

The second aspect links to the students' future career. Multiple students recognized the potential for applying design thinking in professional work. For instance, when answering the question "Do you consider applying design thinking to other projects in the future?", students asserted: "Yes, in both my work as a startup co-founder and a professional" (participant B); and "Yes, I'm applying now" (participant I).

The final aspect links to the students' everyday life, where students asserted their mindfulness of design thinking. For instance, one student stated that design thinking could be applied for general problem-solving: "I find that design thinking can be applied in other aspects of our life in solving problems" (participant D). Another student noted that design thinking could be applied to enhance work and life: "It's practical in real life. Maybe they can learn how to work effectively and efficiently in a team" (participant J). All in all, students asserted that design thinking supports practical problem-solving, professional work, and everyday life.

The results support the relationship between attentiveness to practice and the process and solution model elements. At the same time, the results also suggest that attentiveness to practice encompasses other elements, in particular problems and prototypes.

Pursuit of novelty and progress

Most students asserted the importance of novelty and creativity in developing solutions. In particular, they emphasized the generation of new ideas: "By thinking new ways to make customers happy with our products"; "To create new ideas and testing whether their application works" (participant E); and "We need to try and research new ideas to evaluate if it is possible to apply [them] to the project" (participant D). Pursuing novelty also plays a vital role in developing innovative solutions: "To come

up with new ideas and bring out the optimal solution, to eliminate unnecessary factors that distract the outcome" (participant D). As a result, the participants asserted their confidence and capabilities for processing novelty and progress: "I was able to know how to properly arrange and innovate in a structured manner and to develop myself more" (participant B). The results support the relationship between the pursuit of novelty and progress and the solution, which is consistent with the proposed model.

Orientation towards action

Orientation towards action was also highlighted by students. This disposition is important when students move from an idea (solution) to a prototype, which serves to illustrate the idea and experiment whether it can be developed or not.

Two students used Figma to prototype their solutions: "By exploring new functions of Figma, our team was able to illustrate our application idea using a prototype" (participant C). Students considered prototyping as one of their main achievements in the course: "One of the most [important] achievements our team has gained was finishing the prototype, even if we had not used Figma before" (participant I). Prototyping motivated students to be action-oriented: "I was motivated as it is my first time experimenting and trying out design thinking in a real scenario" (participant B). Therefore, the results support the relationship between orientation towards action and prototyping.

Enthusiastic collaboration

Most students asserted the importance of enthusiastic collaboration in design thinking. For instance, one student compared and uplifted the importance of teamwork: "This course helps me in not only building a strong soft and professional skills foundation but also building a great team. A good team is even more important than a good business idea" (participant H). Further, students also suggested that they gained teamwork skills: "I gained different skills like teamwork"; "[Now,] I know how to work more effectively with my teammates"; and "Besides the classes, I think our team has improved our teamwork skill" (participants F & I).

As the course assignments asked students to work in teams, we were unsure if this disposition came from design thinking or the course assignments. Having this concern, we further analyzed the students' rationales for enthusiastic collaboration. Some students stated that they could learn from each other during teamwork: "Because we can learn from each other as a team, and understand others' perspectives" (participant D). Others appreciated the collaborative process: "Working as a team, each member had their own specified tasks, which could make the process of planning and solving problems easier" (participant A). Others found collaboration around design thinking as a strong motivator: "It's the first time I have ever got the most motivation while working in the team"; and "Thanks to this course, it helped me to communicate and lead the team better than what I ever done in my life" (participants J & K). Taking these elements together, what we find is a strong interaction between design thinking and

teamwork. Consequently, the results support the relationship between enthusiastic collaboration and the process as in the proposed model.

Overall, our findings are that students developed the identified design thinking dispositions and that these dispositions have some significant links to the proposed model. Therefore, we suggest that the proposed model helps teaching and learning design thinking dispositions. Even though not all links between dispositions and the structural elements of the model were supported by the results, the overall balance goes towards model support, as the missing links can be supported through logical reasoning. For instance, this is the case of the environment element, which was not reported in the results. The results also identified one possible additional link between attentiveness to practice and users.

6 Scenarios for teaching design thinking dispositions

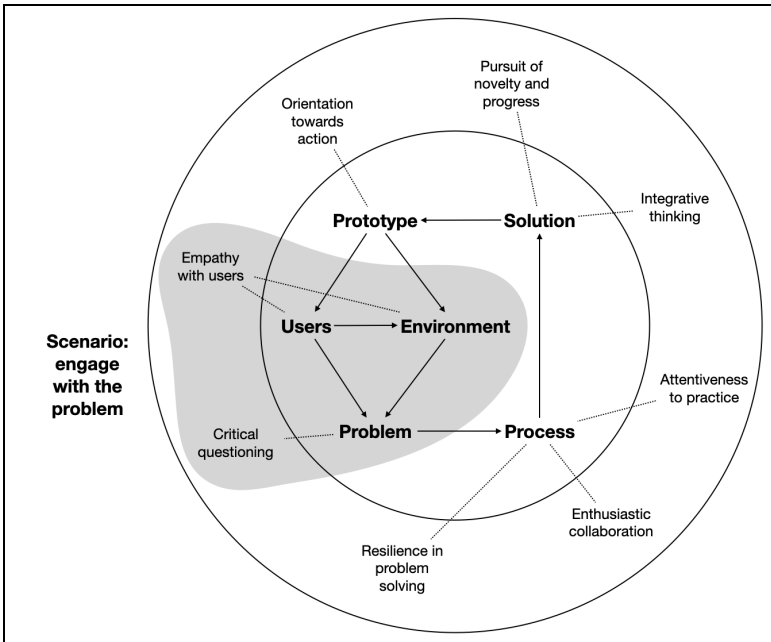
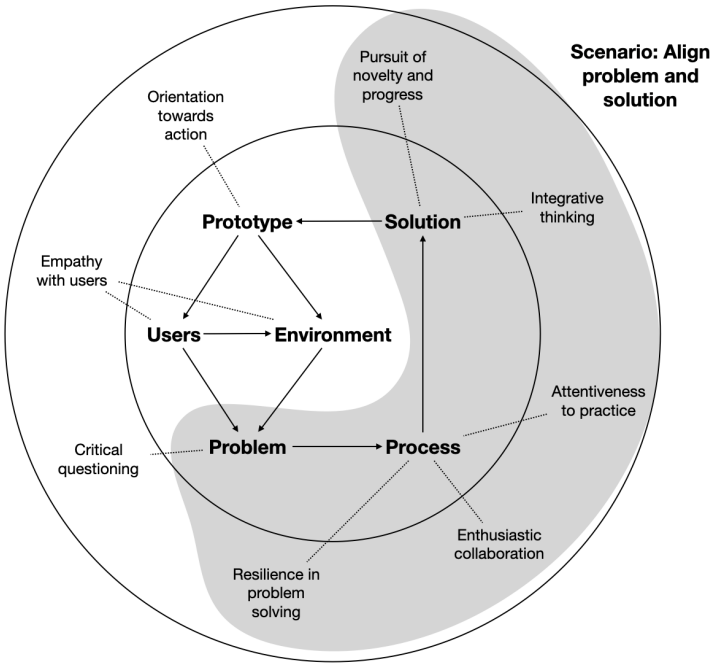
To further support how to use the model in different educational contexts, we now develop certain usage scenarios. This addresses the educators' expectations regarding 1) teaching design thinking in different educational settings; and 2) utilizing design thinking dispositions for selecting, enacting, and optimizing learning experiences in concrete scenarios. For this purpose, we segment the model in three educational scenarios, which organize different parts of the model goals and associated conditions (requirements and acceptance criteria). We define three scenarios: engage with the problem, align problem and solution, and take on action. These scenarios are summarized in Figure 3 and discussed below.

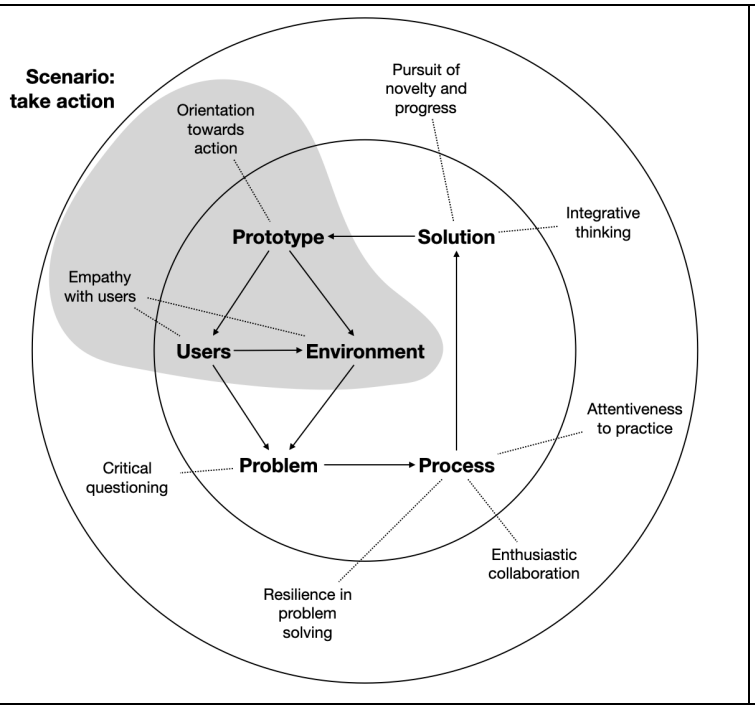
Scenario 1: Engage with the problem. This scenario emphasizes the relationships between two dispositions, empathy with users and critical questioning (Figure 3, top). Coming up with a problem requires having a situated understanding of the users and their operating environment. This is the essence of empathy with users. On the other hand, coming up with the problem also involves critical questioning, as the problem may be disguised by and spread through a complex web of other problems and sub-problems. In this scenario, the educator should create an educational experience that requires students to analyze the problem from different angles and levels of detail. Ideally, the problem should be discussed with a variety of stakeholders. The acceptance criterion for this scenario is for the problem definition to demonstrate diversity in problem understanding. Example problems include aging well, increasing participation in democratic processes, and reducing water consumption.

Scenario 2: Align problem and solution. This scenario concerns five dispositions, all related to the problem, process, and solution. Integrative thinking and resilience in problem solving emerge from making the problem and solution iteratively co-dependent. Therefore, the participants should generate multiple iterations of both the problem and the solution, showing how they have co-evolved. Attentiveness to practice will be reflected in the iterative process. To foster enthusiastic collaboration, the scenario should require group work and collaboration on all tasks. Finally, the solution is expected to be creative and innovative, which should be the acceptance criteria. Examples include using the internet-of-things to support independent living, the design of social media tools supporting democratic

processes (e.g., elections), and using the internet-of-things to increase awareness and efficiency of water consumption.

Scenario 3: Take action. The last scenario is fully orientated toward action, where students are expected to develop a prototype that showcases the developed solution. Acceptance criteria should include proof-of-concept, i.e., that the prototype implements the solution for a particular set of users operating in a particular environment.

<table>
<tr>
<td> 
</td>
<td>Requirements:
• Analyze the problem from different angles and levels of detail
• Discuss the problem with stakeholders (e.g., in interviews)
• Synthesize viewpoints
Acceptance criteria:
• Demonstrate diversity in problem understanding</td>
</tr>
<tr>
<td> 
</td>
<td>Requirements:
• Generate multiple iterations of problem- solution pairs
• Work collaboratively on all tasks
Acceptance criteria:
• Creative, innovative solution</td>
</tr>
</table>



Requirements:

- Build prototype

Acceptance criteria:

- Proof-of-concept

Figure 3. Staging the model with educational scenarios

Overall, this staged approach makes the model more manageable while fostering completeness since all design thinking dispositions are covered. The stages help educators organize educational experiences by defining a set of scenarios and associated conditions (requirements and acceptance criteria), which scaffold the selection and definition of particular cases and tasks. The model does not prescribe particular cases, tasks, or processes. Depending on the educational settings (e.g., course requirements, course focus, length of the course, and chosen design thinking dispositions), these scenarios could be used as stand-alone or in combination.

7 Discussion

Researchers have widely agreed that design thinking is a promising teaching approach in higher education (Guaman-Quintanilla et al., 2023; Lynch et al., 2021). While many existing studies have focused on teaching design thinking knowledge and skills, few studies have addressed how to teach design thinking dispositions. The current study fulfills this gap and highlights the role of design thinking dispositions in shaping learning experiences. It contributes a model for teaching design thinking dispositions (Figure 1 and Table 1), which has been operationalized in design thinking courses. The model evaluation provides insights into the students' experiences in developing design thinking dispositions.

Our findings have implications for design thinking teaching and learning. In particular, while teaching design thinking knowledge and skills is important, it is equally important to develop design thinking dispositions. This is important for students to know-why the structure of design thinking projects. For instance, knowing about empathy and how to build empathy in design thinking is important, but

knowing why is imperative. Citing the participants in our model evaluation: “Empathy with [the] customers’ perspective defines the core problem and [leads our] initiative” (participant D).

We identify eight design thinking dispositions and integrate them with several elements of design thinking. This integration can help educators better construct design thinking courses. We provide further guidance through three scenarios that address common patterns for teaching design thinking dispositions. Although other researchers have already developed scales to measure design thinking dispositions (Tsai and Wang, 2021), our study provides specific guidelines on developing design thinking dispositions in different teaching scenarios. We note that the identified design thinking dispositions and teaching scenarios should not be considered as exhausted. Rather, they should be considered as starting points for further teaching and learning design thinking dispositions.

Our research has several limitations. First, the proposed model is not intended to represent the whole conceptualization of design thinking. For instance, it is recognized that designers move frequently between problem and solution, as they have conversations with the situation at hand (Schön and Wiggins, 1992). Such evolving relationships are not represented in the model. Also, the process element could be further decomposed to represent specific process models described in the literature (Brenner et al., 2016; Brown, 2008). The relationships between the prototype and the users and environment, which are essential for evaluation, are also not represented. These exclusions are projected to build a parsimonious foundation on which to anchor design thinking dispositions.

Second, the evaluation is based on student feedback by the end of the course. In this regard, we note that students acquired the dispositions in an implicit way, through assigned tasks, rather than learning about them explicitly. The fact that students could reflect about the dispositions at the end of the course, to some extent, can be considered a positive impact of the proposed model on the learning outcomes. Finally, the model evaluation is based on a sample of 14 participants. While our sample is reasonable for qualitative evaluation, future research should increase the sample size for generalizability of the research results.

References

Antunes, P., Xiao, L., Pino, J., 2014. Assessing the Impact of Educational Differences in HCI Design Practice. International Journal of Technology and Design Education 24, 317–335. https://doi.org/10.1007/s10798-013-9254-8

Badding, S., Leigh, K., Williams, A., 2014. Models of thinking: Assessing the components of the design thinking process, in: Proceedings of the Design Management Institute’s 19th Academic Design Management Conference/Design Management in an Era of Disruption, London. pp. 2–4.

Baskerville, R., Baiyere, A., Gregor, S., Hevner, A., Rossi, M., 2018. Design Science Research Contributions: Finding a Balance between Artifact and Theory. Journal of the Association for Information Systems 19, 358–376.

Beligatamulla, G., Rieger, J., Franz, J., Strickfaden, M., 2019. Making pedagogic sense of design thinking in the higher education context. Open Education Studies 1, 91–105.

Billett, S., 2009. Realising the educational worth of integrating work experiences in higher education. Studies in Higher Education 34, 827–843.
Brenner, W., Uebernickel, F. (Eds.), 2016. Design thinking for innovation. Springer, Cham Heidelberg New York Dordrecht London.
Brenner, W., Uebernickel, F., Abrell, T., 2016. Design Thinking as Mindset, Process, and Toolbox, in: Brenner, W., Uebernickel, F. (Eds.), Design Thinking for Innovation: Research and Practice. Springer International Publishing, Cham, pp. 3–21.
Brown, T., 2008. Design thinking. Harvard business review 86, 84.
Buchanan, R., 1992. Wicked problems in design thinking. Design Issues 8, 5–21.
Carlgren, L., Rauth, I., Elmquist, M., 2016. Framing design thinking: The concept in idea and enactment. Creativity and innovation management 25, 38–57.
Creswell, J., 2009. Research design: Qualitative, quantitative, and mixed methods approaches, 3rd ed. SAGE Publications.
Cross, N., 2004. Expertise in design: an overview. Design studies 25, 427–441.
Cross, N., 2001. Designerly ways of knowing: Design discipline versus design science. Design Issues 17, 49–55.
Denning, P., 2013. Design thinking. Communications of the ACM 56, 29–31.
Denscombe, M., 2008. The length of responses to open-ended questions: A comparison of online and paper questionnaires in terms of a mode effect. Social Science Computer Review 26, 359–368.
Dong, A., 2015. Design x innovation: perspective or evidence-based practices. International Journal of Design Creativity and Innovation 3, 148–163.
Dorst, K., 2011. The core of 'design thinking'and its application. Design studies 32, 521–532.
Dorst, K., 2010. The nature of design thinking, in: Design Thinking Research Symposium. DAB Documents.
Dorst, K., Cross, N., 2001. Creativity in the design process: co-evolution of problem–solution. Design studies 22, 425–437.
Dosi, C., Rosati, F., Vignoli, M., others, 2018. Measuring design thinking mindset, in: Proceedings of the DESIGN 2018 15th International Design Conference. pp. 1991–2002.
Duan, S., Exter, M., Tagare, D., Sabin, M., 2022. Managerial and Professional Skills and Dispositions from Professionals' Interviews, in: Proceedings of the 23rd Annual Conference on Information Technology Education. pp. 1–8.
Dunne, D., Martin, R., 2006. Design thinking and how it will change management education: An interview and discussion. Academy of Management Learning & Education 5, 512–523.
Duplass, J., Cruz, B., 2010. Professional dispositions: What's a social studies education professor to do? The Social Studies 101, 140–151.
Dwyer, C.P., Hogan, M.J., Harney, O.M., Kavanagh, C., 2017. Facilitating a student-educator conceptual model of dispositions towards critical thinking through interactive management. Educational Technology Research and Development 65, 47–73.
Dym, C.L., Agogino, A.M., Eris, O., Frey, D.D., Leifer, L.J., 2005. Engineering design thinking, teaching, and learning. Journal of engineering education 94, 103–120.
Foster, M., 2021. Design thinking: A creative approach to problem solving. Management Teaching Review 6, 123–140.
Fraser, H., 2011. Business design: becoming a bilateral thinker. Rotman Magazine 71–76.
Frezza, S., Clear, T., Clear, A., 2020. Unpacking Dispositions in the CC2020 Computing Curriculum Overview Report, in: 2020 IEEE Frontiers in Education Conference. IEEE, pp. 1–8.
Garud, R., 1997. On the distinction between know-how, know-what, and know-why. Advances in strategic management 14, 81–102.
Glen, R., Suciu, C., Baughn, C., Anson, R., 2015. Teaching design thinking in business schools. The International Journal of Management Education 13, 182–192.
Goldkuhl, G., Ågerfalk, P., Sjöström, J., 2017. A design science approach to information systems education, in: International Conference on Design Science Research in Information System and Technology. Springer, Cham, pp. 383–397.
Gollwitzer, P., 2012. Mindset theory of action phases. Handbook of theories of social psychology 1, 526–545.

Green, S., Southee, D., Boult, J., 2014. Towards a design process ontology. The Design Journal 17, 515–537.
Groeger, L., Schweitzer, J., 2020. Developing a design thinking mindset: Encouraging designerly ways in postgraduate business education. Design Thinking in Higher Education: Interdisciplinary Encounters 41–72.
Guaman-Quintanilla, S., Everaert, P., Chiluiza, K., Valcke, M., 2023. Impact of design thinking in higher education: a multi-actor perspective on problem solving and creativity. International Journal of Technology and Design Education 33, 217–240.
Haskamp, T., Paul, A., Stöckli, E., de Paula, D., Uebernickel, F., 2020. Implementing design thinking for non-designers: Learning profiles from a q-methodology study. Presented at the ISPIM Connects Global 2020, LUT Scientific and Expertise Publications.
Hastings, B., Schwarz, G., 2022. Mindsets for Change Leaders: Exploring Priming Approaches for Leadership Development. Journal of Change Management 22, 202–229.
Hevner, A., March, S., Park, J., Ram, S., 2004. Design Science in Information Systems Research. MIS Quarterly 28, 75–105.
Hevner, A., vom Brocke, J., 2023. A Proficiency Model for Design Science Research Education. Journal of Information Systems Education 34, 264–278.
Howard, Z., Senova, M., Melles, G., 2015. Exploring the role of mindset in design thinking: Implications for capability development and practice. Journal of Design, Business & Society 1, 183–202.
Hsiao, H.-S., Chang, Y.-C., Lin, K.-Y., Chen, J.-C., Lin, C.-Y., Chung, G.-H., Chen, J.-H., 2023. Applying the design thinking model to hands-on mechatronics STEM activities for senior high school students to improve the learning performance and learning behavior. International Journal of Technology and Design Education 33, 1389–1408.
Huq, A., Gilbert, D., 2017. All the world'sa stage: transforming entrepreneurship education through design thinking. Education+ Training 59, 155–170.
Jobst, B., Köppen, E., Lindberg, T., Moritz, J., Rhinow, H., Meinel, C., 2012. The faith-factor in design thinking: Creative confidence through education at the design thinking schools Potsdam and Stanford? Design thinking research: Measuring performance in context 35–46.
Johansson-Sköldberg, U., Woodilla, J., Çetinkaya, M., 2013. Design thinking: past, present and possible futures. Creativity and Innovation Management 22, 121–146.
Keskin, D., Romme, G., 2020. Mixing oil with water: How to effectively teach design science in management education? BAR-Brazilian Administration Review 17.
Kimbell, L., 2012. Rethinking design thinking: Part II. Design and Culture 4, 129–148.
Kimbell, L., 2011. Rethinking design thinking: Part I. Design and culture 3, 285–306.
Kimbell, R., 2023. STEM education research as 'designerly,' in: Perspectives in Contemporary STEM Education Research: Research Methodology and Design. Routledge/Taylor & Francis Group, Milton Park, Abingdon.
Koh, J., Chai, C., Wong, B., Hong, H.-Y., Koh, J., Chai, C., Wong, B., Hong, H.-Y., 2015. Design thinking and education. Springer, Singapore.
Lahiri, A., Cormican, K., Sampaio, S., 2021. Design thinking: From products to projects. Procedia Computer Science 181, 141–148. https://doi.org/10.1016/j.procs.2021.01.114
Lattemann, C., Arntsen, E., Flaten, B.-T., Fürst, N., Holen, J., Cappelen, B., 2020. Is There a Proper Way to Teach Design Thinking? Empirical Evidence from Design Thinking in Education. Journal of Design Thinking 1, 35–48.
Leavy, B., 2010. Design thinking–a new mental model of value innovation. Strategy & leadership 38, 5–14.
Lehrer, R., 2009. Designing to develop disciplinary dispositions: Modeling natural systems. American Psychologist 64, 759.
Lin, L., Shadiev, R., Hwang, W.-Y., Shen, S., 2020. From knowledge and skills to digital works: An application of design thinking in the information technology course. Thinking Skills and Creativity 36, 100646.
Lynch, M., Kamovich, U., Longva, K., Steinert, M., 2021. Combining technology and entrepreneurial education through design thinking: Students' reflections on the learning process. Technological Forecasting and Social Change 164, 119689.

Meyer, M., Norman, D., 2020. Changing design education for the 21st century. She Ji: The Journal of Design, Economics, and Innovation 6, 13–49.
Micheli, P., Wilner, S., Bhatti, S., Mura, M., Beverland, M., 2019. Doing design thinking: Conceptual review, synthesis, and research agenda. Journal of Product Innovation Management 36, 124–148.
Michlewski, K., 2008. Uncovering design attitude: Inside the culture of designers. Organization studies 29, 373–392.
Novak, E., Mulvey, B., 2021. Enhancing design thinking in instructional technology students. Journal of Computer Assisted Learning 37, 80–90.
Ohly, S., Plückthun, L., Kissel, D., 2017. Developing students' creative self-efficacy based on design-thinking: Evaluation of an elective university course. Psychology Learning & Teaching 16, 125–132.
Owen, C., 2007. Design thinking: Notes on its nature and use. Design Research Quarterly 2, 16–27.
Öztürk, A., Korkut, F., 2023. Design thinking customized to support STEM teachers: Co-developing and implementing STEM activities for fifth graders in Turkey. International Journal of Technology and Design Education 33, 1409–1447.
Pande, M., Bharathi, S.V., 2020. Theoretical foundations of design thinking–A constructivism learning approach to design thinking. Thinking Skills and Creativity 36, 100637.
Panke, S., 2019. Design thinking in education: Perspectives, opportunities and challenges. Open Education Studies 1, 281–306.
Patnaik, D., Becker, R., 1999. Needfinding: the why and how of uncovering people's needs. Design Management Journal 10, 37–43.
Raj, R., Sabin, M., Impagliazzo, J., Bowers, D., Daniels, M., Hermans, F., Kiesler, N., Kumar, A., MacKellar, B., McCauley, R., others, 2021. Professional Competencies in Computing Education: Pedagogies and Assessment, in: Proceedings of the 2021 Working Group Reports on Innovation and Technology in Computer Science Education. pp. 133–161.
Royalty, A., Chen, H., Roth, B., Sheppard, S., 2019. Measuring Design Thinking Practice in Context, in: Meinel, C., Leifer, L. (Eds.), Design Thinking Research: Looking Further: Design Thinking Beyond Solution-Fixation, Understanding Innovation. Springer International Publishing, Cham, pp. 61–73. https://doi.org/10.1007/978-3-319-97082-0_4
Sadler, J., Shluzas, L., Blikstein, P., Katila, R., 2016. Building blocks of the maker movement: Modularity enhances creative confidence during prototyping, in: Design Thinking Research: Making Design Thinking Foundational. Springer, pp. 141–154.
Saldaña, J., 2015. The coding manual for qualitative researchers. Sage.
Sanders, E., Stappers, P.J., 2014. Probes, toolkits and prototypes: three approaches to making in codesigning. CoDesign 10, 5–14.
Schön, D., 1983. The reflective practitioner: How professionals think in action. Basic Books, New York.
Schön, D., Wiggins, G., 1992. Kinds of seeing and their functions in designing. Design studies 13, 135–156.
Schweitzer, J., Groeger, L., Sobel, L., 2016. The design thinking mindset: An assessment of what we know and what we see in practice. Journal of design, business & society 2, 71–94.
Shenton, A., 2004. Strategies for ensuring trustworthiness in qualitative research projects. Education for information 22, 63–75.
Shet, S., Pereira, V., 2021. Proposed managerial competencies for Industry 4.0–Implications for social sustainability. Technological Forecasting and Social Change 173, 121080.
So, C., 2019. What makes good design? Revealing the predictive power of emotions and design dimensions in non-expert design vocabulary. The Design Journal 22, 325–349.
Sobel, L., Schweitzer, J., Malcom, B., Groeger, L., 2019. Design Thinking Mindset: Exploring the role of mindsets in building design consulting capability, in: Conference of the Academy for Design Innovation Management 2019: Research Perspectives In the Era of Transformations. Academy of Design Innovation Management, pp. 1695–1701.
Termeer, C., Dewulf, A., 2019. A small wins framework to overcome the evaluation paradox of governing wicked problems. Policy and Society 38, 298–314.

The Joint ACM/AIS IS2020 Task Force, 2021. IS2020 A Competency Model for Undergraduate Programs in Information Systems. ACM/AIS.
Thornton, H., 2006. Dispositions in action: Do dispositions make a difference in practice? Teacher Education Quarterly 33, 53–68.
Thuan, N., Tate, M., Drechsler, A., Antunes, P., 2023. Special Issue Editorial: Introduction to Design Science Education. Journal of Information Systems Education 34, 256–263.
Tsai, M.-J., Wang, C.-Y., 2021. Assessing young students' design thinking disposition and its relationship with computer programming self-efficacy. Journal of Educational Computing Research 59, 410–428.
Vanada, D., 2013. Practically Creative: The Role of Design Thinking as an Improved Paradigm for 21st Century Art Education. Learn X Design Conference Series.
Verganti, R., Dell'Era, C., Swan, K., 2021. Design thinking: Critical analysis and future evolution 38, 603–622.
Vignoli, M., Dosi, C., Balboni, B., 2023. Design thinking mindset: scale development and validation. Studies in Higher Education 1–15.