Design Thinking as a Toolbox for Requirements Engineering Education: Lessons from the Classroom

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ABSTRACT

Context: Design Thinking (DT) has gained popularity in software engineering education as a human-centered and collaborative approach to solving complex problems. In Requirements Engineering (RE), DT can complement traditional practices by offering concrete tools that support creativity, empathy, and stakeholder engagement. **Goal:** This paper presents a classroom experience in which DT was introduced not as a linear process, but as a toolbox of techniques that students could freely explore and apply to real-world projects involving external clients. **Method:** Students worked in teams on practical RE assignments, each involving a different system and real users. They applied DT techniques of their choice, supported by a curated selection guide called "Universo de Seleção," which helped them identify and adapt methods suitable for their specific contexts. We conducted a qualitative analysis of students' reflections gathered through reports and surveys. **Results:** The toolbox approach led to improved understanding of requirements elicitation, better engagement with users, and development of key skills such as teamwork and communication. Students also demonstrated autonomy and critical thinking in selecting techniques appropriate to their project contexts. **Conclusion:** This experience highlights the potential of using DT as a toolbox to enrich RE education, offering flexibility and encouraging deeper engagement with both technical and human aspects of requirements elicitation.

KEYWORDS

Requirements Elicitation, Design Thinking Toolbox, Teaching Process, Experience Report.

1 Introduction

Requirement Engineering (RE) is a critical stage in the software development process, as it ensures that the needs of users and stakeholders are effectively understood and addressed [5, 26]. However, teaching RE remains challenges in Software Engineering (SE) curriculum due to the need to understand problems from multiple perspectives and to adopt a holistic view of the system [23]. The complexity and abstract nature of RE concepts further intensify these challenges [26], especially in undergraduate programs, where the content is often covered superficially, limited to a single unit or introductory chapter [17, 23].

Given this scenario, educators must rethink pedagogical strategies promoting a stronger RE foundation. One promising alternative is Design Thinking (DT), which can complement traditional RE practices by helping students translate user needs into well-defined requirements [26]. From an educational perspective, DT can foster the development of useful capabilities for professional environments such as creative, adaptive, and collaborative skills by promoting human-centered experiences focused on solving complex problems [13, 14].

Brenner et al. [3] defines three perspectives for adopting DT: as a mindset, as a process and as a toolbox. Despite its multidimensional nature, DT is often introduced in educational settings primarily as a process [1, 23, 26]. As students will be responsible for developing final products [27], it is necessary to introduce DT beyond a process in RE education. Some students may not realize that DT techniques can be applied outside the processes described in the literature, or may choose not to follow a structured DT process. Therefore, effectively integrating DT into SE curricula represents an opportunity to enrich student education and align it more closely with real-world industry demands.

In this paper, we report a classroom experience on applying DT in teaching RE in an undergraduate SE course. Our pedagogical strategy introduced DT not as a fixed process, but as a flexible toolbox. Rather than following a rigid model, we introduced students to a set of DT techniques, supported by a resource called the Selection Universe [15], a guide designed to help them explore and choose the most appropriate techniques for their specific context.

The application of DT techniques took place over three practical sessions, each lasting two hours. During these sessions, students employed various DT techniques to support the elicitation of requirements in real projects they had proposed. Students reported improved understanding of user needs and the elicitation process, and the development of critical skills such as teamwork, empathy, communication, and collaboration. These findings indicate that integrating DT into RE teaching represents a practical and effective approach that can enhance student engagement and promote active learning. Furthermore, using human-centered techniques

contributes to developing practical competencies relevant to both academic settings and the professional environment.

Our work contributes by offering a more flexible and student-centered implementation, supported by a selected toolbox that enables the choice and adaptation of techniques. By describing the course context, the teaching strategies employed, the observed outcomes, and the lessons learned, this report aims to provide practical and reflective insights for educators interested in incorporating human-centered approaches into the teaching of RE.

2 Background and Related Work

2.1 Design Thinking

Dobrigkeit and De Paula [7] defines Design Thinking (DT) as an approach that provides creative and human-centered solutions. DT is also an adaptable approach for problem-solving that focuses on understanding users' needs and developing innovative solutions [18]. One of DT's key points is the visual representation, so an idea under development becomes tangible and accepted, ensuring that those involved recognize the intended outcome during creation [9]. In this context, Sohaib et al. [21] claims that DT provides a process framework that enables constant communication between the development team, stakeholders, and target users. This approach includes various tools and methods for gathering information related to user needs and generating creative ideas.

SE integrates DT in different contexts, within its application observed in academic and industrial environments [19]. One of its areas that benefits from using DT is Requirements Engineering (RE). RE is an iterative socio-technical process that addresses different aspects of a software requirement, consisting of various phases such as elicitation, analysis and negotiation, documentation, verification and validation, and management [8]. RE assists in understanding how to solve a problem through software, and therefore, the quality of its processes' execution directly impacts the quality of the systems under development [6]. Through the use of elicitation techniques, RE also aids in gathering requirements from the stakeholders of a system [6].

Hehn and Mendez [10] states that one of the differences between DT and RE lies in how the activities are carried out — while DT is more oriented towards prototype generation as part of its philosophy, RE is more focused on using technical representations, such as diagrams. Furthermore, artifacts generated through elicitation techniques are limited only to the system's scope [10]. Despite presenting differences in their processes, Hehn et al. [11] highlights that these differences can be seen as complementary activities.

RE benefits from using DT once DT combines the human-centered work mode with the formal and technology-driven world of RE, aiming to develop human-centered solutions effectively [11]. Using DT for RE also may support surpassing existing challenges on RE, such as documenting and specifying requirements [6] through generating well-documented DT artifacts. Canedo et al. [4] assert that DT enhances the requirements-gathering process, allowing the identification of misunderstandings through prototyping and facilitating the implementation of the solution.

DT leads to greater efficiency in the requirements definition process, as the focus is on understanding the problem and defining requirements that meet the real needs of users [26]. It results in reduced uncertainty and a lower risk of gaps in understanding, as the process emphasizes constant communication and feedback cycles. The benefits of using DT for RE activities include enhancing collaborative efforts within development teams, supporting the identification of requirements that accurately reflect users' needs, and promoting the development of better software solutions [20].

2.2 Teaching Design Thinking for Requirements Elicitation

Students present differences in their knowledge, experience, and problem-solving abilities during the learning process [24]. Thus, it becomes important to adopt approaches that consider these factors while supporting students develop their skills. DT is emerging as an innovative and popular teaching method, being employed as an unconventional approach for developing problem-solving skills, creativity, and innovation [29]. Implementing DT makes practical engineering teaching more engaging and effective, helping students learn empathy with end-users, cultivate innovative thinking, and enhance their ability to identify and solve real-world problems [27]. A crucial aspect of teaching DT is empowering students to extract, learn, and systematically apply human-centered techniques to approach problems creatively and innovatively [23].

The application of DT in teaching can improve students' productivity, increase their sensitivity to problems, encourage them to propose creative ideas, and help them gain various insights, resulting in the development of unique ideas compared to their peers [24]. DT also allows students to understand how the users think, do, dream and what are their real needs [25]. Thus, DT can guide students in problem-solving in real-life situations, facilitating the identification of real needs [27]. In this context, evidence suggests that DT positively impacts student learning. Specifically, DT can promote an increase in students' creative thinking, engagement with learning, motivation, problem-solving ability, self-efficacy, and academic performance [29]. Thus, integrating DT into computing curricula can effectively prepare future software engineers with the technical and collaborative skills required for professional practice [1].

DT in RE promotes collaboration, creativity, empathy, and a deeper understanding of user needs [26]. It also improves stakeholder communication and alignment through shared language and early visualization [27]. Traditional RE methods, such as questionnaires and document analysis, emphasize formality and may not sufficiently foster interpersonal skills like communication and creativity, which are essential in current software engineering practice [12]. Integrating DT helps address these gaps with a more human-centered teaching approach.

2.3 Related Work

To enhance the learning process by making it more engaging and compelling, Xu and Cai [27] conducted a study on introducing DT into teaching engineering practices. Their methodology included the implementation of DT Workshops in a Data Mining course, which the authors structured in three phases: teaching and learning DT; workshop practice for students, where they solved challenges designed by the instructors related to Data Mining; and workshop tasks for the instructors. The authors also divided their process into

eight interactive activities, encouraging in-depth research, problem identification, and teamwork collaboration. To evaluate the method's effectiveness, they collected feedback from 135 participants, and their results presented that students perceived a significant improvement in their level of thinking, creativity, and personal qualities. They reported that DT methodologies made learning more engaging and facilitated the identification of real-world problems. The instructors also noted that DT provided practical tools for innovative thinking and problem-solving.

Tiwari and Rathore [23] investigated how applying DT methods can enhance learning in RE. Their study included 315 undergraduate students, and the authors divided it into two phases: initially, instructors taught RE concepts without incorporating DT; later, they introduced DT activities. During the second phase, students participated in a three-hour practical DT activities, and the authors collected their perceptions through pre- and post-activities questionnaires. The analysis included both qualitative and quantitative evaluations of the artifacts generated. Although students understood the RE process, their results showed that students struggled to apply DT techniques. After introducing DT, there was a significant increase in students' perception of DT's effectiveness in requirements elicitation. The artifacts' analysis suggested that the use of DT provided an advantage in problem analysis, improving the understanding of the elicitation process and assisting in the search for solutions. One of this study's limitations is using predefined problem specifications rather than application to real-world problems.

Vilela and Silva [26] conducted a study where they used methodologies such as Problem-Based Learning (PBL) and DT as a means to enhance the learning experience of students in the RE course in a graduate program. Their goal was to report the experience of implementing PBL and DT in an RE course, evaluate the effectiveness of these methodologies in student training, and analyze the positive aspects and areas needing improvement. The participants were 21 graduate students within 17 hours of RE classes spread over five days. The methodological approach included theoretical classes, DT techniques, and PBL activities. For the practical activities, students were organized into groups and used data from simulated projects created by the instructor. The authors performed data analysis through feedback questionnaires and observations during the activities. Although students recognized the usefulness of DT and PBL techniques, the results indicate that students faced challenges in understanding the content and the practical application of the methodologies. Student feedback suggested the need for more time to internalize the concepts and better structure the classes. Areas for improvement included clearer explanations, increased time for practical activities, and additional TAs for support. As the students used simulated projects, the lack of interaction with real users is one of this work's limitations, as it may limit the practice of empathy and the identification of actual needs.

This study differs from previous works in two significant ways. First, while earlier studies commonly treated DT as a linear and prescriptive process, we adopted DT as a flexible toolbox, enabling students to explore and select the techniques that best suited their project context. This shift from a fixed sequence to a customizable set of tools encouraged autonomy and supported diverse approaches to problem-solving. Second, unlike studies that relied on predefined scenarios or fictional problems, our approach placed students in charge of proposing their real-world applications. Each team submitted a project proposal, identifying a problem space and potential stakeholders with whom they could interact directly. Once approved, these projects guided their activities throughout the course.

This direct involvement with real users allowed students to uncover authentic needs and challenges, resulting in a more immersive and practice-oriented learning experience. Our approach brought students closer to the realities of professional software engineering practice by grounding DT activities in authentic contexts and allowing methodological flexibility.

3 Conducting the Teaching Process

This section describes the procedures adopted for teaching requirements elicitation activities using DT as a toolbox in the context of the Introduction to SE course. The Introduction to SE course, with a total workload of 90 hours, is part of the Computer Science graduation curriculum at the Federal University of Amazonas. Its objective is to provide students with a comprehensive overview of software engineering, enhance the development of software systems, and equip future software engineers with the skills needed to apply SE methodologies. The course consists of four modules: (1) Software Engineering Principles, (2) Agile Methods, (3) Requirements Engineering, and (4) Software Verification, Validation, and Testing. We conducted the experience during the Requirements Engineering module.

The class comprised 36 students, and we assessed them based on the execution and submission of practical assignment reports, which enabled them to apply theoretical concepts through hands-on experiences and promote active learning. The use of DT in teaching requirements elicitation aimed to engage students in a collaborative and iterative process by introducing DT as a flexible toolbox of techniques rather than a rigid process. This approach reflected the dynamics of professional practice and allowed students to explore and apply different techniques according to the specific needs of their projects. The following items describe how the teaching process unfolded, each corresponding to a particular topic.

- **Content 1 - Introduction to RE:** the lectures covered the concepts of requirements engineering, including definition and importance of requirements, perspectives on requirements (user requirements and system requirements), and system and software requirements.
- **Content 2 - Types of Requirements:** in these lectures, we discussed concepts related to different requirements, including functional requirements, non-functional requirements, and business rules. Additionally, we presented practical examples of each type of requirement to the students.
- **Content 3 - Requirements Elicitation:** the lectures covered the fundamental concepts of requirements elicitation, including the definition of the process and the main challenges encountered during its execution, such as inadequate scope, lack of understanding of the problem, and requirements volatility. Additionally, we discussed traditional elicitation techniques, such as interviews, questionnaires, and document analysis.

- **Content 4 - Elicitation Techniques (continued):** the lectures covered the concepts of Brainstorming, Joint Application Design (JAD), and Prototyping techniques while also discussing the challenges related to requirements elicitation. During the class, we proposed a practical assignment (an activity that required students to apply their requirements elicitation knowledge in a real-world scenario, involving interaction with stakeholders, identification of needs, and requirements documentation). The full assignment specification is available online.[1] For this assignment, students formed groups, proposed system development projects with actual stakeholders, and had their proposals evaluated by the instructor and Teaching Assistants (TA). The practical assignment aimed to apply theoretical knowledge to a real problem, explore different elicitation techniques, and promote stakeholder interaction to enhance problem understanding. As we proposed the practical assignment before the DT classes took place, we provide an in-depth explanation of the assigment post content 7.
- **Content 5 - Introduction to Design Thinking:** We began preparing students to apply DT with a dedicated two-hour session to introduce the approach's theoretical and practical foundations. We structured this preparation around the three key perspectives of DT: mindset, process, and toolbox [3]. First, we discussed the mindset associated with DT, emphasizing values such as empathy, interdisciplinary collaboration, openness to experimentation, and a strong focus on user needs. We highlighted the importance of deeply understanding the problem before proposing solutions, presenting it as a distinctive feature of DT particularly in the context of RE. Next, we introduced the main DT process models, particularly the IDEO process (also known as the Brown process), the model from the Hasso Plattner Institute (HPI – D.School), and the Double Diamond. By comparing these models, we helped students recognize the common elements across approaches, such as the iterative structure and the alternation between divergent and convergent thinking. Finally, we addressed the toolbox perspective by presenting techniques associated with different stages of the DT process.
- **Content 6 - DT Techniques for Requirements Elicitation - Part 1:** The students participated in a two-hour lecture on techniques aligned with the toolbox perspective. The session aimed to reinforce the application of DT in requirements elicitation by presenting techniques that support empathy, analysis, ideation, and decision-making. We covered the following techniques: Brainstorming, Crazy Eights, Insight Cards, Affinity Diagrams, Card Sorting, and the CSD Matrix. We introduced each technique briefly, explaining its purpose and typical usage contexts. The presentation also included examples from real-world applications to illustrate how these techniques can capture and organize stakeholder needs. After the theoretical part, students engaged in a group exercise, applying one of the selected techniques to their own projects based on qualitative data they had previously collected from external stakeholders. We limited the activity to 20 minutes, and each group received physical materials such as poster boards, post-it notes, and markers. The instructor and three Teacher Assistants (TAs) actively supported the students during the activity. In the end, each group presented the results of their technique application, encouraging discussion and feedback exchange with peers and the teaching staff. Examples of the outcomes from this activity are shown in Figure 2.

Figure 1: Students doing the practical activities.

Figure 2: Some results from Content 6.

- **Content 7 - DT Techniques for Requirements Elicitation - Part 2:** in these lectures, we discussed the concepts of techniques such as Personas, Empathy Map, User Journey Map, Stakeholder Map, Service Blueprint, Business Model Canvas, Exploratory Research, Fly-on-the-wall, Prototyping, and Try-it-yourself techniques. During the explanation, we provide examples of how to use each technique. The students engaged in a hands-on activity where they chose one

[1] https://figshare.com/s/02bdb924c5e5f649484f

of the discussed techniques to apply to the requirements elicitation process for the projects they proposed as part of their practical assignment. The students used the techniques based on data previously collected from the stakeholders. Each group received plain paper, post-its, and markers to complete the activity, which was limited to 20 minutes. Once again, the instructor and three TAs were available to support and clarify any questions regarding using the techniques. At the end of the activity, each group presented the technique they used and the results to the rest of the class (see Figure 3).

Figure 3: Some results from Content 7.

For executing the practical assignment, we organized students into eight convenience-based groups (four groups of five members and four groups of four members). Each group was responsible for proposing a system project, describing the type of system they intended to develop, and identifying the potential stakeholders involved. The proposals had to be based on real-world scenarios to foster learning about requirements elicitation in authentic contexts. To formulate their proposals, students conducted internal brainstorming sessions. They consulted the instructor and TAs to validate the feasibility of their ideas, with particular attention to the possibility of engaging real stakeholders. We evaluated the proposals based on two main criteria: (i) the proposed problem should not be trivial, and (ii) the project scope should be compatible with the time and resources available during the course. Table 1 summarizes the system proposals and their respective contexts. Students conducted stakeholder interactions autonomously, mainly through semi-structured interviews, questionnaires, and remote or in-person meetings to apply the selected techniques. Although the number of interactions varied across groups, we required at least one initial contact with stakeholders for data collection and a second interaction for applying techniques or validating requirements. Students documented these interactions in partial reports, which served as a basis for monitoring progress and providing feedback throughout the project.

We instructed the groups to apply at least two DT techniques in the requirements elicitation process. Adopting these techniques was essential, as DT promotes a user-centered approach, encouraging empathy, collaboration, and innovation. By using these techniques in the context of requirements elicitation, the students had the opportunity to develop a deeper understanding of the needs and expectations of the end users, resulting in solutions that were more aligned with the project's objectives. To assist in selecting appropriate DT techniques for each project, students used the Selection Universe approach [2] (In Portuguese) [15], a tool previously validated in both academic and industry contexts. Although its use was not evaluated in this study, it was made available to help students align techniques with their project goals.

After finishing the assignment, during the following three class-meetings, each group presented their outcomes on eliciting requirements by applying a dynamic similar to a workshop. Each group presented their outcomes one-by-one, and they had 20 minutes each. These outcomes presentations encouraged discussions on how each group applied DT techniques for eliciting requirements, engaged with the system's stakeholders, and documented the requirements. The goal of the meeting was to foster learning based on the others' experiences, as both the instructor and classmates provided feedback for the presenting group once they had finished.

Table 1: Students systems proposals

Group	System Context
1	Sci Sphere - A platform for the dissemination of scientific projects. Users: undergraduates students, graduate students and professors.
2	Coworking Space Reservation Management System. Users: freelancers, small business owners, coworking space owners and corporate space administrators.
3	InvestMax - Investment Manager. Users: novice and experienced investors.
4	NoHarapp - Harassment Reporting App. Users: individuals who have experienced workplace harassment.
5	Visit X - App for promoting fairs and cultural events in City X. Users: Local residents, tourists, event organizers and vendors.
6	Blood Donation Encouragement Software. Users: blood donors and donation requesters.
7	K-binder - Organizing, selling, buying and trading K-pop photocards. Users: photocards collectors.
8	A website and smartphone app that allows users to view recycling collection points in City X. Users: schools, universities and social institutions.

4 Results

After presenting their outcomes, we invited the students to participate in the study. Although the class consisted of 36 students, only 23 agreed to participate. Consequently, the data analyzed and discussed in this paper pertains exclusively to the information provided by these 23 participants. Those who agreed to participate signed a consent form and completed a survey designed to collect feedback on the use of DT as toolbox in the classroom. The survey included questions to characterize the participants' experience with

[2]Selection Universe: https://sites.google.com/view/universodeselecao/

RE and DT, as well as their perceptions of various aspects of the experience[3]. The Research Ethics Committee approved this study under protocol number CAAE: 79890324.2.0000.5020.

Table 2 summarizes the 21 techniques selected by the student groups to be used during their requirements elicitation process. Figure 4 illustrates the frequency of usage for each technique, showing how often each was applied throughout the study. Additionally, Figure 5 presents examples of artifacts generated by the students during the assignment. Participant characterization data is available at: https://figshare.com/s/02bdb924c5e5f649484f.

We analyzed the participants' responses based on Grounded Theory (GT) procedures, as described by Strauss and Corbin [22]. The analysis process included the Open Coding phase, with ongoing revisions and discussions among the researchers regarding emerging findings. The codebook is available in the supplementary material. In the following subsections, we provide a brief qualitative analysis of the students' perceptions regarding various aspects of the experience. Each subsection focuses on a specific aspect, presenting an analysis and categorization of participants' feedback on the following points:

(1) The execution of the practical assignments: We analyzed participants' comments from their assignment reports.
(2) The DT techniques applied for eliciting requirements: We examined participants' feedback on the most frequently used techniques during their requirements elicitation process.
(3) The use of DT as toolbox in teaching requirements elicitation: We reviewed participants' comments addressing positive aspects, negative feedback, and suggestions for improvements regarding various aspects of the teaching process.

Table 2: Techniques used by each group.

Group	Number	Techniques Used
01	8	Brainstorming, Interview, Questionnaire, Joint Application Development (JAD), Crazy Eights, Focus Group, Benchmarking and Business Model Canvas
02	3	Brainstorming, Scenarios and Business Model Canvas
03	3	Personas, User Stories and Swot Analysis
04	7	Personas, Interview, Brainstorming, Crazy Eights, Affinity Diagram, User Journey Map, Stakeholders Map
05	10	Interview, Questionnaire, Brainstorming, Insight Cards, CSD Matrix, Personas, Stakeholders Map, Business Model Canvas, Empathy Map and Try it Yourself
06	4	Brainstorming, CSD Matrix, Personas and Empathy Map
07	8	Questionnaire, Interview, Personas, Empathy Map, Insight Cards, Affinity Diagram, Benchmarking and Brainwriting
08	3	Questionnaire, Business Model Canvas and Service Blueprint

[3]Survey content available at: https://figshare.com/s/02bdb924c5e5f649484f

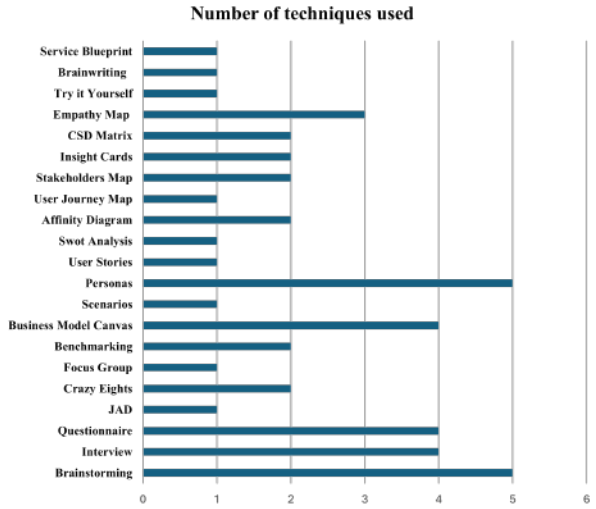

Figure 4: Number of techniques used

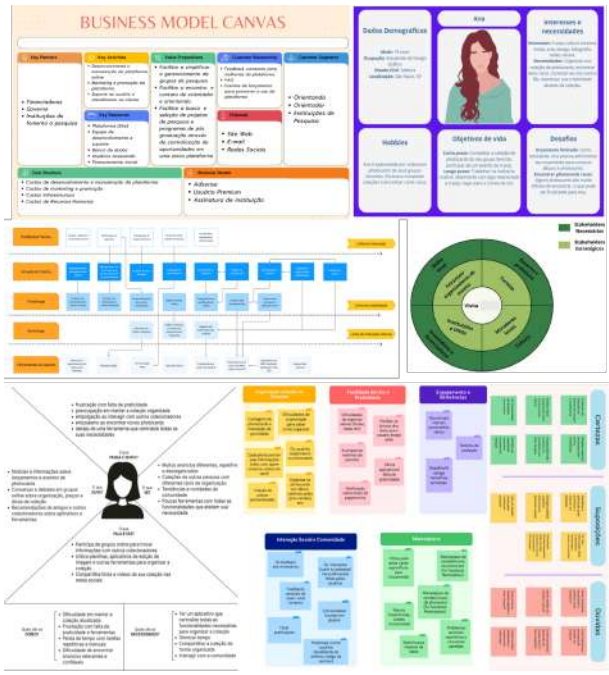

Figure 5: Results produced by different techniques - Business Model Canvas, Service Blueprint, Personas, Stakeholders Map, Empathy Map, Affinity Diagram, and CSD Matrix techniques (In Portuguese)

4.1 Students' perception regarding the execution of the practical assignment

Having various DT techniques assisted understanding users' needs: On using different techniques for eliciting requirements, P2 highlighted that "*the application of various requirements elicitation techniques allowed for a more complete understanding of the users'*

needs and the essential functionalities of the system." Similarly, P21 noted that "*the use of various requirements elicitation techniques was useful, though labor-intensive, for the project's implementation, as it brought different perspectives on the main points of this application.*" These observations suggest that the availability of multiple elicitation techniques enabled students to gain a broader understanding of users' needs and the system's functionalities.

Students liked to apply the use of DT techniques in practice: P15 emphasized that "*during the execution of this work, I was able to acquire various learnings. Although I was already familiar with some Design Thinking techniques, I learned a lot by applying them in a different context.*" P19 also commented on this subject, stating that "*developing this work brought me many new learnings, especially because I was not yet familiar with many of the Design Thinking techniques for requirements elicitation. This experience with Design Thinking techniques was very enriching and will greatly help in future projects.*" These observations suggest that the practical activity offered students the opportunity to apply various techniques across multiple scenarios and address real-world issues.

The practical assignment contributed to developing teamwork, communication, and collaboration skills: Students reported that the activity enhanced their skills for working in teams, improved communication, and fostered collaboration, as P20 stated: "*another important point developed during the work was my teamwork ability. The project as a whole was based on a lot of communication among team members, and I believe this contributed to the improvement of my soft skills.*" P12 corroborates this by saying that "*the discussions and conversations with the group were very productive; almost 90% of the techniques were applied together, which generated a huge and positive productivity.*" The practical assignment fostered teamwork, communication, collaboration, and stakeholder interaction—skills aligned with those expected of requirements engineering (RE) professionals. These competencies are highlighted in the literature as critical for successful elicitation and project effectiveness [2, 12]. By involving students in real-world projects with external stakeholders, the course offered continuous opportunities to develop these essential soft skills.

4.2 Students' perception regarding the use of the techniques

Figure 6 shows an overview of the student's perceptions about Empathy Map, Personas, Business Model Canvas, and Brainstorming techniques. We selected these techniques based on the valuable insights students shared. Each quadrant of the figure highlights a technique and the main aspects students perceived, grounded in their feedback. Due to page limitations, we included our complete qualitative analysis of each DT technique in the supplementary material.

4.3 Students' perceptions regarding the application of Design Thinking in requirements elicitation teaching

Our analysis focused on different aspects. We examined the students' perceptions of the adopted methodology and their evaluation of how practical activities improved their understanding of applying DT techniques. We also considered the effectiveness of the materials and resources provided, their suggestions for improving the lessons, and the preparation they received for eliciting requirements in real projects.

4.3.1 Participants' perception regarding the methodology **Improving content retention:** Regarding the methodology we adopted in class, P3 expresses that it is a "*good methodology, teaching the theory and giving students a practical activity is a functional model for retaining the topic, even though I personally don't like the idea much.*" Similarly, P9 asserts that "*the class was very dynamic and straightforward, the assignments helped reinforce the subject matter, so it was very good.*" According to the students' comments, combining theory with practical activities facilitated content retention. Its dynamism may improve content retention in requirement elicitation practices, as highlighted by P21: "*for me, the classes in which the design thinking techniques were presented were very productive, I really liked the way of explaining how to use them and especially the practical activities where we had to apply them in practice, as that is the way I learn best, and they are also the classes I remember most clearly.*" To mitigate the limitations of balancing theory and practice, we involved TAs in practical sessions and provided ongoing instructor support. Two dedicated sessions (Contents 6 and 7) integrated theory and practice to reinforce learning. We also offered the Selection Universe and additional materials to foster autonomy, encouraging students to explore techniques aligned with their project needs.

Practical Assignment contribution for improving technique selection: The use of examples and applying techniques with the support of the instructor and TAs helped the students select appropriate techniques, as P13 states: "*I found it quite interesting. They tried to show all the main techniques and had the class practice some in real-time to clear up possible doubts, which helped us think about which would be more interesting to use in the project.*" P15 corroborates with this affirmation, declaring that "*I believe the methodology used was extremely efficient. By dedicating parts of the class to applying the techniques taught, it was possible to understand the process of each technique, and relate it to the context of Assignment 02 done during the course.*" P11 suggested "*more practical activities with real-life simulations*," which highlights the need to bring more hands-on activities that simulate or show real-life situations on teaching requirements elicitation.

4.3.2 Participants' perception regarding the practical activities **Improved Understanding of Technique Application:** Regarding the practical activities, P2 comments that "*they were excellent as well, as they helped me better understand the dynamics of each technique. The second practical assignment showed me how to use these techniques in a real problem.*" Likewise, P10 points out that "*the activities, especially those in class, contributed to a better understanding of how to use and how these techniques work.*" These observations suggest that the students agree the practical activities effectively enhanced their understanding of how to apply DT techniques for requirements elicitation. Furthermore, both in-class and out-of-class practices were highlighted as valuable for improving their learning experience.

Improvement in retention of the taught content: Practical activities seem to facilitate the understanding and retention of the requirements elicitation content, as P15 indicates that "*the practical*

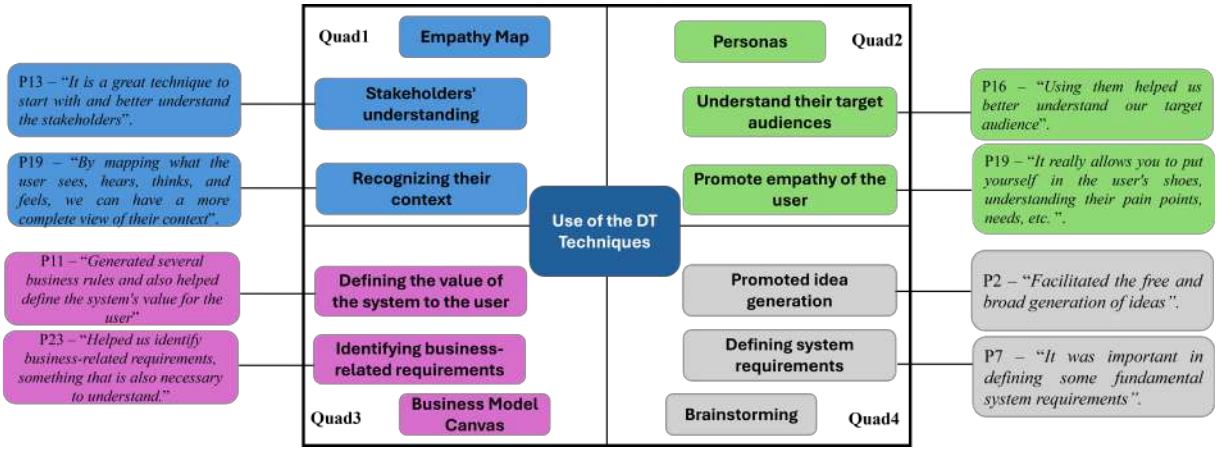

Figure 6: Students' perception regarding the use of the Empathy Map, Persona, Business Model Canvas, and Brainstorming techniques

activity was essential for the elicitation process. Setting aside time for these practices made the classes less monotonous and more dynamic. By practicing, we could more easily identify doubts about how to use the techniques in general". In that sense, the activities have contributed to more dynamic and engaging lessons. On the other hand, P21 states that "*the lessons where I had to apply the techniques in practice are the ones I remember most. It was the best way to retain the content; I believe that if I had only seen the theory in class, it would have been more difficult to apply it later in the project*". It suggests that practicing within the techniques also supports retaining the content. For improvement, P6 shares that "*it would be important to have more lessons to delve deeper into the explanations of DT techniques*," this highlights the need to devote more time to teaching DT techniques, as well as to have more practical examples illustrating their application.

4.3.3 Participants' perception of the effectiveness of the materials and resources used **Effectiveness of the materials used:** Regarding the materials, students' comments suggest that the materials and resources were effective, as P17 mentions that 11*the materials used during the classes were of excellent quality. One thing I liked was the availability of a link containing detailed explanations of the techniques*." Still, P6 explains that "*the materials were excellent for use and very effective in helping to understand DT and how to apply them in projects*." These insights suggest that providing clear, detailed, and easily accessible materials significantly enhances students' understanding of complex topics such as requirements elicitation.

Limitations of the Materials Used: P10 pointed out that "*although the explanation in class was excellent, some slides contained little information, which made it somewhat difficult to review the topics outside of class time*." It emphasizes that providing insufficient information for reviewing the content outside the classroom may prejudice students. Conversely, P7 mentions that "*I thought that part of the content was heavily theoretical*," which reflects a need to avoid overloading the students.

Suggestions for Improvement: P7 expresses their need for "*Bring real success and failure cases in the application of the techniques, especially guests who have interesting stories about this. Additionally, emphasize that there is no fixed path or exact way to do it*." Similarly, P17 mentions that "*I would suggest that the classes be more practical, as I believe this topic becomes clearer when we have the opportunity to apply it directly. It would be interesting to adopt approaches that include practical activities, such as visits to companies that use Design Thinking*." These comments suggest that integrating case studies of DT applications and organizing technical visits can enhance students' engagement and willingness to adopt DT in real-world software projects.

4.3.4 Participants' Perception Regarding Preparation to Apply DT in RE for Real Projects **Students feel confident in working with DT for requirements elicitation:** On feeling prepared for applying DT in RE real projects, students such as P20 declare that - "*I feel more prepared than before taking the course. The successes and mistakes made in the activities and projects helped me better understand the context of SE in practice*." P22 also comments on this topic, mentioning that - "*I understand the application processes and general characteristics of the techniques I learned. So, I could handle a real project well*." P12 complements their point of view expressing that "*I feel very prepared. It was very positive; the way it was explained and applied in a practical project gave me more confidence*." The comments highlight that practical experience boosts students' confidence and readiness to apply DT techniques in real-world requirements elicitation projects.

General concerns on using DT for real projects: Although most participants expressed confidence in feeling ready for applying DT, few ones shared theirs concerns, such as P11, who states that "*I do not feel very confident. Initially, I would use other methods, mainly because I do not see a use case for DT daily*," which shows that they perceive a limited usefulness of DT in everyday situations. Additionally, P16 mentions that "*I believe I have the necessary knowledge, but I still think I do not have the experience to lead a requirements' elicitation project in a real project*," which emphasizes that the lack of experience in using DT may limit their confidence

in leading real projects that employ DT in requirements elicitation activities.

4.3.5 ***The instructor's perception of teaching*** The course instructor had the following perception regarding the use of DT during requirements engineering teaching: "*The content on requirements engineering is extensive. If only theoretical lectures had been delivered, students would not have been able to benefit from the content fully. Therefore, I restructured the class sessions to include focused, time-limited practical exercises, allowing students to apply DT techniques effectively without disrupting the course schedule. All project proposals were reviewed and approved in advance, which required significant effort but aimed to ensure that each team had access to real stakeholders and problem contexts. Additional instructional materials, including detailed technical guides and examples, were provided through an online repository to support independent learning. In terms of student engagement, I observed a significant increase in motivation and active participation, especially during the practical sessions. Students took greater initiative in conducting research and applying techniques, often exceeding the minimum requirements for assignments. Many displayed a sense of ownership over their projects and enthusiasm when presenting their results to peers and receiving feedback. These behaviors suggest that DT fostered a more dynamic and meaningful learning experience.*"

5 Lessons Learned

By conducting the experience of using DT to support the teaching of RE, we learned some lessons that we summarize in this section.

- **Integrating DT as a toolbox enriches the practice of requirement elicitation:** Our experience showed that DT techniques are valuable tools to support the requirements elicitation process by promoting a user-centered approach focused on deep understanding of the problem. Although the intervention took place in a course covering multiple pillars of software engineering, we observed that incorporating DT content into elicitation-related activities expanded students' technical repertoire. As a result, students could select techniques that better suited the context of the problems they faced, considering the nature of the stakeholders and the goals of each project. Therefore, we recommend including DT as toolbox in courses focused on requirements elicitation to enhance practical training and encourage methodological flexibility among future software engineers.
- **Importance of Practice:** Hands-on activities were fundamental for understanding and solidifying the concepts of DT. Participants reported that applying the techniques in real situations helped improve their knowledge of implementing these methodologies in requirements elicitation. It highlights the importance of instructors incorporating DT as a practical approach in the classroom, enabling students to experience theory in practice.
- **Importance for Appropriate Materials:** Many participants pointed out the materials' limitations, highlighting the need for more information and practical examples. Emphasizing theoretical aspects can hinder applying content outside the classroom. Thus, the instructor should provide and use materials that balance theory and practice, facilitating the understanding and applying concepts in real-world scenarios.
- **Resource Diversification:** Participants suggested including additional resources, such as videos, real case studies, and visits to companies that utilize DT, to make learning more dynamic and relevant. These approaches help students visualize the application of techniques in practical contexts, enhancing the relevance of the content covered in the classroom.
- **Effective Learning Requires Structured Content and Ongoing Support:** The well-defined structure of content and activities, with a logical progression and clear objectives, helped students understand and apply the concepts discussed. Furthermore, the support provided by the TAs during practical activities proved to be an important factor in engagement and overcoming difficulties. This support enabled students to resolve doubts quickly, giving them greater confidence as they explored and implemented the stages of the DT process. The presence of TAs can also create a collaborative environment where students can share experiences, exchange ideas, and receive immediate feedback, which enhances content assimilation and the quality of the solutions developed. Therefore, the instructor must combine a well-planned lesson structure with continuous support during the practical activities.
- **Interacting with real stakeholders can enhance the student's practical knowledge:** Students perceived that engaging with real stakeholders contributed to a deeper understanding of user needs and problem contexts. Although no comparative study was conducted, qualitative feedback suggests that this interaction increased students' confidence in applying elicitation techniques.
- **DT in practice can improve teamwork and communication skills:** The practical activities played an important role in developing teamwork and communication skills, as students were challenged to collaborate in eliciting and documenting requirements. After submitting their practical assignments, students had to present the results of their elicitation process to other groups, facilitating communication with different groups, instructors, and TAs as they received feedback on their work. This highlights the need for instructors to create educational environments that encourage student interaction, promoting the development of technical and interpersonal skills.
- **The flexibility in selecting and applying DT techniques can enhance understanding of DT concepts**: Allowing students to choose DT techniques that best suited the context of their projects fostered greater engagement and accountability during the requirements elicitation process. This flexibility not only encouraged the practical application of these techniques but also deepened their understanding of DT concepts. By experimenting with and reflecting on the effectiveness of the selected techniques in real-world scenarios, students were able to connect theory to practice more effectively.

- **Student ownership of project proposals can improve autonomy:**Allowing students to define the projects to be developed throughout the course proved an effective strategy for fostering autonomy in practical activities. Students took greater ownership of their learning process by proposing systems based on real-world problems and selecting stakeholders with whom they could interact. This authorship facilitated the contextualization of DT techniques, enabling students to adapt them to the specific characteristics of their projects. Furthermore, the proposal formulation phase required critical reflection from the early stages of the course, encouraging informed decision-making, identifying practical constraints, and developing skills related to scope definition and communication with real users.

These lessons can serve as a foundation for future implementations of DT in RE courses, aiming to enhance the learning experience and teaching effectiveness.

6 Conclusions

Adopting DT as a toolbox in RE education has proven to be an innovative and practical approach to enhancing student learning. The results obtained through hands-on activities and teamwork demonstrated that the flexible use of specific DT techniques, rather than the application of a linear process, not only facilitated the understanding of requirements elicitation activities, but also supported the development of essential skills such as collaboration, communication, and empathy, which are fundamental for professional practice.

Participants' feedback highlighted the importance of incorporating more practical activities, reinforcing the role of DT as a repository of techniques adaptable to different contexts. These practices enabled students to freely explore various approaches and gain autonomy in selecting and applying the most suitable techniques for their needs. Diversifying educational materials also proved to be relevant in enriching the learning experience and supporting continuous development of the curriculum.

In the context of RE learning, the toolbox-based approach provided by DT allowed students to engage with multiple perspectives of end users. This engagement enhanced their ability to understand complex problems and translate user needs into well-defined requirements. The artifacts generated by the students during classroom activities and assignments contributed to fostering a creative mindset oriented to problem solving and proposing innovative solutions supported by software systems. Consequently, this approach strengthened the perspective of in-training software engineers on addressing real-world challenges in system development.

In our study, reported improvements such as better understanding of user needs, technique application, and content retention reflect students' self-assessed learning after applying DT in real projects. These perceptions align with the concept of reflection-on-action [28], as students revisited and analyzed their experiences. As described in Section 4, we conducted a qualitative analysis of survey responses using Grounded Theory procedures, revealing consistent patterns of perceived learning. Although subjective, these reflections offer valuable insight into how learners experienced the activities, consistent with Nikolic et al. [16] on the role of perceived learning in educational evaluation.

Adopting DT as a toolbox in RE education stands out as a powerful strategy for preparing software engineers capable of identifying and solving complex problems while effectively meeting user needs. The lessons learned and improvement suggestions presented in this study can serve as valuable guidance for future implementations of DT in RE courses, ensuring that RE education continues to evolve and adapt to market demands.

ARTIFACT AVAILABILITY

The dataset and material used in research are currently maintained as an open-source project accessible at: https://figshare.com/s/02bdb924c5e5f649484f. To avoid leakage of sensitive data and ensure privacy, we choose to anonymize all personal information provided in this paper.

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