

The Students' Perspectives on Applying Design Thinking for the Design of Mobile Applications

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Abstract— Design Thinking (DT) is relevant for companies committed to developing a more creative and innovative application. DT provides a human-centered view of technological artifact design. Therefore, it is important to learn DT in Computer Science and Software Engineering courses as an analytic and creative process, in order to better prepare students for the software development industry. We conducted an empirical study with 17 postgraduate students in the context of mobile applications design. We used coding procedures from the Grounded Theory method for analyzing the obtained qualitative data. Based on the results, we identified some difficulties that participants experienced in using different DT techniques. The results of this study can help teachers understand the difficulties faced by students in learning DT and, consequently, help them to look for new teaching strategies for their classes. Moreover, these results can contribute to the software industry showing the competitive advantages of using DT in the design of the applications under development, especially in mobile applications.

Keywords – Design Thinking; mobile application design; qualitative analysis.

I. INTRODUCTION

Due to the rapid development of mobile applications and the highly competitive market, the software industry has required new skills from software engineers [1, 2]. Thus, current and future software engineers should be trained in order to obtain more comprehensive and high-level skills, besides programming skills [3]. One method that has given software engineers new skills and allowed them to design effective solutions is called Design Thinking (DT) [2]. Design Thinking has emerged among the important skills for the twenty-first century and has brought innovation to organizations [4].

Johansson-Sköldberg et al. [5] state that DT was considered the best way to be innovative and creative. DT is defined as a method for understanding problems and producing innovative, compelling solutions [6]. DT uses a systematic human-centered approach to explore the definition of problems and synthesizes solutions in a process encompassing inspiration, ideation, and implementation [7]. Some of the perceived outcomes of Design Thinking are: understanding and meeting the users' needs, and having a different way of thinking and innovation [8].

Due to the benefits of DT for new software products, it is important to disseminate it to software engineers and to teach it to current software engineering students. There is a current trend to help students shift from “technology-centered design” to “human-centered design” [9]. In the development for human-centered design, iteration plays a significant role, where design processes that are more human-centered are also involving more iteration [10]. According Mendoza-Garcia and Cardella [9], “teaching students the relevance of iteration will help them to develop skills to become what we can call “human-centered informed designers”. Design Thinking promotes the learning of social skills [8] and, consequently supports human-centered design.

Learning Design Thinking is highly complex due to the specific nature of its activities. Due to these difficulties in DT classes, instructors are trying to teach only the concepts, components and process of Design Thinking, and then carrying out practical activities applying these learned concepts [11]. This happens because DT students learn better by doing, after learning these basic concepts [11]. Moreover, their experience plays a key role in learning. According to Goldman et al. [11], the growing interest for learning DT raises questions about how this complex set of ideas, concepts, processes and techniques can be best taught.

Considering the context described above, it is necessary to have a better understanding of what are the perceptions of students regarding learning Design Thinking. To guide our research, we defined the following main research question: “What are the perceptions of students regarding learning Design Thinking?”. We focused on mobile applications due to the increase of this type of application in the software market.

Aiming at answering the main research question, we conducted an empirical study with seventeen postgraduate students who learned and applied Design Thinking in the design of a mobile application. We collected qualitative data through feedback questionnaires from participants after using the process and techniques of DT. We performed the analysis of this study using Grounded Theory procedures [12]. The results showed some difficulties that students experienced regarding Design Thinking and the techniques that they applied. These results can help teachers to look for new teaching strategies for their classes. In addition, the students pointed out some difficulties in using the process and techniques of DT.

The remainder of this paper is organized as follows. Section II presents theoretical background and concepts on Design Thinking and related work. Section III describes the Design Thinking process and some techniques. In Section IV, we describe the empirical study, while Section V presents its qualitative results. In Section VI we present a discussion of our findings. Finally, Section VII presents our conclusions and future work.

II. BACKGROUND AND RELATED WORK

In the latter half of the 20th century, design became an increasingly valuable resource [7]. Therefore, the design of products and services is a key component of business competitiveness [2]. Nowadays, rather than asking designers to make an already developed idea more attractive to consumers, organizations are asking them to produce ideas that better meet consumers' desires and needs [7].

To support this role, Design Thinking emerged as an approach to problem-solving that applies creative principles to a variety of fields in order to help businesses and individuals take innovation to a higher level [13]. According to Brown [7], Design Thinking employs the designer's sensibility and techniques to correspond consumers' needs with what is technologically feasible. Moreover, this business strategy can be converted into customer value and new market opportunities.

DT involves several stakeholders in the process, and offers and tests ideas rapidly. It supports iterative idea generation, constant review, and reporting on performance, where the development team elicits the decisions according to the goals [14]. Therefore, Design Thinking is an effective way to engage various stakeholders, such as software engineers, in addressing the consumers' needs [14].

According to Hiremath and Sathiyam [15], DT is increasingly used in software development organizations as a tool for innovation. DT follows a human-centered approach to thinking, giving equivalent importance to human needs, technical feasibility and business requirements [15]. The culture of innovation used in DT not only helps in the development of new products and services for customers, but also new strategies and concepts for organizations [13].

Mentzer et al. [16] state that Design Thinking helps students improve skills such as creativity, learning core subjects, problem solving and communication. It also teaches younger students how to work collaboratively. In addition, DT empowers students to acquire empathy towards others within and beyond their community [8]. In this way, the social and cognitive skills of students are upgraded [16].

Akili [17] presents a relationship between how designers think, learn and make decisions. In his work, the author shows that this relationship is the main reason why it is complex to teach Design Thinking. The author also presents how Design Thinking processes could be taught and learned. A solution proposed by author is to use a pedagogical model for teaching design, namely: Project-based Learning (PBL). PBL is a way for students to learn design with a more active and participative view.

Melles et al. [18] described the development of a Design Thinking curriculum of an Industrial, Interior, Communication and Digital Media Design course. Five similar programs and courses were used for preparing that curriculum, and also the authors employed their own Design Thinking practices. Additionally, the authors describe the difficulties during the implementation of the course, such as teaching the course for the first time, since it was necessary to align the students with the design background, and time limitations, which did not allow students to fully develop projects.

Retna et al. [8] performed a study that examined teacher's perceptions, experiences and challenges faced when adopting Design Thinking in Singaporean schools. The findings show that, in the perception of teachers, design thinking helped to improve some skills of students, such as problem solving and creativity. The results also showed several challenges such as inadequate resources, time constraints and the difficulty of using a new way of teaching and learning Design Thinking, since it is different from the traditional instructional teaching.

These studies present a discussion from the perspective of teachers on how they perceived Design Thinking. We have noticed the absence of studies that address the applicability of Design Thinking from the perspective of students. Also, there is a need for investigating the use of DT in the context of mobile applications. Thus, this work fills this gap by seeking to understand the perception of students when using DT for the design of mobile applications.

III. DESIGN THINKING PROCESS AND TECHNIQUES

Brown [7] suggests that Design Thinking is best thought of as a process of three spaces and not a sequence of orderly stages (see Figure 1). Design Thinking has three iterative stages: inspiration, ideation and implementation.

The first stage is Inspiration, which represents situations generated through interactions with stakeholders that motivate the search for solutions [14]. Ideation is the next stage in the process of generating, developing and testing a variety of ideas that may lead to solutions [14]. The final Implementation stage of design thinking plans a path to develop and run the selected concept [14].

Projects will loop back through these stages – mainly the first two [11]. The ideas can be refined at any stage of the design thinking process and may lead to new directions [14].

During the first two stages of the Design Thinking process some techniques are used. Below, we present some of the best-known techniques and how they are used in our empirical study (see Section IV).

1) *Personas*: a persona is a hypothetical archetype of a real user, which describes a user's goals, interests and skills [19, 20]. In order to describe personas, it is important to detail their characteristics, such as: name, occupation, family, friends, sex, age, ethnicity, education, socioeconomic status, goals, life story and tasks that (s)he can perform [19].

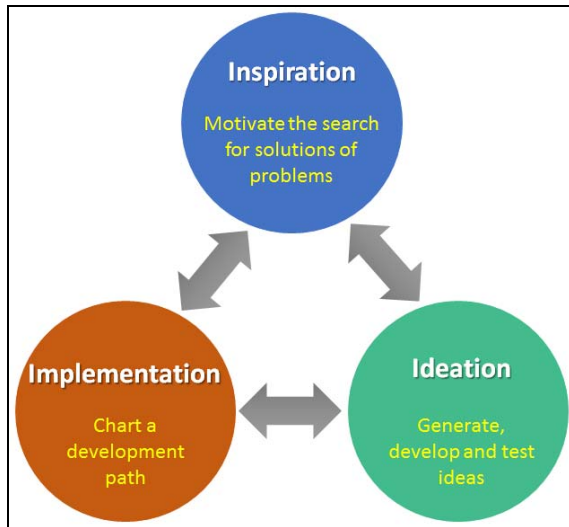


Figure 1. Three stages of DT Process (adapted from Brown [7]).

Software engineers can choose various ways to represent personas, but they are usually represented in textual form, enriched by a photo [21]. A Persona template is illustrated in Figure 2. Personas can motivate teams into thinking about users during the design process, making efficient design decisions without inappropriate generalization, and communicating about users to various stakeholders [22].

2) *Empathy Map*: Empathy Map (EM) is a technique that supports designing business models according to customers' perspectives. It develops a better understanding of a customer's environment, aspirations, concerns and behavior [19]. According to Gray et al. [23], the EM goal is to create a degree of empathy for a specific person (or group of people). Four different areas should be covered when creating an EM. Thus, one should ask: What does the person [23]:

- Hear? (how the environment influences the user);
- Think and Feel? (what happens in the user's mind);
- See? (what the user sees in his/her environment);
- Say and Do? (what the user says and how s/he behaves in public).

The author mentioned Pain (the frustrations, pitfalls and risks that the user experiences) and Gain (what the user really wants and what can be done to achieve his/her goals) as important areas to look for, resulting in the template depicted in Figure 3.

Figure 2. Persona template [21].

3) *Brainstorming*: Taking one provocative question at a time, the team may generate ideas [24]. Each idea is shared with the team. One rule during the brainstorming process is to postpone judgment. It is important to discourage anyone taking on the often obstructive, non-generative role of devil's advocate [25]. Instead, participants are encouraged to come up with as many ideas as possible. This lets the group move into a process of grouping and sorting ideas. Good ideas naturally rise to the top, whereas the bad ones drop off early on. Some of the key concepts of the Brainstorming are shown in Figure 4, such as thinking outside the box.

4) *Co-creation Workshop*: The goal of a Co-Creation Workshop is to convene a group of people you are designing for and then bring them into the design process. According to Sanders and Stappers [26], co-creation refers to any act of collective creativity, i.e., creativity that is shared by two or more people. Hirano et al. [27] suggest a co-creation process. The first phase is the Question Sharing. A method with a focus on dialog is used to share "why" or the goal and sense of value for broadening the themes. The second phase is Idea Generation. In this phase, recognitions and experiences in fieldwork with a focus on the sense of value that can be empathized with and direct observation are used to increase ideas. The third phase is Conception creation, where a concept and specific scene are visualized to make a prototype. Repeatedly, improvements are made. Finally, the fourth phase is Verification, where a user verification is conducted to bring out hidden needs by comparison with user needs and the visualized concept. Moreover, prototypes are used for verifying feasibility and business effects.

Personas and Empathy Maps are techniques that can be applied in the Inspiration phase of the Design Thinking Process. Brainstorming and Co-Creation Workshops can be applied in Ideation Phase. These techniques can provide more creativity and innovation to software development projects. Therefore, verifying the perception of students in apply these techniques in the design of mobile application is considered a relevant task. We do not present any technique of the implementation stage because we had no time to reach this stage in the courses where DT was applied.

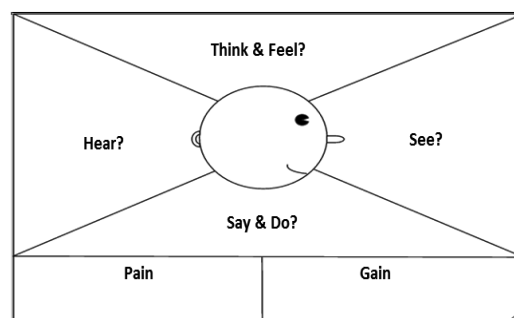


Figure 3. Empathy Map template [23].

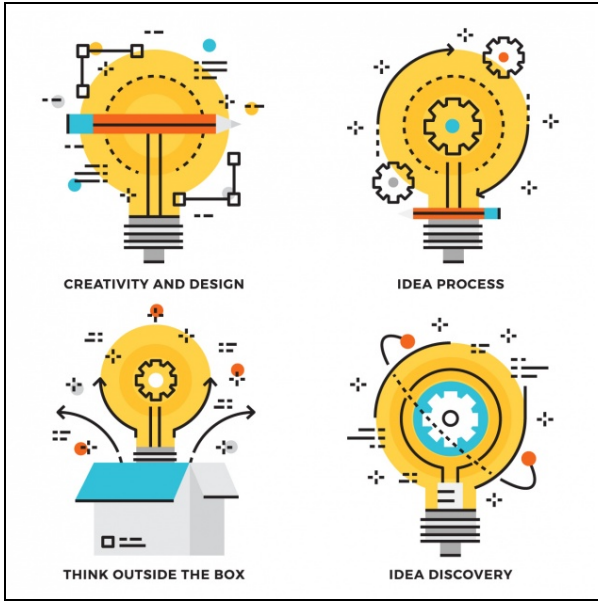


Figure 4. Key concepts of the Brainstorming.

The description of the empirical study is presented in the following section.

IV. EMPIRICAL STUDY

This section describes the performed empirical study. Through this study, we gathered the perceptions of students about the use of Design Thinking in the design of mobile applications.

A. Goal and Research Question

As mentioned, many researchers investigate Design Thinking from the perspective of teachers. However, it is relevant to investigate what students understand and learn about Design Thinking. Therefore, this empirical study aimed at characterizing the application of the Design Thinking process and its techniques during the design of a mobile application by students. This study is important to identify some gaps in the DT learning process and what can be improved in teaching DT.

Based on this, the empirical study has the following main research question: “*What are the perceptions of students regarding learning Design Thinking?*”. To answer this main research question, we defined the following research questions:

- RQ1: How is the Design Thinking process (first and second stages) perceived by the students?
- RQ2: How do students perceive the Design Thinking techniques?
- RQ3: Which difficulties were encountered when applying the Design Thinking process (first and second stages) according to the students’ perception?
- RQ4: Which difficulties were identified when applying the Design Thinking techniques in the students’ opinion?

In this empirical study, all research questions were answered from the perspective of students.

B. Participants

The empirical study was conducted with postgraduate students with the following degrees: Computer Science Specialist, Master and Doctor. The courses were taught at Federal University of Amazonas (UFAM) and the University Center of the North (UNINORTE) in Brazil. Seventeen students agreed to participate in this empirical study. They signed a consent form and filled out a characterization form. The characterization form addressed the participants’ expertise in software development projects. This form was employed to categorize the subjects as having: none, low, medium or high experience regarding their participation in software development projects. The second column (Expertise with software development projects) in Table 1 shows each student’s categorization respectively and the project they were assigned to.

We categorized our subjects into:

- High experience: when a subject had more than 5 years of experience with software development projects in the industry;
- Medium experience: when a subject had from 1 to 4 years of experience with software development projects in the industry;
- Low experience: when a subject had at least one year of experience with software development projects in the industry;
- No experience: when a subject had no prior experience with software development projects in the industry.

The students created the groups by convenience, i.e., they decided who would be part of their group. Overall, there were five groups of three or four students each (see third column of Table 1). Each group had a different mobile application development project. In Project 1, the group designed an application that provides information about events that are occurring in the city in the current day when the user searches for events. In Project 2, the goal of the designed application is to manage the requests for a breakfast company.

TABLE 1. STUDENT PROFILE CHARACTERIZATION

Student	Expertise with software development projects	Project
S01	None	Project 1
S02	Medium	
S03	High	
S04	High	Project 2
S05	Medium	
S06	Medium	
S07	Medium	Project 3
S08	High	
S09	Medium	
S10	Low	Project 4
S11	None	
S12	None	
S13	Medium	Project 5
S14	Medium	
S15	Medium	
S16	None	Project 5
S17	Medium	

In Project 3, students designed an application to automate the cargo inspection process of a company. In project 4, students designed an application that provides access the main services periodically offered by a university. In project 5, students designed an application to allows the registration of a complaint and provides information to the government agencies.

C. Preparation

At the beginning of the course, the Design Thinking Process (presented in Figure 1) and the techniques (presented in Section III) were introduced to the students. During the course, to assimilate the contents, the students did exercises and asked questions to the teacher in order to better understand the applicability of the techniques. The teacher emphasized that in Design Thinking, innovation is a key goal. In this study, we consider innovation the translation of an idea or invention into a good or service that creates value for customers. The students were aware that their performance in this study would also be part of the final exam of the course.

D. Execution

The mobile application design process was carried out following the first two stages of the design thinking process suggested by Brown [7] (see Figure 5): Inspiration and Ideation Phase. The Implementation Phase was not performed because there was a short period of time to allow the students to apply all stages of the design thinking process. Therefore, they would not have had enough time to implement the mobile application. Moreover, in this study, the students only applied the techniques that were introduced in Section III.

In the first phase (Inspiration Phase), students used the following techniques: Personas and Empathy Map. In this phase, the students tried to emphasize with the users, understanding their point of view. In this phase, the students tried finding out what the real needs of users who would use the applications were. The results of this phase were the Personas and Empathy Maps created by each participant.

In the second phase (Ideation Phase), the students applied the Brainstorming and Co-Creation Workshop techniques. By using the Brainstorming technique, each participant presented and explained details of the created personas. In addition, discussions took place on the user needs that were identified through the use of the Empathy Map.

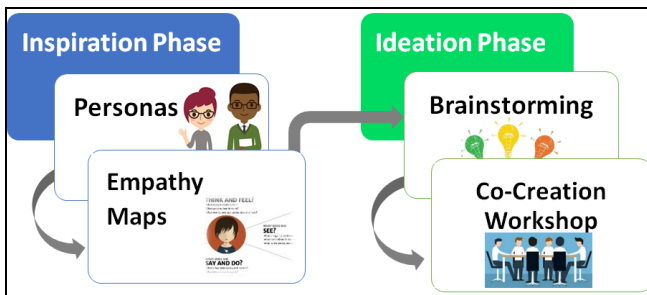


Figure 5. DT Process and Techniques used in empirical study.

TABLE 2. ORDER OF THE TECHNIQUES USED PER PHASE

Phases	Techniques used	Techniques used in combination
Inspiration	Personas	None
	Empathy Map	None
Ideation	Brainstorming	Personas and Empathy Map
	Workshop Co-Creation	Personas, Empathy Map and Brainstorming

The application of brainstorming focused on the identification of the application requirements and in the creative solution of the identified opportunities. The created personas served as a stimulus to the team during this process. After that, the students performed the Co-Creation Workshop. This technique intended to promote discussion and to generate innovative ideas on the applications' interfaces. During the Co-Creation Workshop, the students used the personas, the empathy maps and the creative ideas identified in the Brainstorming. These artifacts previously created served as basis in the decision-making. As a result of the Co-Creation Workshop, the main functionalities of the application were defined, and the main screens of the mobile application were sketched. One person of the group in a paper noted all decisions that were being taken.

For each technique (for both phases), the participants had one hour for perform the activity. Participants did not use any tool to support these activities. After using the DT process and techniques, the students reported their perceptions through a questionnaire.

V. QUALITATIVE DATA ANALYSIS

We carried out an analysis of the qualitative data that we obtained. The comments that the students gave provided data on their difficulties and questions during the use of DT. The qualitative analysis was based on the procedures of Grounded Theory (GT) [12].

The collected qualitative data were analyzed using a subset of the stages of the coding process suggested by Strauss and Corbin [12] for the GT method: the open coding (1st phase) and axial coding (2nd phase). When analyzing the qualitative data, we created codes related to the comments of the students (open coding - 1st phase). Then, the codes were grouped according to their properties, forming concepts that represent categories and subcategories. Finally, these codes were related to each other (axial coding - 2nd phase). The theoretical saturation was not reached [12], therefore, the selective coding was not performed (3rd phase of the GT method). However, the stages of the open and axial coding were enough to understand the perception of the students to apply the process of Design Thinking in the design of a mobile application. Also, we managed to identify their difficulties.

A. Analysis of the Purpose of the Design Thinking process (RQ1)

This subsection presents the analysis of the students' perception regarding the purpose of DT. From the perception of the students, we have identified three major purposes of

DT for designing mobile applications: (i) understanding the users' needs and desires, (ii) understanding the mobile application, and (iii) interaction between the project team.

Regarding the understanding of the users' needs and desires (i), the students believe that DT allows them: to place themselves not as mobile application developers, but as users; to understand how the users think, do, dream and what are their real needs; and to develop a mobile application that can help users (see quotation from S06 below). Also, it allows them to see the context differently, focusing on the user (see quotation from S11 below).

"Using Design Thinking helped us enough to fill the shoes of the users instead of being application developer. It helped us understand how the users think, do, dream and what are their real needs to develop the application so we can help". (S06)

"You can see the world differently, much more focused on your neighbors". (S11)

Regarding the understanding of the application (ii), the students stated that DT helped them to have ideas to develop the mobile application and allowed them to generate a different application that catches the attention of the target audience (see quotation from S12 below). It also allows the ideas to generate possible functionalities for the mobile application (see quotation from S14 below). They also stated that DT allowed them to create a mobile application together with their team to achieve better end results (see quotation from S11 below). Finally, they stated that DT allows understanding that the mobile application should have something different from anything that the user has seen and used (see quotation from S12 below).

"I believe I could help with my ideas to develop what we have done today in relation to the application, I find something different and that can draw public attention". (S12)

"I saw some of my ideas go beyond the paper and receive possible functionalities for the application". (S14)

"I discovered that the main goal at that time was to create together for a better end result". (S11)

"(...) to make the target audience use the application because it is unlike anything that the user has ever seen or used". (S12)

Regarding the interaction with the team (iii), participants said that DT: allows the development of the project to become much more interactive, dynamic and efficient (see quotation from S16 below); makes the development team listen to what others are talking about and to think how personal attitudes influence the ideas of others (see quotation from S11 below); and allowed them to check whether the trajectory of the mobile application is correct (see quotation from S16 below).

"I could see a great interaction (...) in the team causing the development of the Project to become much more interactive, dynamic and efficient". (S16)

"(...) not just be quiet when the others talk, but fully hear what they are talking about. I also started to think more about my actions and how it somehow could influence the ideas of others". (S11)

"(...) We have an idea [if] the software we are producing (...) is in the right track". (S16)

Overall, we also identified that, for the students, DT aims to involve the development team from a collective (see

quotation from S09 below) and personal (see quotation from S09 below) perspective. For subject S09, the techniques that allow collective engagement are Co-creation Workshop and Brainstorming. Additionally, the techniques that allow personal involvement are Personas and Empathy Map.

"The collective (...) involves team members, the engaging and the discussion of improvements, features (...)". (S09)

"The staff (...) just involves the target person, the user. (...) We can understand our audience, what we will achieve it and how can we reach it". (S09)

B. Analysis of the Purpose of the Design Thinking techniques (RQ2)

The students also provided their perceptions about the purpose of the DT techniques for the design of mobile applications: Personas, Empathy Map, Brainstorming and Co-creation Workshops.

Regarding the Personas technique, the participants believe that it: helps in creating new ideas for mobile applications and understanding how the users think and like something (see quotation from S05 below); helps to prepare in the functionalities of the application in a creative and innovative way (see quotation from S07 below); allows thinking about developing an idea through a character (see quotation from S04 below); allows to understand that one cannot please all users, but should seek to please / draw the attention of most of them (see quotation from S15 below); allows the identification of expectations and needs of people with respect to a context (see quotation from S04 below).

"Personas helped me come up with new ideas, and understand how users think and what can please them in order to develop something (...)". (S05)

"Personas (...) helped me create, in a creative and innovative way, the application features". (S07)

"In Personas (...) when I think of developing an idea, and something I could not put into practice, I think about persona". (S04)

"And through the persona we can see that (...) we cannot please everyone but we can please / draw the attention of many of our users. It helps us see that we can always make changes to better suit our users". (S15)

"[Persona] helps us think of the needs and expectations of people in relation to a context". (S04)

Regarding the Empathy Map, the students said that this technique allows each project member to think differently about each user's profile (see quotation from S16 below), allows to see clearly errors and improvements that have not been previously seen (see quotation from S15 below), and allows the software engineers to put themselves in the place of the user without worrying whether it can be implemented (see quotation from S08 below).

"The Empathy map makes each project member think differently for each user". (S16)

"It was possible to clearly see mistakes and improvements I could not see before through my way of thinking". (S15)

"I tried to abstract the coding and really put myself on the user's place without worrying if it could be implemented". (S08)

With regard to Brainstorming, participants described that this technique allows discussing ideas in a quite fun and interactive way, while it helps in creating new ideas in

collaboration with colleague (see quotation from S05 below); It also allows sharing ideas and choose the best ideas for the application under development (see quotation from S17 below). In addition, the subjects indicated that the discussion of the Personas within the Brainstorming facilitated teamwork (see quotation from S07 below).

“Brainstorming, with no doubt, is one of the richest, (...) as the discussion of ideas can be quite fun and interactive, and the opinion of the teammates can help a lot in creating and analyzing ideas”. (S05)

“[In Brainstorming] all members share ideas and choose the best ideas to implement in the application”. (S17)

“My team colleagues remind me that I also needed to look at the Personas that were created. This tip also facilitated teamwork”. (S07)

Regarding the Co-creation workshop, participants believe that this technique allows the interaction and vision of each team member to improve application (see quotation from S08 below). Also, it allows to think of a simple and easy way instead of having a robust idea (see quotation from S07 below) and it helps to think of new features (see quotation from S17 below).

“This interaction between team members only enriches the app”. (S08)

“[When] someone thought of a robust idea, another member thought of a simpler and easier way”. (S07)

“[Co-creation workshop allows having] (...) several ideas, but we had to select some ideas to avoid the screens becoming polluted and too complex. However, through these thoughts it was possible to think of new features through the user needs”. (S17)

C. Analysis of the Difficulties of the Design Thinking process (RQ3)

This subsection describes the difficulties perceived by participants when using the first two stages of the DT process and the employed techniques. From the perception of the students, we have identified four major difficulties in applying the first two stages of the design thinking process: (i) difficulty of using Design Thinking, (ii) difficulties related to the interaction inside the team, (iii) difficulties related to the needs and desires of users, and (iv) difficulties related to understanding of the application.

Regarding the difficulty of using Design Thinking, participants said they had difficulty in: understanding the purpose of the DT techniques (see quotation from S16 below); think creatively (see quotation from S12 below); have ideas for the application interface (see quotation from S14 below); and that the short time affected the project execution (see quotation from S01 below).

“(...) a difficulty was the initial understanding of the purpose of the techniques in the development, which was getting quite explicit when running the project”. (S16)

“(...) my greater difficulty was to understand and think creatively under the suggestions of Design Thinking”. (S12)

“(...) mainly, I had great difficulty in having ideas for the application interface”. (S14)

“Another difficulty was the time to carry out the project”. (S01)

With regard to the difficulty of the interaction between the team members, the students mentioned that one of the biggest difficulties was that they had to use the Design Thinking process (see quotation from S11 below).

“One of the biggest difficulties I believe was (...) discussing with the team members and try to reach a consensus that would be the most ideal, the debate of opinions about something”. (S11)

Regarding the difficulty of identifying the needs and wants of the users, the participants had difficulty regarding how to create empathy with the user in order to identify the needs of users for the application being developed (see quotations from S05 and S09 below):

“It was also difficult to try to put myself in the place of the user and create a whole story about him [end-user]”. (S05)

“It is very difficult to think and act like someone else (...) not taking into account the expectations of those who will actually use it”. (S09)

Subject S06 emphasized that this was difficult because they had no training directed to the user (see quotation from S06 below).

“(...) since we are more focused on technical aspects, we do not usually do this type of exercise, writing a life script of someone else”. (S06)

With regards to the difficulties related to the understanding of the application, the students had difficulty in defining the overall view of the application using Design Thinking (see quotation from S05 below).

“One of the biggest difficulties I believe was trying to get into a consensus regarding the idea for the application” (S05)

D. Analysis of the Difficulties of the Design Thinking techniques (RQ4)

Students also provided their perceptions of the perceived difficulties in using the DT techniques for the design of mobile applications: Personas, Empathy Map, Brainstorming and Workshop Co-creation.

Regarding the difficulty of using the technique Empathy map, participants had trouble: thinking like someone else (in this case, the end user) (see quotation from S15 below); and creating a whole context for this user (see quotation from S05 below).

“I found it difficult to think like another person with other types of thinking”. (S15)

“It was difficult (...) to create a whole story about him [the user]”. (S05)

Regarding the difficulty of using the Personas technique, the students said that: it was difficult to think of a fictitious user (see quotation from S03 below); and in the Empathy map, it was difficult to think like someone else (see quotation from S15 below).

“(...) create a pretend user with problems that can be real”. (S03)

“(...) because I had to think like another person with other types of thinking” (S15)

Regarding the difficulty of using the Co-creation workshop technique, it was difficult because of the little team connection (see quotation from S02 below). Another perceived difficulty was to add new features and deciding where they should go in the application (see quotation from S03 below).

"(...) the workshop was what actually gave us more work because of the [little] bond inside the team".
(S17)

"(...) the most difficult was to have ideas to improve what we had already thought of, such as the screens and adding new features, and where these features would be in the application" (S03)

With regard to the difficulty of using the brainstorming technique, students had trouble thinking of creative, innovative and intuitive applications for users (see quotation from S13 below).

"(...) because we had to think of something innovative, creative, and that was intuitive at the same time for the user". (S13)

VI. DISCUSSION

During this empirical study, several perceptions were observed. Some of these perceptions in applying the first two phases of the Design Thinking process and the techniques applied for the design of mobile applications are discussed below.

A. Perceived benefits and difficulties

With respect to the understanding of user needs and desires, some participants think DT helps to better understand the users. This occurs from the initial phase of the DT process because students are encouraged to think as the users. DT guides students to think and reflect on the needs and wishes of the user. However, some other participants said they had difficulty in understanding the needs and wants of users. This may have occurred because the participants have difficulties to empathize or do not how they should put themselves in place of the user.

Regarding the understanding of the application, DT helps to think of innovative features for the application. This, in a way, guides the student to get out of his/her comfort zone and to think and create features / new interfaces for the application. This shows the advantage of DT when compared to other software development processes.

For some participants, DT helps improve the interaction inside the team. Instead of centralizing the design of the application in a single person, as it sometimes occurs in the development of traditional software, DT makes the software development process more interactive and dynamic. For these participants, DT makes everyone in the team to contribute in the design of the application. This way, everyone can suggest new features and improving existing ones. Nevertheless, other participants stated that they had difficulties during the interaction as a team. These participants stated that since the discussions had to come to a consensus, it was a complicated task. For example, what would be the availability of a particular feature in the

application interface? Another issue that the participants pointed out was the little connection inside the team. This occurred because the students had difficulties to discuss their views with colleagues.

The Personas technique, specifically, helped in understanding what can please a large proportion of users. Participants commented that if various personas are described, more users may be represented in the application. In addition, a participant may care to describe some features that other team member did not think of. This type of specificity of each persona can generate discussions between the team members, thereby improving the completeness of the application. With regards to the Empathy Map, as in the use of Personas, it supported the students to describe specific aspects of the potential users, such as the users' needs and desires. The participants used this information to group discussion, helping identify discrepancies the needs and desires of different users represented in Empathy Map. However, some participants reported difficulties using both techniques. This occurred because the participants had to understand the users by looking at the world through their eyes. Unfortunately, this skill is not common, it requires prerequisites, and is considered by most people to be difficult to understand and learn.

In Brainstorming, one of the mentioned benefits was the sharing of ideas and the fun way to debate them. Through this technique, the team members have improved the implementation of the project. And during the Co-creation workshop, as all team members are realizing that the ideas are taking shape on paper, two of the benefits identified were: the interaction between team members will occur and the vision of the members will converge to the same. In addition, participants commented that this technique also provides the generation of innovative ideas, as the team members have in mind that they need to "get away from the standard" already adopted in the software market. Therefore, they seek to "think outside the box" and develop something different and innovative. However, some participants said that it was hard to think creatively. In addition, some participants were focused only on their own proposed solution. This meant that they had an initial difficulty to discuss with the team the new alternatives and new ideas that were being suggested.

B. Lessons learned on teaching Design Thinking

One of the lessons learned in this case study was the time used for teaching and applying design thinking in the classroom. Having been taught and applied in a postgraduate course with a total duration of two weeks, the time turned out to be too short for the execution of the projects. In this course, in a first stage, the teacher's focus during the classes was to present the theoretical part of DT and its techniques. Later, in the second stage, the focus was to use in practice the first two stages of the DT process and techniques for the design of mobile applications. In other words, the groups met and applied the DT techniques in their projects. The professor found that the time available to apply DT (1 week) would be enough to use the techniques, because they are simple to apply. However, students commented that the time

was short and therefore it might have influenced some of the application design decisions. In this sense, the teachers who will teach DT should keep in mind that even if the techniques are simple to apply, students need more time to assimilate and put into practice the learned content. For future classes, this result indicates that it is necessary to provide students with more time to discuss the phases that compose the DT process and apply other techniques in their projects. Discussing the phases of DT process would permit that the students understand better each phase and discover that Design Thinking is a very flexible and adaptable process. In addition, combining other DT techniques could help students better understand the problem, express their difficulties and propose solutions more appropriate to the context of the software. For instance, the Storyboard technique can be used together with the Brainstorming technique, to aid in the generation of new ideas (Ideation Phase). It is also relevant to present the software tools that can support the DT techniques. For example, the Smaply tool [28] supports the Personas technique (Inspiration Phase).

Also, it is necessary to expand the knowledge on concepts such as creativity/innovation and design rationale. McCall [29] states that some methods for rationale elicitation and documentation can encourage creativity in software design by identifying and promoting feedback-driven critical conversations in projects. The author still states that critical conversations are rationale discussions in which the ideation is interlaced with evaluation of those ideas in which the feedback from evaluation leads designers to invent new ideas [29]. Design rationale is advantageous and can lead to better design results [30]. According to Tang et al. [30], designers who explicitly reason about their design decisions generate better designs. Moreover, design reasoning seems to help inexperienced designers. Therefore, it is relevant consider this concepts e reflections in teaching Design Thinking.

Finally, we noticed in this case study that the interaction between the participants inside the team can influence the implementation of the project. For this reason, during the application of techniques, we try to encourage students to create the most relaxed environment possible, so that students could always expose their ideas, without worrying about whether the idea would be too simple. We suggested that all the ideas that were shared among the team members were not judged negatively, but always seeking improvement. Brown [31] states that the team should always hold positive discussions in order to reflect on what can be improved so that the design of the application can evolve. However, there were participants who did not feel free to comment their ideas because they were shy and had the fear that their ideas were not as good as the ones of the other colleagues. To help participants with this type of behavior, new techniques or strategies could be proposed to help them express their ideas.

VII. CONCLUSION AND FUTURE WORK

This paper presented an empirical study the aimed to identify the perceptions of students in the design of their mobile applications. The empirical study aimed to answer the research question “*What are the perceptions of students*

regarding learning Design Thinking?”. To answer this question, the empirical study had the participation of 17 graduate students. The students were divided into 5 groups, in order to design different mobile applications.

The results of this empirical study show two major results. The first result analyzes the students’ perceptions about Design Thinking and its techniques. Students considered DT valuable to their mobile application projects. This is indicated directly by the answers on research questions RQ1 – “*How is the Design Thinking process (first and second stages) perceived by the students?*” and RQ2 – “*How do students perceive the Design Thinking techniques?*” Second, the students described their difficulties when applying the Design Thinking process and its techniques. This is indicated by the answers on research questions RQ3 - “*Which difficulties were encountered when applying the Design Thinking process (first and second stages) according to the students’ perception?*” and RQ4 – “*Which difficulties were encountered when applying the Design Thinking techniques in the students’ opinion?*”

Based on the qualitative data, from the point of view of the students, DT helps to design an application from two perspectives: personal and collective. Regarding the personal perspective, DT allowed students to understand by themselves what the users’ needs of the mobile application are by using the techniques of Personas and Empathy Map. Since these techniques were applied individually, the students consider these techniques as being from the personal perspective towards the collective perspective because they help students work more as a team. This happened because the Brainstorming and Co-Creative Workshop techniques guide the team to discuss/create/develop aspects related to improving the application from different points of view.

Design Thinking offers a methodology built on a human-centered approach through direct observation and identifying peoples’ needs. Therefore, to develop the capabilities of design thinking as key tools for the design of mobile applications to prepare the students (future software engineers) with the generic capabilities to operate in software industry. Moreover, we observed trough this empirical study two lessons learned on DT teaching: time used for teaching and applying DT in the classroom and interaction among the participants of the team.

As future work, we intend to replicate this empirical study with a larger sample. We also intend to carry out further studies with Design Thinking, investigating whether indeed the design and applications generated by using this process were more innovative and creative than if designed and developed using a traditional approach. In addition, we would like to investigate whether applications developed using DT have fewer usability problems and provide a better user experience than applications developed by other software processes.

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