Eurasian Journal of Educational Research 96 (2021) 30-50

Eurasian Journal of Educational Research
www.ejer.com.tr

The Impact of Design Thinking on Problem Solving and Teamwork Mindset in A Flipped Classroom.

Nguyen THI-HUYEN[1], Pham XUAN-LAM[2*], Nguyen Thi THANH TU[3]

ARTICLE INFO

Article History:

Received: 16 September 2021

Received in revised form: 12 November 2021

Accepted: 20 December 2021

DOI: 10.14689/ejer.2021.96.3

Keywords
Design Thinking, Problem-Solving, Teamwork, long-term education.

ABSTRACT

Purpose: In this study, we presented the Design Thinking model called DITC (Design Thinking in Class) and conducted an experiment during one month with 197 engineering students at Hanoi University of Technology (HUST) to determine how this model could aid in the growth of problem solving and teamwork mindset in a flipped classroom. **Method:** A Design Thinking mindset questionnaire was given to 197 participants before and after this model was applied. A t-test was used to analyze the data. **Findings**: the DTIC model fostered students' mindsets such as empathy, holistic view, problem reframing, and teamwork. Students showed very positive feedback and reviews on the model. **Implications to Research and Practice**: DITC can assist students in grasping Design Thinking concepts, allowing them to understand real-world problems more effectively. This model can be used to support teamwork and problem-solving skills for online learning environments, especially during the Covid19 pandemic. We also included some suggestions for incorporating Design Thinking into the classroom so that this model can be applied more widely.

[1] Hanoi University of Science and Technology, VIETNAM,
E-mail: huyen.nguyenthi2@hust.edu.vn, ORCID: 0000-0001-6546-2116
[2] Corresponding Author, National Economic University, VIETNAM,
E-mail: lampx@neu.edu.vn, ORCID: 0000-0003-1392-3755
[3] Hanoi University of Science and Technology, VIETNAM
E-mail: tu.nguyenthithanh@hust.edu.vn, ORCID: 0000-0002-4564-1579

Introduction

Design Thinking is a design methodology that focuses on finding solutions to problems which have been a subject of teaching, research and real-life application in almost every domain(Shé, Farrell, Brunton, & Costello, 2021). This methodology includes tasks like understanding the human needs, re-framing the problem in human-centric ways, creating many ideas in brainstorming sessions, and taking a hands-on approach in prototyping and testing(Pande & Bharathi, 2020). Design thinking have been proven that it is useful in tackling complex problems that are ill-defined or unknown.(Brown, 2008; Ejsing-Duun & Skovbjerg, 2019; Mahe, Adams, Marsan, Templier, & Bissonnette, 2019; Razzouk & Shute, 2012; Shé et al., 2021; Wolcott, McLaughlin, Hubbard, Rider, & Umstead, 2021).

Although the word "Design Thinking" was coined in 1959, the design strategies to which it refers have been around since the early 1950s(Norman, 1992). Herbert A. Simon was the person who laid the foundation for the development of this system. In his book "The Sciences of the Artificial(Suchman, 2008), he described an 8-step process for how a human can come up with creative solutions. Design Thinking began to be taught at Stanford in 1980. In 1991, IDEO was established by a Stanford professor, David M. Kelly (Brown, 2008). IDEO was a design consulting firm that helped lay the groundwork for the global popularity of Design Thinking. This company used Design Thinking as a key tool in the development of toothbrushes, software, electronics, shopping carts, classrooms, and clean water projects, among other things. Stanford University's Hasso Platner Design Institute (D.School) was one of the foremost educational institutions dedicated to fostering Design Thinking in education. D.School's curriculum was created with college students in mind, with the goal of honing their imaginative and problem-solving abilities. To date, several projects have been launched to encourage and investigate Design Thinking as a modern learning paradigm or learning model in college or K-12 classrooms. Some of these programs aimed at improving students' 21st - century skills (Barrie, 2006; Goldman & Zielezinski, 2016; Noel & Liub, 2017).

Many companies and colleges have adopted Design Thinking as a result of these initiative(Cereja, Santoro, Gorbacheva, & Matzner, 2018). Today, Design Thinking is popular with a 5-step process that is very similar to Simon's 8-step process.

1. Empathize - Empathy is the ability to understand the needs of others.
2. Define - Definition: In a person-centered manner, adjust and define the issue.
3. Ideate - Ideas: During the imagination session, come up with a lot of different ideas.
4. Prototype - Using a functional prototyping approach to the prototyping method.
5. Test: Create a unique prototype / solution to the problem.

Although Design Thinking has attracted increased attention from business and management scholars in recent years, critics feel that scholars have drawn attention away from the unique challenges associated with Design Thinking practices in different contexts and from advancing knowledge on how Design Thinking is understood, interpreted and applied.(Berg, Lindholm, & Högväg; Moreno, Ponte, & Charnley, 2017). For broadly applying Design Thinking in class, there is a need for simple and effective model that teacher could follow, however, researchers have not treated this topic in much detail, especially for applying this method to non-designer students(Mosely, Wright, & Wrigley, 2018). Therefore, this study aimed to propose a model called Design Thinking in Class (DTIC) and apply this model in practice. An experiment with 197 engineering students at Hanoi University of Technology was conducted for one month to see how it affected students' problem solving and teamwork skills. Students were given the Design Thinking mindsets questionnaire derived from a previous study(Dosi, Rosati, & Vignoli).

Literature review

Design thinking is now commonly used to solve problems and discover new solutions in all facets of life including executive management, product design, education, and community services. Many studies have shown that Design Thinking is an important skill for people in the twenty-first century (Henriksen, Richardson, & Mehta, 2017). According to research(Du, Jing, & Liu), a solution is assessed with higher quality when many people express their personal opinions on an issue and a solution is chosen and synthesized from all such opinions. Another research (Henriksen et al., 2017) claims that collaborative work in Design Thinking leads to increased innovation and knowledge depth. A number of other studies in the field of education have shown that when teachers use Design Thinking in the process of creating learning materials and lectures for students, the quality of classrooms improves(Jamal, Kircher, & Donaldson, 2021; Zupan, Cankar, & Setnikar Cankar, 2018). For example, (Wolcott et al., 2021) describes strategies that health professions educators can use to prepare for conduct and support Design Thinking in a twelve-point paper. Learners, practitioners, and organizations may find these strategies useful in addressing complex problems.

Another study (Koria, Graff, & Karjalainen, 2011) provides the foundation for a three-day extracurricular "Social Innovation Jam" program aiming at teaching Design Thinking in the context of sustainable development. As entrepreneurial educators include the United Nations Sustainable Development Goals into their curricula, the Social Innovation Jam may be duplicated to give local answers to global challenges using Design Thinking and "learning by teaching" methodology, both inside and outside the classroom. A few other studies(Androutsos & Brinia, 2019; Daniel, 2016; Lynch, Kamovich, Longva, & Steinert, 2021; Sarooghi, Sunny, Hornsby, & Fernhaber, 2019) performed a comparative case study on Design Thinking and business planning in the context of entrepreneurship education and found that students in the Design Thinking course felt more inspired and pleased with their success.

As Design Thinking has become an integral part of the design, engineering, and business fields, it has also had a positive impact on twenty-first century education because it involves creative thinking in problem solving(Razzouk & Shute, 2012). Some educators are considering the greater influence of Design Thinking through the curriculum at the college level as a result of the growth of digital media and educational technologies(Burdick & Willis, 2011; Wrigley, Mosely, & Tomitsch, 2018). Besides, the study from(Gachago, Morkel, Hitge, Van Zyl, & Ivala, 2017) analyzed lecturers identified as eLearning champions, who display a 'Design Thinking mindset', such as collaboration, empathy for the learner and problem orientation. They argued that promoting this mindset in academic staff development interventions around the use of technology in teaching and learning could support more academics to innovate their practices.

A study from (Shé et al., 2021) stated that Design Thinking is a flexible methodology that emphasized the importance of student empathy. In this study, the fully online #OpenTeach course was created with Design Thinking principles and was delivered in Spring 2020. Design thinking's five stages (design, define, ideate, prototype, and test) were incorporated into the course materials' development. The findings of this study suggest that instructional designers can use the Design Thinking process to achieve empathy with their students, ensuring that they are fully engaged and achieve the course's learning objectives. Another study (Pande & Bharathi, 2020) explains how to recognize the tenets of constructivist learning theory (constructivist principles) within the teaching-learning of the Design Thinking process. The study further picks up the thread of developing and fine-tuning a Design Thinking course.

In addition, Design Thinking can also be seen as a pedagogical strategy by certain academics (Jamal et al., 2021; Luka, 2014). Educators rethink conventional curriculum on a variety of subjects, including mathematics, literature, geography(Carroll et al., 2010), and history. Studies in other contexts have shown that Design Thinking has the ability to make secondary school students more distinctive, motivated, engaged in learning, and that it assists them in mastering new skills and responsibly applying their talents (Carroll et al., 2010; Royalty, 2018; Wagner & Cennamo).

As can be seen from the above research, Design Thinking has a lot of advantages when it comes to finding solutions for a problem. However, as abovementioned, Design Thinking has diverted attention away from the unique challenges associated with Design Thinking practices in various contexts and away from advancing knowledge on how Design Thinking is understood, interpreted, and applied. The current study aims to fill this research gap and address the concerned issues in detail.

Method

Research design: Design Thinking in Flipped Classroom – Model

A 5-step Design Thinking in Class (DTIC) model was adopted for this study (Figure 1) for lecturers to incorporate Design Thinking into flipped classroom activities. With this model, Design Thinking was seen as a mindset and approach to learning, collaboration, and problem solving. DTIC is applied to each small group of students to facilitate collaboration and teamwork. During each phase in Design Thinking, the teacher plays a supportive role, asking open-ended questions, watching the groups working independently, and explaining only when required.

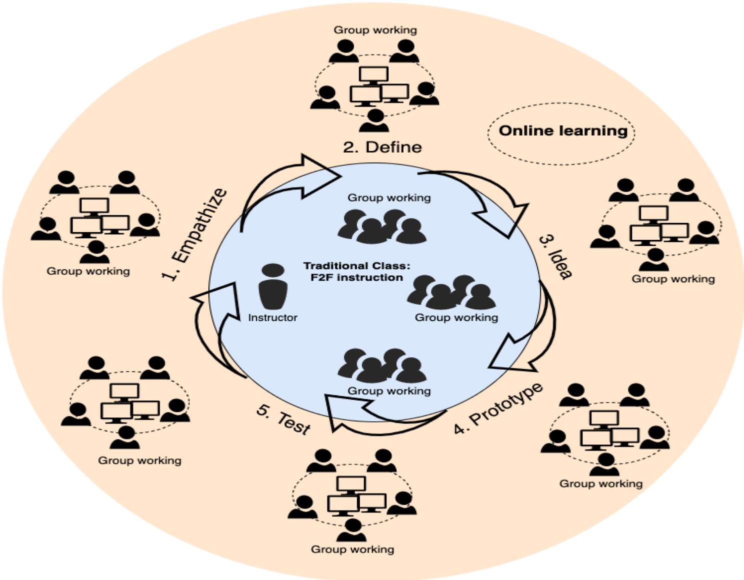

Figure 1. *DTIC model in flipped class.*

Each of the five steps had specific class activities as explained below:

Stage 1: Empathize

The requirement for this step is a more in-depth understanding of the problem being solved. To achieve this goal, a teacher can guide students by asking questions to identify relevant factors. Kipling's questions and the 5-Whys are two questioning tools that can be used in this step. Using 5-Whys is an iterative interrogative technique to explore the cause-and-effect relationships underlying a particular problem. The primary goal of this technique is to determine the root cause of a defect or a problem by repeating the question. The 5-Whys technique is a part of the lean production system and was invented by Sakichi Toyota, the founder of Toyota Industries. The technique was first used in the 1950s, became extremely popular in the 1970s and is still used in the Toyota today.

Teachers can see how the 5-Whys strategy can help concentrate, identify the root cause of the problem, and enhance the process, as shown in the following example:

- A coolant is leaking from the machine. Why?
- A seal was damaged. Why?
- Metal shaving got into the coolant. Why?
- A screen on a coolant recycling pump was broken. Why?
- The screen is in the place where it was likely to be damaged by dropped parts. Why?

Action: Redesign a machine or add guard to cover the screen and prevent damage. If the seal is merely replaced, it would have soon need repair again as the damage repeats itself.

Using Kipling question: If teacher wants students to look at an issue from multiple perspectives or come up with new ideas, this approach may be useful. Its aim is to gain a better understanding by asking questions like What, Where, and When, How, why, and Who. For example:

- What is the problem?
- Where is it happening?
- When is it happening?
- Why is it happening?
- How can you overcome this problem?
- Who do you need to get involved?
- When will you know that you have solved the problem?

Stage -2: Define

Teachers can consider asking students use fishbone diagram to aid in brainstorming and categorizing ideas to identify potential causes of a problem. A fishbone diagram is a graphic representation of cause and effect. It is a more formal solution than any of the other problem-solving methods on the market (e.g., the 5-Whys tool). Root cause-analysis is a structured team process that assists in identifying underlying factors or causes of an adverse event and understanding the contributing factors or causes of a system failure.

Stage 3: Idea

Brainstorming is the one most used technique used in team activities. However, brainstorming sessions often encounter problems when the ideas are discrete; they go too far from the problem or there are too many opposing opinions. No one accepts anyone's ideas as everyone actively defends their opinions. To ensure the effective use of brainstorming tasks in the class. teachers could set the rules like following:

- Warm up and introduce the problem: Present the issue and the fishbone diagram so that everybody can appreciate the important facts. This is critical for the idea to progress in the right direction and address the key issues.
- Explain the rules: All should be aware of the discussion rules. At this stage of brainstorming, there is only one rule: No judgment on any given concept.
- Gather suggestions: On a sticky note, students write down all the ideas that come to mind. The aim is to collect as many ideas as possible, regardless of their consistency or appropriateness.
- Discussion: Students will stick ideas on the board in each region at this stage, with each

area containing ideas that are similar or identical. Subsequently, they will conduct discussions on each idea in turn and choose 1-2 ideas that are most optimal. This is a time for free judgment and offer a rationale. Controversial ideas will be set aside.

- Evaluation: Following the selection of the best ideas. This step will re-evaluate the best solutions to come up with. Any ideas that continue to be contentious and inconsistent will be removed. At this stage, the goal is to narrow down to 1-2 ideas or a group of the best and most relevant ideas. Following is the example how students can do group brainstorming in the class.

Stage 4 & 5: Prototype and Test

In this step, teacher encourage students to explore new ideas, visit relevant people and places, and build and test physical solutions. Students design collaborative activities in and outside the classroom, so that students are directly engaged in information gathering, knowledge generation, communication, and presentation. Through the test, students analyze subject concepts or material, evaluate experiences, and build theory relevant to the subject through feedback. Careful feedback will give students the opportunity to put their views, thoughts, and values to the test and ask questions about them. Finally, students may refine the approach by observing, asking questions, and integrating facts, concepts, and perspectives.

Research Sample

In one soft skill class, we introduced DTIC to a sample of 197 students at Hanoi University of Technology and Science for one month in January 2021. The students were divided into small classes of ten students each. Each group was required to solve a problem using DTIC model. **Table 1** presents the demographics of the sample.

Table 1.

Participant's demographics (N= 197)

Majors	Computer science (8%) Automation (10%) Physics (9%) Bioengineering (9%) Textile (17%) Electrical Engineering (15%) Mechanics (10%) Food science and technology (12%) Chemistry (10%)
Ages	Ages between 20-23 years
Genders	76% Male, 14% Female

Table 1 shows that most students were male (76%) while female participants numbered only (14%), which is common in any engineering school. Students at HUST ranged in the age group of 20 to 23 years and came from a variety of engineering fields.

Data collection instruments and procedures

A Design Thinking mindset questionnaire presented in a study (Dosi et al.) was selected for this study . The original questionnaire consists of 83 items, assessing 19 aspects. However, in this study, only 28 items were selected that belonged to the eight aspects that were most relevant to this study. All 28 items were graded on a 5-point Likert scale, with scores ranging from 'Not at all in agreement' to 'Completely in agreement'.

The research procedure was very simple. At the start of the experiment, groups were given a "warm up" section This section contained the course introduction, experiment instructions and a pre-thinking and post-thinking questionnaire. The procedure ended with interview with the sampled informants.

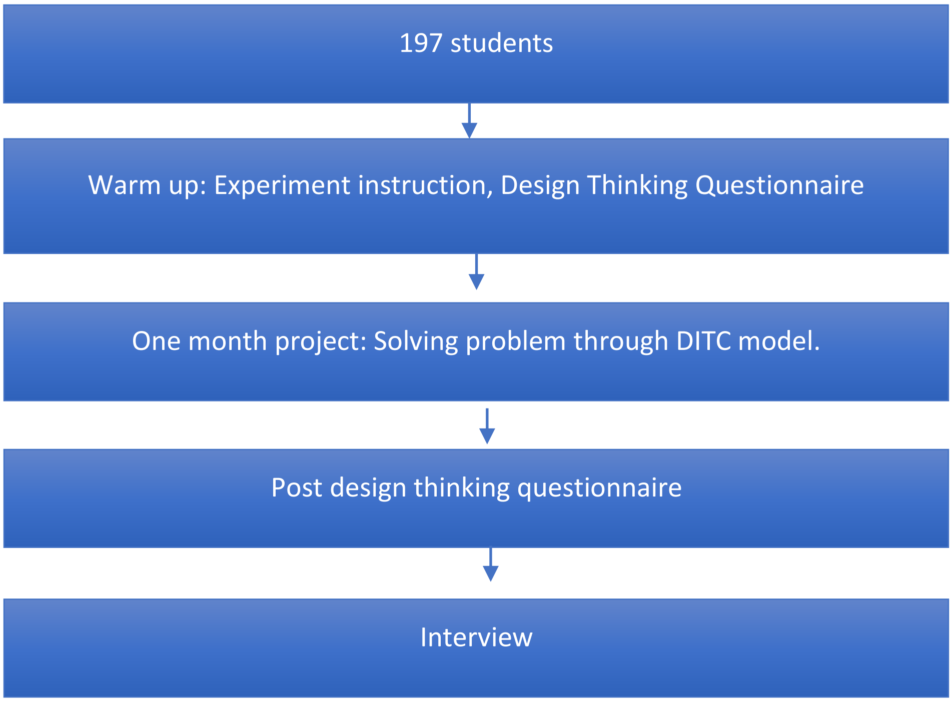

Figure 2. *Research procedure*

Data analysis.

The data analysis comprised descriptive statistics, test the validity and reliability of the items on the scales with Cronbach's Alpha. The purpose of this test was to analyze the internal consistency of the responses based on the correlation between items on the same scale, between number of items, mean and standard deviation, and Cronbach`s Alpha values of the scales

Results

The experiment started with a Design thinking Questionnaire. A pre and post questionnaire was used to look at the differences in students' Design Thinking mindset before and after DTIC. Since this questionnaire was not mandatory, students were given the option to participate in the questionnaire or not. Consequently, 136 pre-questionnaire survey forms and 139 post-questionnaire survey forms were received. After eliminating some inappropriate survey forms (for example, students only participated in the pre or post questionnaire), 120 pairs (pre and post) of survey forms were finalized for this study. The average score of all items belonging to each aspect was calculated and differences were compared using pair-sample T-test data analysis.

During this experiment, students were specifically introduced to the Flipped learning environment, which included the learning management system (LMS), group project assignment, project outputs, and evaluation. The flipped learning environment consisted of following elements:

- LMS system: it contained all the online learning material (video lectures, books, quizzes, assignments) where students can get access 24/7.
- Face to face class: During the experiment, in each two weeks, there was one regular 3-hour face-to-face class to assist students on any question or concern that they might have during the online course as well as to check on their progress of the group project.
- Group project: In terms of the group project, each group of students was asked to add common issues (that is most relevant to their students' lives) to the issue list. Finally, 20 issues were selected and placed on the list.

Participants were then introduced to DTIC and asked to solve the issue via 5 processes below:

- Empathize: Gathering information about the issue to have better understanding on the problem and solve it by discussing with the author of the issue on 5W1H question (What, when, why, who, where how) or via group chat or face-to-face meeting, while using the internet to search for necessary information.
- Define: List the main root causes of the problem.
- Ideate: Brainstorming the idea.
- Prototype: Simulate and present the idea for solution in a video.
- Test: Present the solution (video presentation) and get the feedback from the author group to see if the idea of solution can solve the issue.

The following is example of video product in authentic context that a research group worked on during this study.

Issue: Is the university the only way for bright future?	Issue: We have a store that sells genuine goods. A consumer once discovered that a commodity purchased from here was counterfeit. What is the best way to deal with this problem?	Issue: Find a shared room for new students

Figure 3. *Solution videos representing a group activity*

Figure 2 is an example of solutions presented in a video form. A real issue was identified with one participant who worked as a storekeeper.

Issue: We have a store that sells genuine goods. A consumer once discovered that a commodity purchased from here was counterfeit. What is the best way to deal with this problem?

Solution:

1. First, after the store staff receives information from the consumer, the product should be recalled, while an apology and negotiation with the customer could be made to handle the issue and resolve it in the shortest time possible. This protects the store's integrity by ensuring that consumers do not spread misleading details.
2. Next, a thorough inspection of the product should be done to ensure whether the item was from the store itself. The sales invoice should be examined to see if the camera recognized the buyer and if the delivery time was precise.
3. Survey, review, and discipline, to check if there were irresponsible importers and members of the management team who were ineffective in avoiding errors when bringing products to customers.

If the fake product is from store:

- Recall the product immediately
- Apologize and explain everything clearly to the buyer.
- Customers can be compensated by exchanging products of equal value in exchange for promotions or coupons for future purchases. It is also possible to refund the amount of a customer's purchase.

If the product is not the fault of the store, but is the result of unfair competition from another store or dishonest customers:

- Provide evidence that the fake product was not from the store.
- Request that the buyer clarifies the incident, provides a specific explanation, and commits not to repeat the behavior that has harmed the store's reputation.

At the end of experiment, the Design Thinking questionnaire was then administered to all students once again. Finally, a telephone interview was conducted (due to COVID-19) to clarify some findings. Students who actively participated in the experiment were chosen. A duration of 5 minutes per student was allotted to each student to answer questions like: "*Please let us know what you think about the empathy stage or the Idea stage?" "Please explain your perception of teamwork before and after this project. Is there a difference?"*

We selected a part of Design Thinking mindset questionnaire that was presented in the study (Dosi et al.). The original questionnaire consisted of 83 items, assessing 19 aspects. However, in this study, only 28 items were selected which belonged to the following eight aspects of this study.

- **Human centeredness**: Human centeredness means focusing "on understanding human behaviors, needs, and values", a way to solve "complex and strategic problems".
- **Empathy**: Empathy is the foundation of a human-centered design process." It is the ability to see things "from multiple perspectives", to create "customer intimacy" or "the ability to see and experience through another person's eyes, to recognize why people do what they do".
- **Mindfulness and awareness of process**: Design Thinkers were aware of the process in the sense that they know where they are in the design process, whether they are involved in a converging or diverging phase, if they must be "highly generative versus when it is necessary to converge on a single solution path".
- **Holistic view**: This is the ability to consider the whole problem, considering many factors like "socioeconomic patterns, relationships, dependencies", "including customer needs, technical feasibility, organizational constraints, regulatory implications, competitive forces, resource availability, Strategic Implications as well as the Costs and Benefits of Different Solutions Proposals", thus achieving a 360-degree view of the problem.
- **Problem reframing**: Problem reframing means reformulating "the initial problem" in a "meaningful and holistic way", "widen, challenge the problem, taking all the findings and discovering a right interpretation.
- **Team working**: Design Thinkers needs to collaborate, share their knowledge, discuss using visualization tools to better communicate and clarify what they have in mind.
- **Open to different perspectives/diversity**: Diversity can be understood as "encompassing collaboration in diverse teams, and the integration of diverse outside perspectives throughout the process".

All 28 items were graded on a 5-point Likert scale, with scores ranging from 'Not at all in agreement' to 'Completely in agreement'. Table 2 presents the 28 items detailed in this study:

Table 2.

Design Thinking mindset questionnaire (selected from (Dosi et al.)

Aspects	Items
Human centeredness	1. I actively involve users in diverse phases of the design process
	2. People are source of inspiration while identifying the direction of the design solution
	3. During the design activity I dedicate a considerable amount of time to understand what users need
Empathy	4. I can tune into how users feel rapidly and intuitively
	5. I am comfortable to see problems from the users' point of view
	6. I am comfortable to put myself into the shoes of user
	7. I easily empathize with the concerns of other people
Mindfulness and awareness of process	8. I am capable to recognize when there is the necessity to iterate one phase of the process
	9. I trust in the process to find new discoveries, rather than focusing on where the outcomes may fall
	10. I am able to recognize when we are in a divergent or convergent phase of the process
Holistic view	11. I am able to consider what I am doing from a broader perspective
	12. I am able to understand which are the impacts on the external environment of the solution we are proposing
	13. I am comfortable to insert into the final solution factors coming from a broader vision
Problem reframing	14. I think it is important to reframe the initial problem in order to achieve a good result
	15. I am interested in better understanding the problem that is given to us
	16. I am capable to reframe the initial problem statement
Team Working	17. I am comfortable to accept the group's decision even if I have a different opinion (removed after running Cronbach's Alpha)
	18. I prefer to work in a team rather than working alone
	19. I am comfortable to share my knowledge with my teammates
	20. I am comfortable to develop new knowledge with other teammates
Multi-/ inter-/ cross-disciplinary collaborative teams	21. I am comfortable working with people from outside of my organization
	22. I think in team is preferable having different competences
	23. I am comfortable to work with people having diverse perspectives and abilities from mine
	24. I like to spend time with people doing different work than mine
Open to different perspectives /diversity	25. I am comfortable to change my opinion
	26. I am open to collaborate with people having different backgrounds
	27. I find value in other people's diversity (perspectives, abilities)
	28. I believe that teams with diverse perspectives result in superior outcomes

The reliability of the answers of the scales was tested by the Cronbach's Alpha. The purpose of this test was to analyze the internal consistency of the answers based on the correlation between items on the same scale. Number of items, mean and standard deviation, and Cronbach`s Alpha values of the scales are summarized in Table 3, according to the interpretation of the results of (McFadyen, Webster, & Maclaren, 2006) based on the Cronbach`s Alpha coefficients, the internal consistency of three scales was significant.

Table 3.

Descriptive Statistic of Study Variables

Scale	Pretest (n= 120)			Posttest (n= 120)		
	Mean	SD	Reliability	Mean	SD	Reliability
Human centeredness	3.95	.740	.640	3.89	.620	.830
Empathy	3.53	.660	.720	3.87	.660	.708
Mindfulness and awareness of process	3.46	.515	.705	3.38	.427	.726
Holistic view	3.42	.405	.620	3.79	.677	.637
Problem reframing	3.69	.669	.674	3.94	.734	.650
Team Working	3.49	.551	.672	3.97	.607	.634
Multi-/ inter-/ cross-disciplinary collaborative teams	3.58	.627	.734	3.59	.721	.668
Open to different perspectives /diversity	3.54	.682	.723	3.43	.564	.675

Table 4 presents the Pair sample T-test analysis on Design Thinking mindset score

Table 4.

Pair sample T-test on Design Thinking mindset score.

Variables	Group Type	N	Mean	SD	Sig. two-tail
Human centeredness	PRE	120	3.95	.74	0.515
	POST	120	3.89	.62	
Empathy	PRE	120	3.53	.66	0.000**
	POST	120	3.87	.60	
Mindfulness and awareness of process	PRE	120	3.46	.515	0.150
	POST	120	3.38	.427	
Holistic view	PRE	120	3.42	.405	0.003**
	POST	120	3.79	.677	
Problem reframing	PRE	120	3.49	.551	0.012*
	POST	120	3.94	.734	
Team Working	PRE	120	3.69	.669	0.001**
	POST	120	3.97	.607	
Multi-/ inter-/ cross-disciplinary collaborative teams	PRE	120	3.58	.627	0.587
	POST	120	3.59	.721	
Open to different perspectives /diversity	PRE	120	3.54	.682	0.278
	POST	120	3.43	.564	

Note. P* < .05; p** < .01. p*** < .001.

Table 4 presents that out of 8 research variables, there are statistically significant differences in 4 research variables, namely Empathy, Holistic View, Problem reframing and Team working. In the following subsection, these differences are discussed.

Empathy

The analysis shown in Table 4 is the evidence of DITC, students' mindset score regarding empathy had been changing from (M=3.53) in pretest to (M=3.87) in posttest with p=0.000** (<0.05). It reveals that throughout the empathy stage of DTIC, students recognized the important to develop the best possible understanding of users, their needs, and the problems that underlie the development of solution. During the empathy stage, students also gained an empathic understanding of the people and the problem that they were attempting to solve by asking 5 whys and Kipling's question. This process entails studying, communicating, and empathizing with people to better understand their perspectives and motives, as well as immersing students in the physical world of "people" to gain a more intimate understanding of the problems, needs, and context in which they live. Table 5 presents some feedbacks from the students in the interview section.

Table 5.

Student feedback on empathy stage

Questions	*Please tell us what you think about status empathy stage?*
Responses	*Student ID_23: "In the Empathy stage of a Design Thinking process, you will develop the empathy, understandings, experiences, insights and observations on which you will use to build the rest of your design project"* *StudentID_08: "We cannot stress enough how important it is for designers such as us to develop the best possible understanding of our users, their needs. I was surprised at how much insight I and my team easily gained via practical empathy methods."*

Holistic View

In terms of problem-solving and understanding how best to improve errors and accidents, there are two types of approaches. There is the reductionist approach and the holistic (systems thinking) approach. When errors and accidents happen, a reductionist approach focuses on the error itself and addresses the "how" and immediate cause of the error's occurrence. For example, if a patient fell while getting out of bed the reductionist approach would say it was due to the patient's weakness. A holistic approach would come to a different conclusion.

From the analysis shown in Table 4, it was seen that DITC, students' mindset score regarding holistic view changed from (M=3.42) in pretest to (M=3.79) in posttest with p=0.003** (<0.05). It shows that fostering empathy and following the DTIC steps helped them with this mentality.

The holistic problem-solving approach reviews errors in the context of the larger whole and steps involved. Other essential parts of the system are considered and reviewed when determining not "how" an error happened, but "why" it happened within the context of the whole. It is obvious that practicing the empathy and define steps of DTIC could support enhancing this mindset. In interview section, students were encouraged to describe the differences that occurred before and after they practiced Design Thinking. The following are a few comments from students regarding these results (Table 6):

Table 6.

Student feedbacks on Holistic Point of View

Questions	*Please explain your viewpoint on problem-solving abilities. Is there any difference before and after this project? Which aspect do you think is important?*
Responses	*Student ID_11: Before: "when dealing with a complication, I often make assumptions about the constraints and obstacles that prevent certain solutions". After: "I tried to examine everything, I think is true about the situation … and then consider that it's not. The other person might not have the same information as me. They might have interpreted something differently."* *Student ID_38: "You are stuck on a single way of looking at a problem or solution and unwilling to think about it differently. You think since it worked before, it is guaranteed to work again. This kind of rigid thinking resists compromise". After: "I might be wrong! Or everyone could be wrong. Or I might be right, and there could still be a better way. Consider that there might be a solution I have not thought of yet."* *Student ID_98: "I do not like to hear that I am at fault and need to change. If someone hears they are wrong, it is natural to be defensive — which does not fix the conflict!" After: After all, I realized the only person you can control … is you!"*

According to the comments above, we can see that most of the students who participated in the experiment had developed the concept of problem solving and were familiar with the problem-solving steps via Design Thinking model. Students who had learned problem solving skills could achieve success at all stages of their lives by using these skills to solve their problems and problems.

Problem reframing

Problem Reframing enables to see the current situation from a different perspective, which can be helpful in solving problems, making decision and learning (Ellis, Grant, & Haniford, 2007). When people get stuck in recurring issues, such as a complicated situation or a complex problem, it is almost never because they are lacking a specific step-by-step plan for resolving the issue. It is seen as if they are trapped in their perceptions of the situation. From the analysis shown in Table 4 we can see that with DITC, students' mindset score regarding problem reframing has changed from (M=3.49) pretest to (M=3.94) posttest with p=0.012* (<0.05). It demonstrated that conforming to the DTIC steps would help with this mindset.

A participant of this experiment, for example, was searching for time management courses. It seemed he had signed up for many but none of them seemed to help him improve how he spent his time. Instead, if he explored the root causes of his time management problems by creating a fishbone diagram in the define stage, he listed all potential aspects and eventually discovered that the main problem is that he never followed through with any of the recommendations made during those courses. As a result, he shifted his perspective on the solution to his dilemma. The goal of reframing is thus to change one's viewpoint so that they are better able to behave – and possibly improve at the same time. Reframing one's outlook on a situation may also help people shift how they feel about it as well. Throughout Design Thinking task of this experience, some students stated that they have learned how to reframe the problem after getting stuck in "old way". Therefore, the score of this mindset was significantly improved in posttest. **Figure 4** depicts a picture taken during a class presentation by a group of students. Students used fishbone diagram to determine what was causing their inability to handle their financial condition.

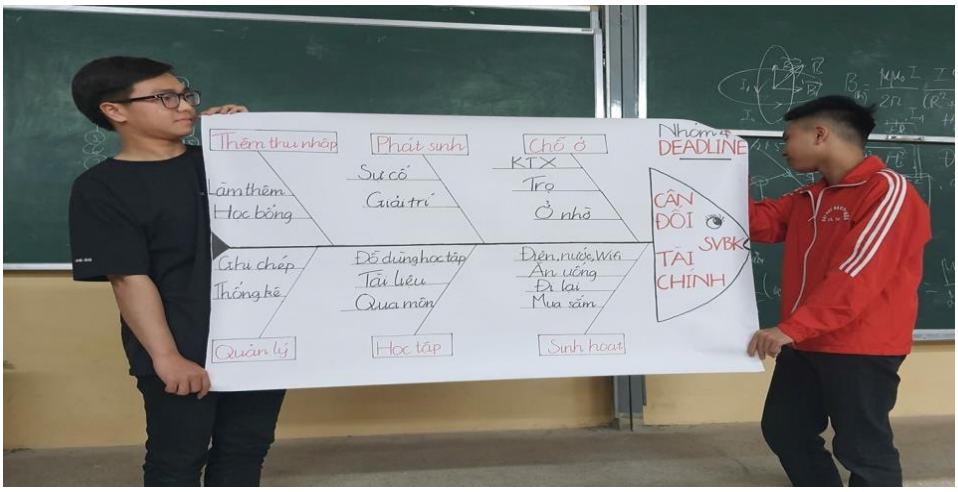

Figure 4. *Students used fishbone to define the root cause of the problem*

Team Working

Table 4 presents that the score of teams working variable shows statically significant difference. It raises from M= 3.69, pretest, to M=3.97 in posttest, with p=0.001** (<0.05) after one month working in group. We interviewed students to better understand the results, and most of them agreed that during the DTIC activities, students in groups had several opportunities to practice teamwork skills such as communication, persuasion, chair meeting, and conflict resolution. In the idea stage of DTIC, students often gave and received feedback that it was essential in any team-working situation. In prototype and test stages, they learned to give clear and effective feedback to others that they recognized was vital to keep the group process running effectively. It also helped to ensure that members would not get irritated and angry with the way that others were behaving. It followed those students who needed to receive feedback gracefully, and then act on it calmly. Some students realized that dealing with challenging people or circumstances, or even resolving a conflict, was something they would do on occasion. If the group were to find consensus, for example, during the idea stage, several members might need to be persuaded to make a specific decision. Furthermore, students stated that they were frequently involved in meetings during idea, prototype, and test tasks. As a result, they learned how to chair meetings as well as to act as facilitators and coordinators. In the interview section, students were encouraged to describe the differences that occurred before and after they practiced Design Thinking. Table 7 lists a few comments from students regarding these results:

Table 7.

Students' viewpoints on teamwork skill sets

Questions	*Please explain your perception of teamwork before and after this project. Is there a difference?*
Responses	*Student ID_ 07: Before: "I know that teamwork skill is essential for any students, however, I prefer to work alone since it seems faster way". After: "Working alone is faster way, but working in teams bring more ideas, more solutions that I never thought of. I love brainstorming sessions."* *Student ID_12: Before: "I am not very good at communication; therefore, I do not want to work in team, and I always struggle with peers because we do not understand each other". After: "From this course, I learned to view from other perspective and feel like I understand my team mate better."* *Student ID_ 117: Before: "I often avoid teamwork because I do not like other comment on my task or tell me what to do what not." After:" The obvious way to enhance teamwork skills is to be part of a team! There are lots of opportunities to do this in school and education. I could work on a class project in pairs or as a group. I could join a school sports team, orchestra, or drama production. I could participate in a school-wide charity event and encourage friends and family to contribute and take part too."*

A variety of studies have shown that collaboration in the Design Thinking process increases the vitality and innovation of the proposed solution (Du et al.; Leinonen & Gazulla, 2014a). It enables people to carefully analyze the problem, look at the issue from various perspectives, and think critically to find the best solution(Barrie, 2006; Carroll et al., 2010; Daniel, 2016; Leinonen & Gazulla, 2014a).

Discussion

The results of this study suggest that students hold a positive opinion about the steps in the Design Thinking process: first, they fully understand the problem; second, they explore a wide range of possible solutions; and third, they iterate extensively through prototyping and testing. According to the findings, students' Design Thinking mindsets have shifted in four areas that can be considered the heart of Design Thinking namely:

Empathy: The results showed that students recognized the importance of developing the best possible understanding of users, their needs, and the problems that underpinned the development of a solution throughout the DTIC empathy stage.

Holistic view: Holistic problem-solving looks at errors in the context of the bigger picture and the steps involved. It is self-evident that practicing empathy and the DTIC steps could help to improve this mindset.

Problem reframing: The results showed that students' mindset scores for problem reframing raised up. It demonstrated how adhering to the DTIC steps could aid in the development of this mindset.

Team Working: From the findings, we believed that DITC approach encouraged students to think creatively and openly, allowing them to identify the true problem and possible solutions. Educators could use Design Thinking to help engineering students develop a solution to a problem when they create a product, based on the findings.

Beside these four research areas that showed the differences before and after the DTIC was applied, we also further investigated other research variables that did not show any statistically significant difference. Human centeredness and Mindfulness and awareness of process were two such variables. We expected that DTIC would change these mindsets of the students too, but the statistical analysis did not confirm it; perhaps because of the limited time available to carry out the experiment, or because the nature of the problem was so broad that it may not have a direct impact on any specific person. In future, we intend to conduct experiments on more specific topics over the course of a semester to determine the impact of DTIC on Human centeredness, mindfulness, and process awareness. This results is in line with the study (Leinonen & Gazulla, 2014b) which proved that "Design thinking" did not only assist people in designing a solution, but also facilitated them during the process. Last, but not the least**, s**tudents can use the five stages of Design Thinking to carefully analyze the problem and think critically to find the best solution.

Conclusion, Recommendations, and Implications

The findings of this study revealed that the DTIC model influenced students' attitudes toward problem solving and teamwork in a positive way. Based on the obvious benefits of Design Thinking in class as demonstrated by the findings of this study, we propose that it was beneficial for students to apply the steps of the DTIC model in a flipped classroom. From there, it aids students in grasping Design Thinking concepts, allowing them to efficiently understand real-world problems. Especially in these times of COVID-19 outbreak, there is a need for a model that can support teamwork and problem-solving skills for online learning environment.

The teacher and educator can use DTIC for class activity to help students develop a solution to a problem. Students can use the five stages of Design Thinking in DTIC to thoroughly analyze a problem and think critically to find the best solution. It integrates students into the design of a product or solution. It also aids students' reintegration by examining the issue from a broader perspective. Design Thinking can be applied in a variety of contexts, such as a course design guide or as a method of team activities. Educators can customize their own contextual Design Thinking processes with model DTIC, accelerating the adoption of Design Thinking in education. The instructor can use the instruction of DTIC to progress from basic steps (empathy, description, ideas, prototyping, and experimentation) to subject-specific activities.

We also acknowledge the study's limitations. First, the survey forms returned were relatively small (N=120); in future, we will increase the sample size to make the results more realistic. Second, in addition to the Design Thinking mindset, which is objectively based on students' perception, we will investigate some problem solving and creativity scale to assess the impact of DTIC on the quality of solutions produced. Third, we will examine how technology support DTIC.

Acknowledgements

The research is sponsored by Hanoi University of Science and Technology (HUST) under project number T2020-TT-204.

References.

Androutsos, A., & Brinia, V. (2019). Developing and piloting a pedagogy for teaching innovation, collaboration, and co-creation in secondary education based on design thinking, digital transformation, and entrepreneurship. *Education Sciences, 9*(2), 1-13. doi:https://doi.org/10.3390/educsci9020113

Barrie, S. C. (2006). Understanding what we mean by the generic attributes of graduates. *Higher education, 51*(2), 215-241. doi:https://doi.org/10.1007/s10734-004-6384-7

Berg, J., Lindholm, J., & Högväg, J. How do we know that it works? Designing a digital democratic innovation with the help of user-centered design. *Information Polity*(Preprint), 1-15.

Brown, T. (2008). Design thinking. *Harvard business review, 86*(6), 84.

Burdick, A., & Willis, H. (2011). Digital learning, digital scholarship and design thinking. *Design Studies, 32*(6), 546-556. doi:https://doi.org/10.1016/j.destud.2011.07.005

Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., & Hornstein, M. (2010). Destination, imagination and the fires within: Design thinking in a middle school classroom. *International Journal of Art & Design Education, 29*(1), 37-53. doi:https://doi.org/10.1111/j.1476-8070.2010.01632.x

Cereja, J. R., Santoro, F. M., Gorbacheva, E., & Matzner, M. (2018). Application of the design thinking approach to process redesign at an Insurance Company in Brazil. In *Business Process Management Cases* (pp. 205-233): Springer.

Daniel, A. D. (2016). Fostering an entrepreneurial mindset by using a design thinking approach in entrepreneurship education. *Industry and Higher Education, 30*(3), 215-223. doi:https://doi.org/10.1177/0950422216653195

Dosi, C., Rosati, F., & Vignoli, M. (2018). *Measuring design thinking mindset, 1991-2002.*

Du, J., Jing, S., & Liu, J. (2010). *Shared design thinking process model for supporting collaborative design*.

Ejsing-Duun, S., & Skovbjerg, H. M. (2019). Design as a mode of inquiry in design pedagogy and design thinking. *International Journal of Art & Design Education, 38*(2), 445-460. doi:https://doi.org/10.1111/jade.12214

Ellis, M. W., Grant, M., & Haniford, L. (2007). Reframing problems in secondary education: Alternative perspectives, new insights, and possibilities for action. *The High School Journal, 91*(1), 1-5. doi:https://doi.org/10.1353/hsj.2007.0021

Gachago, D., Morkel, J., Hitge, L., Van Zyl, I., & Ivala, E. (2017). Developing eLearning champions: a design thinking approach. *International Journal of Educational Technology in Higher Education, 14*(1), 1-14. doi:https://doi.org/10.1186/s41239-017-0068-8

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

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. *Thinking Skills and Creativity, 26*, 140-153. doi:https://doi.org/10.1016/j.tsc.2017.10.001

Jamal, T., Kircher, J., & Donaldson, J. P. (2021). Re-Visiting Design Thinking for Learning and Practice: Critical Pedagogy, Conative Empathy. *Sustainability, 13*(2), 964.

Koria, M., Graff, D., & Karjalainen, T.-M. (2011). Learning design thinking: International design business management at Aalto University. *Review on Design, Innovation and Strategic Management, 2*(1), 1-21.

Leinonen, T., & Gazulla, E. D. (2014a). Design thinking and collaborative learning. *Comunicar. Media Education Research Journal, 22*(1), 12-20.

Leinonen, T., & Gazulla, E. D. (2014b). Design thinking and collaborative learning. *Comunicar. Media Education Research Journal, 22*(1).

Luka, I. (2014). Design thinking in pedagogy. *The Journal of Education, Culture, and Society, 5*(2), 63-74. doi:https://doi.org/10.15503/jecs20142.63.74

Lynch, M., Kamovich, U., Longva, K. 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. doi:https://doi.org/10.1016/j.techfore.2019.06.015

Mahe, N., Adams, B., Marsan, J., Templier, M., & Bissonnette, S. (2019). Migrating a Software Factory to Design Thinking: Paying Attention to People and Mind-Sets. *IEEE Software, 37*(2), 32-40. doi:https://doi.org/10.1109/MS.2019.2958646

McFadyen, A. K., Webster, V. S., & Maclaren, W. M. (2006). The test-retest reliability of a revised version of the Readiness for Interprofessional Learning Scale (RIPLS). *Journal of interprofessional care, 20*(6), 633-639. doi:https://doi.org/10.1080/13561820600991181

Moreno, M. A., Ponte, O., & Charnley, F. (2017). Taxonomy of design strategies for a circular design tool. In *PLATE: Product Lifetimes And The Environment* (pp. 275-279): IOS Press.

Mosely, G., Wright, N., & Wrigley, C. (2018). Facilitating design thinking: A comparison of design expertise. *Thinking Skills and Creativity, 27*, 177-189. doi:https://doi.org/10.1016/j.tsc.2018.02.004

Noel, L.-A., & Liub, T. L. (2017). Using design thinking to create a new education paradigm for elementary level children for higher student engagement and success. *Design and Technology Education, 22*(1), n1. doi:https://doi.org/10.21606/drs.2016.200

Norman, D. A. (1992). Design principles for cognitive artifacts. *Research in Engineering Design, 4*(1), 43-50. doi:https://doi.org/10.1007/BF02032391

Pande, M., & Bharathi, S. V. (2020). Theoretical foundations of design thinking–A constructivism learning approach to design thinking. *Thinking Skills and Creativity, 36*, 100637. doi:https://doi.org/10.1016/j.tsc.2020.100637s

Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important? *Review of educational research, 82*(3), 330-348.

Royalty, A. (2018). Design-based Pedagogy: Investigating an emerging approach to teaching design to non-designers. *Mechanism and Machine theory, 125*, 137-145. doi:https://doi.org/10.1016/j.mechmachtheory.2017.12.014

Sarooghi, H., Sunny, S., Hornsby, J., & Fernhaber, S. (2019). Design thinking and entrepreneurship education: Where are we, and what are the possibilities? *Journal of Small Business Management, 57*, 78-93. doi:https://doi.org/10.1111/jsbm.12541

Shé, C. N., Farrell, O., Brunton, J., & Costello, E. (2021). Integrating design thinking into instructional design: The# OpenTeach case study. *Australasian Journal of Educational Technology*, 33-52. doi:https://doi.org/10.14742/ajet.6667

Suchman, L. (2008). Feminist STS and the Sciences of the Artificial. *The handbook of science and technology studies, 3*, 139-164.

Wagner, T., & Cennamo, K. (2017). *Benefits and Challenges of Design-Based Learning in a Middle School Classroom*.

Wolcott, M. D., McLaughlin, J. E., Hubbard, D. K., Rider, T. R., & Umstead, K. (2021). Twelve tips to stimulate creative problem-solving with design thinking. *Medical Teacher, 43*(5), 501-508. doi:https://doi.org/10.1080/0142159X.2020.1807483

Wrigley, C., Mosely, G., & Tomitsch, M. (2018). Design thinking education: a comparison of massive open online courses. *She Ji: The Journal of Design, Economics, and Innovation, 4*(3), 275-292. doi:https://doi.org/10.1016/j.sheji.2018.06.002s

Zupan, B., Cankar, F., & Setnikar Cankar, S. (2018). The development of an entrepreneurial mindset in primary education. *European Journal of Education, 53*(3), 427-439. doi:https://doi.org/10.1111/ejed.12293