Guiding the Way: Facilitating Requirements Elicitation with Selection Universe Approach

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ABSTRACT

Context: Requirements Engineering is crucial in software development, and Design Thinking (DT) emerges as an alternative to improve it, especially in requirements elicitation. The literature reports the utility of DT in this activity, offering a large number of techniques, although choosing one of them can be challenging. To mitigate this challenge, we propose the Selection Universe, an approach that assists in selecting among the DT techniques available. **Goal:** To present how the Selection Universe can support selecting the DT techniques for requirements elicitation. **Method:** Two empirical studies were conducted to evaluate the approach. The first study involved undergraduate students and utilized the techniques focus groups and card sorting. The second study was conducted with industry professionals and utilized the technique questionnaire. **Results:** The focus group application revealed that the approach helped selecting techniques by objectively demonstrating what was necessary to use the technique and the outcome it would generate. The card sorting revealed the need to change the nomenclature of one of the approach's categories. The questionnaire technique highlighted that the approach facilitates requirements elicitation and technique selection, providing an overview of each technique. **Conclusion:** These studies revealed that the Selection Universe supports the requirement's elicitation stage, as the approach provides a clearer understanding of the DT techniques, thus facilitating the best choice amongst them.

CCS CONCEPTS

• **Software and its engineering → Requirements analysis**.

KEYWORDS

Design Thinking, Design Thinking techniques, Technique Selection

1 INTRODUCTION

Design Thinking (DT) is an approach that provides a process framework facilitating constant communication among the development team, stakeholders, and target users [17]. This approach incorporates various tools and methods to gather information related to user needs and generate creative ideas [17].

The use of DT has been extensively explored in Software Engineering. In this respect, Prestes [16] conducted a systematic mapping in the literature and identified four primary purposes for using DT in Software Engineering: 1) DT in the education of Software Engineering courses; 2) DT was incorporated into development due to its similarities with agile methods; 3) DT aimed at a proper understanding of the problem; and 4) DT is used for innovation.

In this work, we propose using DT to gain a genuine understanding of the problem, namely, DT being used in requirements engineering. In this regard, Hehn and Uebernickel [9] mention that software projects increasingly require human-centered approaches for specification and elicitation of requirements, i.e., to discover and address the often ambiguous needs of various stakeholders. As a human-centered approach, DT is a promising alternative to assist in discovering requirements and aiming to satisfy stakeholders' needs [10]. Parizi et al. [13] assert that DT can be used in the early stages of the software development process to understand and identify what the client needs, providing better support for development activities, especially those related to determining an appropriate solution to the problem.

Brenner et al. [2] consider DT from three perspectives: mindset, process, and toolbox. When adopting DT from the toolbox perspective, several techniques can be employed to elicit requirements. In this context, Parizi et al. [13] mentions that the literature provides many DT tools and methods that make up the toolkit for conducting DT activities. However, more studies need to mention support strategies for the decision-making process on which techniques to use and detailing which factors (e.g., prior knowledge about the problem to be solved, client involvement, etc.) affect the decision in selecting DT techniques. In this context, Prestes [16] states that choosing which methods to use can be a challenge, especially for professionals starting to use DT, as anyone employing a technique or tool must have the necessary knowledge, experience, and competence to apply it effectively.

Aiming to contribute to how DT techniques can be selected for the requirements elicitation activity, this work aims to present how the Selection Universe approach [1] can support the choice of DT techniques for requirements elicitation. To achieve this, two detailed empirical studies allowed the target audience (undergraduate students and industry professionals) to use the Selection Universe. The first study was conducted with undergraduate students from an introductory software engineering course and Super Project

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

[2]. The second study was conducted with industry professionals. These studies revealed that the Selection Universe provides a better understanding of the techniques, thereby facilitating the selection of one of them.

2 BACKGROUND

In this section, we discuss the use of Design Thinking in the software development process and present a synthesis of related works.

2.1 Design Thinking in the Software Development Process

According to Alhazmi and Huang [1], in the software development process, DT has been used as a problem-solving approach to support understanding of the problem to be solved, propose and validate solutions that meet user needs, contributing from the requirements elicitation[8] to fostering an innovative mindset among developers, engineers, and managers [5]. Sohaib et al. [17] mention that the primary goal of DT is to develop a solution closely related to stakeholders and target users to ensure the solution's convenience, practicality, and feasibility. Thus, DT supports a deep understanding of user needs, enhances team collaboration, and explores innovation that promotes the development of user-centered software solutions [5].

In this context, Duarte et al. [7] mentions that DT has been employed in software development to assist in the requirements engineering process, which increasingly demands a human-centered perspective. Hehn et al. [8] claim that DT can be used in the early stages of the software development process to identify customer needs, providing better support for development activities, especially those related to identifying an appropriate solution for the problem.

Still on this subject, Hehn and Uebernickel [9] asserts that DT combines a strongly human-oriented work mode with the more formal and technology-oriented world of requirements engineering, aiming to develop more effective human-centered solutions. Canedo et al. [3] ensure that DT enhances the requirements-gathering process, allowing for the identification of understanding gaps through prototyping and facilitating the implementation of the solution. Hehn and Uebernickel [9] report that DT is not just a supportive methodology for requirements engineering practices but one of the most promising methodologies for dealing with complex problems and defining innovative solutions.

2.2 Related Work

Parizi et al. [14] present research aimed at developing a collaborative tool named Helius, designed to provide recommendations on potential DT techniques to support requirements engineering activities. The proposal for the Helius tool was created from the results of a DT session, followed by a requirements elicitation activity to define the scope of the tool and an initial empirical study based on interviews with professionals using DT in the industry. Helius is a collaborative recommendation tool that considers the project context and professionals' experiences to recommend DT techniques in software development. Helius plans to implement features for DT techniques, including recommendation, filtering, evaluation, community feedback, information on DT techniques, and management of projects and DT techniques. The initial evaluation results indicated that Helius has the potential to facilitate the selection of DT techniques and improve the quality of the entire software development process.

Dobrigkeit et al. [6] conducted a study to support agile development teams with the benefits of DT techniques. To achieve this goal, they developed the DT@IT Toolbox approach, a toolkit software teams can use to select and apply DT methods according to their needs. The approach was evaluated by a development team from a medium-sized company based in Germany over 12 weeks. For data collection, the authors conducted interviews before, during, and after the methods were applied. Additionally, they administered a questionnaire to assess each technique at the end of its application. Furthermore, they administered two questionnaires measuring team members' empathy towards users, which were answered once before the methods' application period and after all the methods had been introduced. The questionnaires were used to measure whether the application period influenced empathy. As a result, participants reported that using the DT@IT Toolbox improved team communication, enhanced problem-solving skills, increased empathy, and a better understanding of user needs.

Souza et al. [18] conducted a study using the DTA4RE tool to suggest DT techniques for requirements elicitation. DTA4RE consists of a set of 27 techniques that can be recommended to users through a recommendation questionnaire based on the primary sources of requirements, the characteristics of each stage of the process (Inspiration, Ideation, and Implementation), and especially the features of each of the 27 DT techniques. The questionnaire items are organized according to the phases of Brown's process. DTA4RE also has an open repository with support materials for applying these techniques. For the tool's evaluation, the authors conducted two empirical studies, one with undergraduate students and another with postgraduate students in software engineering and industry professionals. The results of the studies showed that DTA4RE can assist in selecting and learning DT techniques when considering real-world problems.

As observed in related work, the problem is the existence of numerous DT techniques (85 techniques mapped in the literature) for ER activity. Some approaches have been proposed to assist in the selection of these techniques. The DTA4RE tool [18] recommends DT techniques through a questionnaire. Still, it has limitations: (1) the questionnaire questions are challenging to answer, and (2) the suggestions must be more specific, resulting in many technique options for the same problem. Helius [14] needs to describe how technique recommendations are made for different scenarios, teams, and stakeholders. The DT@IT Toolbox [6] offers a catalog with 14 techniques and information on their application but does not recommend which techniques to use in different contexts. A common problem is the need for detailed categorization of DT techniques according to specific objectives, which makes it difficult for developers and project teams to select the most appropriate techniques.

The approach presented in this study differs from other works because it proposes a strategy to facilitate the selection of DT techniques according to the specific objectives of each project. This approach employs comparative tables that provide a detailed analysis

[2]SUPER Project: https://webdev2.icomp.ufam.edu.br/

of the different DT techniques available for requirements elicitation. By providing this structure of comparison tables, the approach offers a valuable tool for professionals involved in project development, allowing for an informed and careful choice of the most suitable techniques aligned with each project's specific needs and goals. Thus, this research introduces some advancements on the topic, as it proposes an approach that presents a categorization of DT techniques that simplifies the selection of techniques based on the project's objectives. Therefore, the proposed approach streamlines the decision-making process by considering the following factors: (1) Direction: the proposed approach categorizes the 27 DT techniques (used in the work of Souza et al. [18]) into specific categories, facilitating the identification of available options and providing a clear structure for users to explore relevant techniques for ER; (2) Comparison and Analysis of the techniques: the approach includes a comparison table that highlights the differences and similarities between techniques in each selected category, allowing for a detailed and informed analysis of available options; and (3) Decision Facilitation: by providing precise and structured information about DT techniques and their applications, the approach assists professionals in making more informed and accurate decisions when choosing the most suitable techniques to meet the specific ER needs of each project.

3 SELECTION UNIVERSE WEB VERSION

Due to the significant number of DT techniques defined in the literature, choosing the most suitable ones for requirements engineering as the project evolves is challenging. Addressing this gap, this research initially proposes categorizing the 27 DT techniques used in the work of Souza et al. [18]. into categories according to the objectives of each method. DT techniques exhibit a variety of objectives, reflecting their diversity and applicability in different contexts. For example, some techniques aim to **analyze** and **acquire information** relevant to stakeholders and explore their motivations, pains, and needs. Others are intended to **organize and structure** the data obtained through other collection techniques. Additionally, some techniques are designed to stimulate **idea generation**, standing out among various objectives inherent in the requirements elicitation process for software development. Information about the categorization of the techniques can be seen in our previous works [11, 12] and in the supplementary material available (in Portuguese) at this link: https://figshare.com/s/5fa72236e1459e0efd79

After analyzing participants' perceptions from empirical studies conducted in our previous works Meireles et al. [11, 12], we identified the need to develop a web version of the Selection Universe approach [3] to make it more intuitive and attractive to users.

Figure 1 shows a practical example of the approach in action.

The approach proposed in this research follows a well-defined flow, consisting of the following stages: (1) an initial menu screen where the software engineer can select from different categories of DT techniques for use. After choosing a specific category, the software engineer is directed to (2) a subsequent screen that provides a detailed definition of the selected category. While navigating the tab corresponding to the chosen category, the software engineer is led to (3) a screen displaying a list of techniques within that category, along with detailed information about their input requirements, control procedures, resources needed for applying the technique, expected outcomes, and examples of application. Subsequently, after thoroughly analyzing the available techniques, the software engineer is directed to (4) a comparison table highlighting the differences and similarities among the techniques in the selected category. Therefore, through this approach, the process of choosing DT techniques is simplified and straightforward, allowing the software engineer to make an informed and precise choice regarding the most appropriate technique to meet their project's specific requirements elicitation needs. As an example of use, consider a scenario where a software engineer aims to acquire information about the user's motivations or needs that justify a request for software development. The engineer can identify that the Empathy Map technique provides the desired outcomes through the proposed approach. In this way, the approach offers the necessary information for selecting and implementing techniques suited to the specific demands of software project requirements elicitation.

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

4 EMPIRICAL STUDIES

Two empirical studies were conducted to evaluate this version of the approach, detailed in the subsections below.

4.1 First Empirical Study

We conducted an empirical study using focus groups and card-sorting techniques. The focus group aimed to verify participants' perceptions regarding the web version of the Selection Universe approach. The card sorting was intended to ascertain the grouping of DT techniques into categories. Specifically, it assessed whether the techniques were adequately categorized in the participants' opinions.

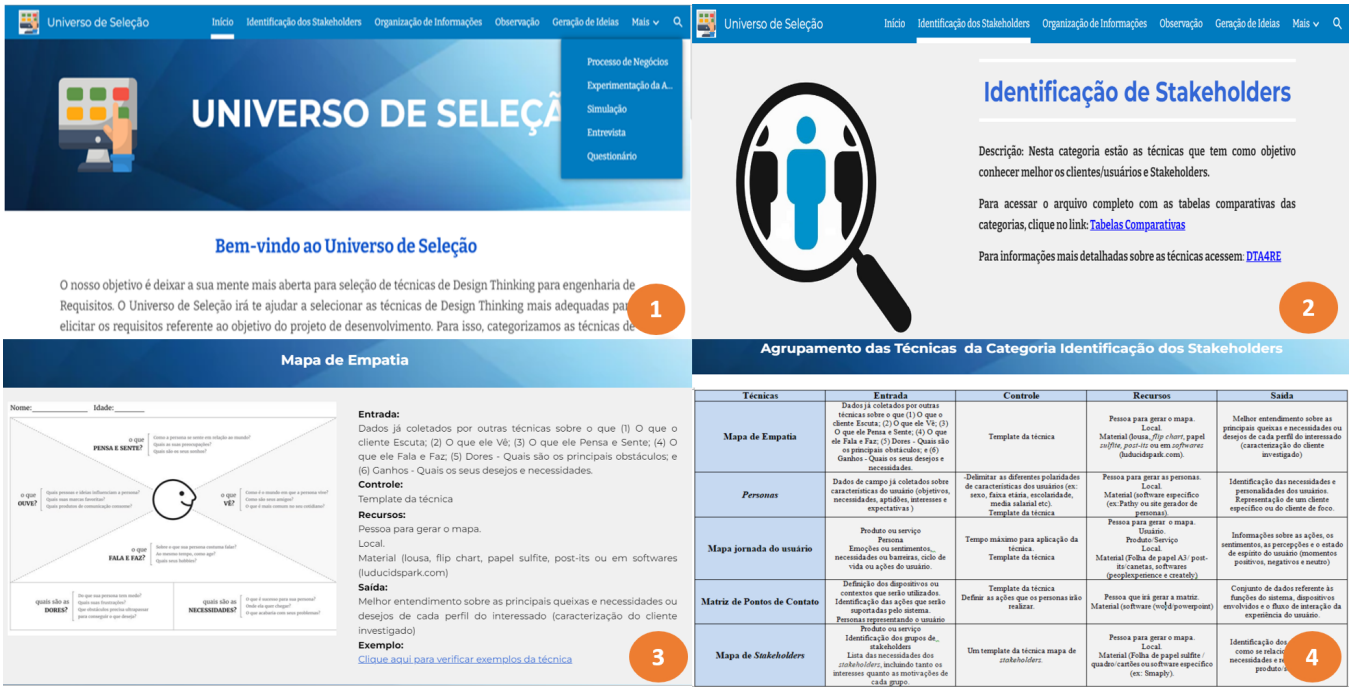
4.1.1 Purpose of the Study. After developing the web version of the Selection Universe, an empirical study was conducted with a class from Super Project. Super Project is a project aimed at fostering training and research in technology-related courses. The general objective of Super Project is to provide students with opportunities to participate in qualification and innovation actions in strategic areas (Computing, Engineering, and Design), resulting in high-impact scientific and technological development.

For this study, we conducted training on DT, introducing concepts and DT techniques that can be used for requirements elicitation as part of the proposed approach. After presenting the DT concepts and techniques, a requirements elicitation work for IoT systems was carried out, where participants used the stakeholder identification category from the Selection Universe to identify the users of the proposed systems and their pains, motivations, and needs. After submitting their work, they participated in a focus group to verify opinions regarding the use of the Selection Universe and a card sorting exercise to analyze the grouping of DT techniques. For this, they responded to the following questions:

Q1: Did using the Selection Universe help or hinder your choice of techniques?

Q2: Do you have any suggestions for improvement?

Figure 1: Selection Universe V2.0 Web Version In Portuguese (elaborated by the authors)



4.1.2 Participants. The participants were 15 undergraduate students who held scholarships from Super Project. All study participants had completed the Introduction to Software Engineering course in the previous semester and had previously performed practical exercises involving DT techniques to elicit requirements for IoT systems. Additionally, participants underwent training titled "Design Thinking v2.0" during a course offered by Super Project, aimed at enhancing students' skills in basic requirements engineering concepts in specific contexts, such as IoT, using DT approaches and the proposed techniques. They carried out the project's practical work, which involved eliciting requirements for IoT systems they chose themselves. It is important to emphasize that, the students voluntarily agreed to participate in the research (this was not mandatory). All of them signed the Informed Consent Form (ICF).

The participants formed pairs, each designing different IoT systems, as shown in Table 1.

Table 1: Techniques use scenarios.

Duo	Application Scenarios
D1	A system for intelligent public transport
D2	A system for a smart shower
D3	A smart greenhouse system
D4	A smart security system for homes
D5	A system for the intelligent management of water consumption
D6	A system for intelligent identification of critical health situations
D7	A smart collar system

4.1.3 Execution. This study highlighted the practical application of Design Thinking using a set of techniques from the Selection Universe. For this purpose, a two-hour intensive session was conducted where DT concepts and techniques were presented to the students of Super Project. This meeting equipped the participants with advanced knowledge of Design Thinking and prepared them to apply the techniques directly to their projects.

DT was made available to the students in a traditional format (presentation slides), along with the corresponding link to the Selection Universe. Working in pairs, the students were required to use DT techniques from the stakeholder identification category (empathy map, user journey map, stakeholder map, touchpoint matrix, motivation matrix, and Personas), with no limit on the number of techniques they could use. The practical work was submitted approximately four weeks later. After submission, they shared their opinions about the Selection Universe through a focus group and discussed grouping techniques into categories via card sorting.

The subsections below show how the techniques were applied in this study.

4.1.4 Application of the Focus Group technique. The focus group took place during a meeting with the participants, where a moderator asked questions, and the participants provided their perceptions of the inquiries.

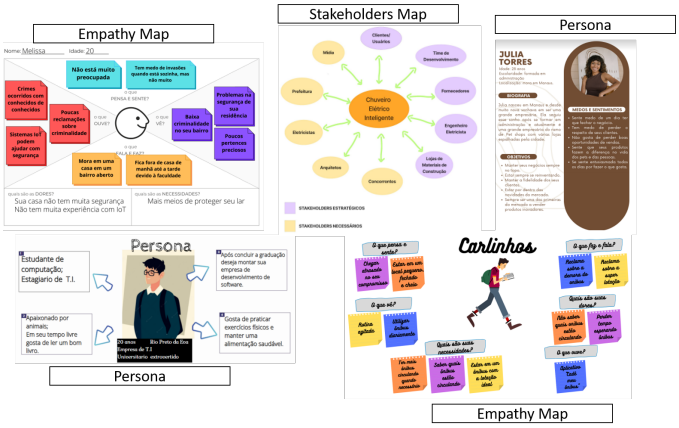
Regarding the use of DT techniques by the participants, personas was the most used. Table 2 shows the techniques used by the 8 pairs (D1, D2, D3, D4, D5, D6, D7, and D8).

Table 2: Techniques used by the participants (compiled by the authors from the participants' work)

Techniques/Duo	D1	D2	D3	D4	D5	D6	D7	D8
Empathy Map	X			X				X
Personas		X	X		X	X		
Stakeholder Map							X	

Figure 2 shows examples of using the Personas, Empathy Map, and Stakeholder Map techniques by different pairs.

Figure 2: Examples of using the Personas, Empathy Map, and Stakeholder Map techniques



4.1.5 Participants' perceptions of the Selection Universe. Regarding the question of whether the approach helped or hindered in selecting the most suitable DT techniques for eliciting requirements for the proposed systems, the participants reported that the Selection Universe assisted in choosing the techniques, as it objectively showed what was necessary to use the technique and the result it would generate, as expressed by the participants: P2 - "*the Selection Universe helped me choose the stakeholder identification technique because it clearly and objectively showed me what inputs I needed to use a technique and what result I would have at the end of the application*", P5 - "*what made it easier is that the Stakeholder Identification option was already visible at the top, so I knew where to start. The input and output objects of each technique make it much easier when choosing a technique, helping to save time*" and P8 - "*it helped a lot, especially because the Selection Universe has a good variety of techniques, which is important when deciding which will fit best in a particular situation.*"

Regarding the question of whether the participants liked the web version approach, some of them stated they did, experienced no problems during use, and believed the approach could assist beginners in DT, as evidenced by the participants: P4 - "*During the work I did, whatever I needed, I came here to the site, entered easily, searched here, found what I needed, and left the site at ease. That was my experience; I had no problem* ", P6 - "*I liked the Selection Universe; this is the thing, I liked the Selection Universe. I think it makes things much easier; I knew most of the techniques but did not know how to divide them for which part of the DT process to use them. For example, I am used to doing empathy maps in all my work; I've always enjoyed making empathy maps. But I did them without knowing that it was precisely for stakeholder identification, so I liked the Selection Universe*," and P7 - "*my experience with the Selection Universe was positive; for me, it delivers exactly what it proposes, the explanations of each thing are obvious and objective, and the fact that it contains examples helps a lot; it's an excellent tool to guide people who are starting to use design thinking, besides saving a lot of work and time during the elicitation process.*" Some participants had previously used the Selection Universe in doc/pdf format (see supplementary material), and during this study, they used the web version. One of them mentioned preferring the document format because it presented an overview of all techniques from the categories, as stated by the participant: P1 - "*I think I preferred it with Google Docs because the information was all there. On the site, I had to navigate through options. The first thing I did was browse, but I didn't find what I was looking for, so I saw I had to look up where the options were. There was some time lost; they were all separated, like when I entered one, there was no information about the others.*"

Regarding suggestions for improvements, some participants mentioned that the icons and examples of the techniques should be standardized and improved, as stated by the following participants: P2 - "*I think the Selection Universe could have a more refined curation of the examples or the links provided for consultation*", P3 - "*I believe things need to be standardized; I feel that the examples, the icons, etc., are not standardized there. Something more aesthetic like that. I feel a lack of quality regarding the examples; they are different from each other. I believe if there were standardization of both the site and the examples, icons, etc., it would make navigation much easier*" and P5 - "*the examples could be better. The documents and links should be updated.*"

Regarding the limitation of this study to the use of just one category of the approach, some participants mentioned that specifying the category they should use limited their choice of specific techniques and also delimited their exploration fields about the use of the approach, as expressed by the participants: P1 - "*I think there wasn't much of a problem because we were quite well delimited in what we had to do, since it was just to research one of this type and we just had to go there and choose one. There wasn't much opportunity to have problems*," and P3 - "*in this case, the application of the Selection Universe, you guys already gave us the technique that fit, which was stakeholder identification. However, personas gave me exactly what I wanted when I clicked on stakeholders. I also wonder, if you hadn't told me it was stakeholder identification, would I have picked personas? You see, maybe if it wasn't for that, I might have picked a different technique, and maybe it wouldn't have been the best technique of all.*"

4.1.6 Application of the Card Sorting Technique. According to Conrad and Tucker [4], card sorting is an interactive research technique to clarify how participants understand and organize concepts. The

technique works as follows: participants arrange cards into categories that make sense to them. The sorting can be done on pieces of paper or online. Card sorting provides a deep understanding of the user's mental model, explaining how users typically group, sort, and label tasks and content in their minds.

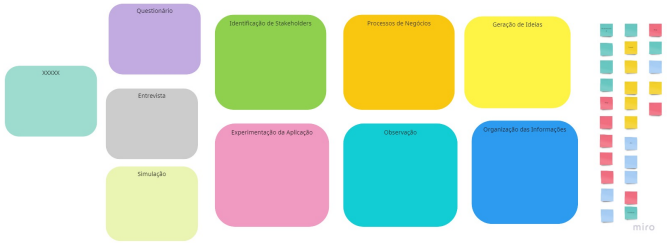
The technique was applied online using the Miro tool [4]. The technique used was hybrid card sorting, where categories were provided to the participants, but creating new categories was possible. The card sorting was conducted in two rounds, namely:

- **First round:** the participants grouped the DT techniques into the nine existing categories in the Selection Universe provided to them;
- **Second round:** the participants explained why the techniques were placed in the categories. They had the opportunity to move the techniques to different categories based on the explanations of other participants.

Result - First Round

In the first round, participants were shown a card sorting template containing the nine categories of the Selection Universe, the 27 DT techniques used by the approach, and a blank card so they could create new categories if necessary. Figure 3 displays the card sorting template used in this study.

Figure 3: Card Sorting Template Used (developed by the authors)

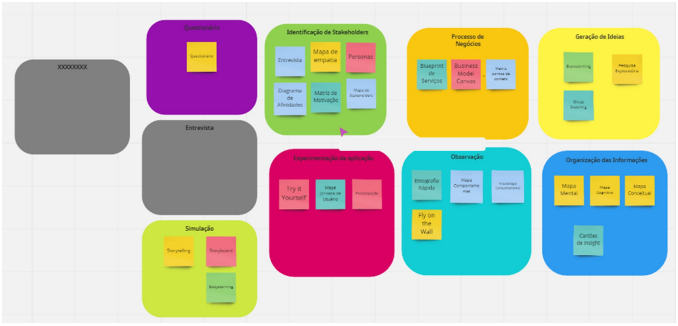


The participants had 15 minutes to group the DT techniques into the categories they deemed correct according to the characteristics of each. Figure 4 shows the result of categorizing the techniques in the first round.

It is evident that in this round, participants grouped some techniques into categories different from those in the Selection Universe approach. In the idea generation category, they added the exploratory research technique. They removed the affinity diagram, behavioral map, and storyboard techniques in the information organization category. They removed storytelling and added the touchpoint matrix in the business processes category. Participants removed the exploratory research technique from the observation category and included the behavioral map. The user journey map and touchpoint matrix techniques were removed from the stakeholder identification category, and the interview technique was added. In the application experimentation category, the user journey map technique was added, and in the simulation category, they

[4]Miro: https://miro.com/app/dashboard/

Figure 4: Categorization of DT Techniques in the First Round (developed by the study participants)

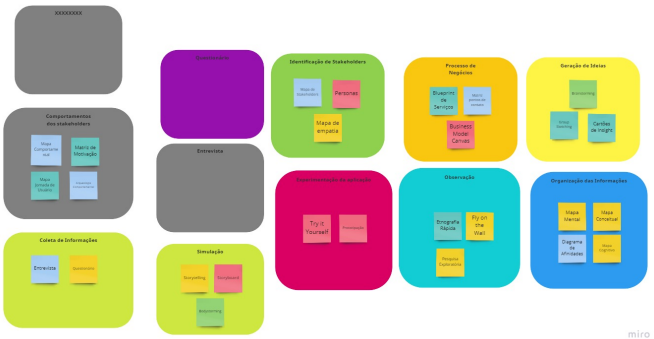


said the storytelling and storyboard techniques, as shown in Table 3.

Result - Second Round

In this round, participants explained the reasons for placing techniques in specific categories. They had the opportunity to move techniques from the categories assigned in the first round and to create new categories. Figure 5 shows the result of the categorization of techniques.

Figure 5: Categorization of DT Techniques in the Second Round (developed by the study participants)



It is evident that participants moved some techniques between categories and created two new categories. The categories of Information Collection, where the interview and questionnaire techniques were placed, and Stakeholder Behavior, including the behavioral map, motivation matrix, user journey map, and behavioral archaeology techniques, were created. Categorization of DT Techniques in the Second Round (developed by the study participants).

Regarding grouping techniques into existing categories, participants included the insight cards technique in the idea generation category. They removed the information organization category's insight cards, behavioral maps, and storyboard techniques. Participants removed storytelling and added the touchpoint matrix in the business processes category. In the observation category, the behavioral archaeology technique was removed. The touchpoint

Table 3: Categorization of DT techniques in the first round (prepared by study participants)

Category	Techniques 1st Round	Categorization in Selection Universe
Idea Generation	Exploratory Research, Brainstorming, Group Sketching	Brainstorming and Group Sketching
Information Organization	Mind Map, Cognitive Map, Conceptual Map and Insight Cards	Insight Cards, Affinity Diagram, Mind Map, Cognitive Map, Conceptual Map, Behavioral Map and Storyboard
Processes Business	Blueprint, Business Model Canvas and Touchpoint Matrix	Blueprint, Business Model Canvas and Storytelling
Observation	Rapid Ethnography, Behavioral Map, Behavioral Archeology and Fly on the Wall	Behavioral Archaeology, Rapid Ethnography, Fly on the Wall and Exploratory Research
Stakeholders Identification	Interview, Empathy Map, Personas, Affinity Diagram, Motivation Matrix and Stakeholder Map	Empathy Map, Personas, User Journey Map, Touchpoint Matrix, Stakeholder Map and Motivation Matrix
Application Experimentation	Try it Yourself, User Journey Map and Prototype	Try it Yourself and Prototype
Questionnaire	Questionnaire	Questionnaire
Simulation	Storytelling, Storyboard and Bodystorming	Bodystorming
Interview	-	Interview

Table 4: Categorization of DT techniques in the second round (prepared by study participants)

Category	Techniques 2nd Round	Categorization in Selection Universe
Idea Generation	Brainstorming, Group Sketching and Insight Cards	Brainstorming Group Sketching
Information Organization	Mind Map, Cognitive Map, Conceptual Map and Affinity Diagram	Insight Cards, Affinity Diagram, Mind Map, Cognitive Map, Conceptual Map, Behavioral Map, Storyboard
Business Processes	Blueprint, Business Model Canvas and Touchpoint Matrix	Blueprint, Business Model Canvas and Storytelling
Observation	Rapid Ethnography, Fly on the Wall and Exploratory Research	Behavioral Archaeology, Rapid Ethnography, Fly on the Wall and Exploratory Research
Stakeholders Identification	Empathy Map, Personas and Stakeholders Map	Empathy Map, Personas, User Journey Map, Touchpoint Matrix, Stakeholder Map and Motivation Matrix
Application Experimentation	Try it Yourself and Prototype	Try it Yourself and Prototype
Questionnaire	-	Questionnaire
Simulation	Storytelling, Storyboard e Bodystorming	Bodystorming
Interview	-	Interview
Information Collection	Questionnaire and Interview	-
Stakeholder Behavior	Behavioral Map, Motivation Matrix, User Journey Map and Behavioral Archeology	-

matrix, user journey map, and motivation matrix were removed from the stakeholder identification category. In the simulation category, the storytelling and storyboard techniques were added. The interview and questionnaire categories were removed, as shown in Table 4.

The participants created a category called **Information Collection**, and in this category, they grouped the Interview and Questionnaire techniques. They justified the creation of the category by stating that both techniques serve to collect information, as mentioned by the following participants: P1 - "*these techniques serve the same purpose so that they can be in the same category*" and P5 - "*the*

two techniques serve the same purpose, which is to collect information, so they can be grouped into a category called information collection."

Another category created was **Stakeholder Behavior**. The participants noted the existence of some techniques that yield results related to stakeholder behavior, necessitating a separate category for these techniques, as mentioned by the participant: P1 - "*The techniques Behavioral Map, Motivation Matrix, User Journey Map, and Behavioral Archaeology show the behavior of stakeholders, so I think it's necessary to create this category and separate these techniques from the Stakeholder Identification category.*"

After analyses conducted by the researchers, it was validated that grouping the Interview and Questionnaire techniques into a category we call Data Collection is appropriate, thus removing the Interview and Questionnaire categories from the Selection Universe. Its creation was not necessary regarding the Stakeholder Behavior category, as the Stakeholder Identification category also encompasses techniques that examine their behavior and perceptions.

4.1.7 Threats to Validity. In this study, the threats to validity include (1) the problem of specification of the material used, (2) the participant's familiarity with the material used, (3) the sample may not be representative of the population studied, and (4) representativeness of the scenarios. To mitigate threat (1), pilot studies were conducted to evaluate and improve the material to be used. To mitigate threat (2), training on Design Thinking, IoT, and the approach used in this study was provided. To mitigate threat (3), the study was conducted in both an academic environment and the software industry. To mitigate threat (4), the study was conducted in 8 scenarios aimed at the development of IoT systems.

4.2 Empirical Study in Industry

4.2.1 Objetive. After making changes related to the standardization of icons, images, and templates in the Selection Universe, we conducted a new study with industry professionals to gather their opinions on using the Selection Universe. For this purpose, they responded to the following questions:

- Q1: Do you believe the Selection Universe can help or hinder selecting the most appropriate technique for requirements elicitation? Please explain.
- Q2: Would you use the Selection Universe? Please explain.
- Q3: What did you like about the Selection Universe? What did you not like? Why?
- Q4: Do you have any suggestions for improvements?

4.2.2 Participants. The participants were 15 industry professionals from a Technological Development Institute. They worked on two software development projects aimed at developing systems for automating the supply line of a production line. All filled out the Informed Consent Form (ICF) along with a characterization form, which assessed their familiarity with DT and the techniques they knew. The characterization form was used to categorize the participants with the following levels of knowledge: none, low, medium, high, or very high regarding the aspects mentioned above. Considerations included: (a) very high, participants who had been involved in more than three industry projects using DT techniques; (b) high, individuals who had participated in one to three development projects in the industry using DT techniques; (c) medium, participants who had contributed to research and/or academic projects using DT techniques; (d) low, individuals who had notions of DT techniques obtained through classes or books; (e) none, participants who had no prior knowledge of DT techniques. Data on the characterization of the participants can be seen in Figure 6.

Figure 6: Characterization of Participants

Participant	Position	Exp	Knowledge about DT	Techniques already used
P1	Product Owner	20 years	Media	Brainstorming
P2	Pleno Test Developer	1 year	Medium	Brainstorming, Business Model Canvas, Storytelling, Exploratory Research, Empathy Map, Personas and others
P3	Pleno Designer	9 years	Medium	Empathy Map, Personas, User Journey, Touchpoints, Insight Cards, Affinity Diagram, Brainstorming, Business Model Canvas, Storytelling, Prototype, Interview and Questionnaire
P4	Pleno Automation Developer	10 years	Low	None
P5	Junior Full Stack Developer	1 year	Low	Brainstorming
P6	Pleno Automation Developer	1 year	Low	None
P7	Senior Automation Developer	6 years	High	Branstorming, Prototype, Mind Map and customer co-participation
P8	Junior Full Stack Developer	2 years	Low	None
P9	Pleno Automation Developer	3 years	None	None
P10	Junior Full Stack Developer	2 years	Low	None
P11	Senior Full Stack Developer	5 years	Low	Insight Cards and Personas
P12	Senior Automation Developer	12 years	Very High	Sitemap, RWP, Storytelling, Blueprint, Golden Path, Canvas and FPR
P13	Senior Telecom Developer	15 years	None	None
P14	Senior Automation Developer	7 years	Low	None
P15	mechanical specialist	7 years	Medium	Touchpoints Matrix, Mind Map, Exploratory Research, Brainstorming, Business Model Canvas, Prototype

4.2.3 Execution. For this study, the concepts of DT and the DT techniques that can be used for requirements elicitation as part of the proposed approach were presented. After introducing the DT concepts and techniques, the participants were invited to use the Selection Universe and reflect on which techniques could be used for eliciting requirements for the systems they were working on. After this reflective exercise, they were invited to complete the evaluation questionnaire for the approach. The instruments used in this stage can be observed at the following link (In Portuguese): https://figshare.com/s/5fa72236e1459e0efd79.

4.2.4 Qualitative Results. For the qualitative data analysis, we used Grounded Theory (GT) procedures based on data coding as described by Strauss and Corbin [19]. The coding process is divided

into three phases: 1) open coding, 2) axial coding, and 3) selective coding. Initially, in the open coding phase, we created codes related to excerpts from the participants' comments. Then, we grouped the codes according to their properties, forming categories and subcategories (axial coding). This analysis aimed to understand the participants' perceptions of the proposed approach. We did not conduct selective coding, as the goal was not to develop a theory but to understand the participants' perceptions. The open and axial coding phases were sufficient Valentim and Conte [20].

Participants Perceptions Regarding the Use of the Selection Universe

Participants were asked whether they believed the Selection Universe could help or hinder selecting the most appropriate technique for requirements elicitation. All participants responded that it would help, and their comments were grouped into the following codes:

Code1 - Helps in requirements elicitation: It was observed from the participants' responses that the approach assists in requirements elicitation, as it provides users with more precise insights into the objectives of the techniques, as reported in the following comments: P1 - "*helps in understanding the best techniques for requirements analysis*," P3 - "*I believe it does help, as the website user can see the techniques with certain objectives and make the best choice*", P5 - "*it helps because it makes the requirements clearer, simpler, and more understandable, even for complex situations and requests*," and P15 - "*it helps because it shows the different options of techniques available to elucidate the requirements and characteristics of the project or product*."

Code2 - Provides an overview of DT techniques: Participants mentioned that the approach provides an overview of DT techniques, which facilitates selection by comparing and informing about the techniques that can be used in a centralized manner, as mentioned by the participants: P10 - "*I believe it can facilitate the selection of more suitable techniques by showing an overview of what is generally used in DT*," and P12 - "*I believe it helps, after all, it condenses a large part of the tools, compares, and informs about their use in a very centralized way*."

Participants Perceptions Regarding Future Use of the Selection Universe

Regarding the question of whether they would use the Selection Universe in future projects, all participants responded affirmatively, and their answers were grouped into the following codes:

Code1 - Understanding the techniques: Some participants stated they would use the approach because it provides a better understanding of the techniques and facilitates selection, as explained by the participants: P3 - "*Yes. The techniques are well grouped according to their purpose, and I can easily access them when needed*," and P11 - *"Yes, I would use it to clear up doubts and understand the purpose of some things*."

Code2 - Remembering how techniques can be used: Some participants mentioned they would use the approach to remember how techniques can be utilized and because the summaries facilitate choice, as evidenced by the participants: P2 - "*Yes, sometimes it is very necessary to choose the right one among so many options*", P12 - "*I believe so because it is an easy summary*," and P15 - "*Yes, because it shows the different options of techniques available to elucidate the requirements and characteristics of the project or product. In my case, it reminds me of the different techniques and their applications.*"

Comments on what they liked and disliked about the Selection Universe: Regarding what participants liked and disliked about the Selection Universe, the responses were grouped into the following codes:

Code1 - Logical Sequence: Some participants reported that they liked the logical sequence in which the approach shows the techniques and also appreciated how the techniques were grouped, as mentioned by the participants: P1 - "*I liked the logical sequence of the activities*", P3 - "*I liked the grouping of techniques according to their purpose," P6 - "the ease and if you understand the concept and follow a logical sequence to use. It works in almost all cases*," and P15 - "I liked the division which seems to be somewhat ordered in sequence."

Code2 - Layout: Some participants mentioned liking the layout of the approach because it was intuitive and the information provided was evident, as stated by the participants: P5 - "*extremely intuitive and complete, though repetitive, but very enlightening*", P10 - "*I liked that the information was very straightforward*," *and P11 - "I liked the layout and the text*." In terms of dislikes, participants reported that the approach was poorly laid out and did not like the dropdown menu, as mentioned by the participants: P3 - "*I didn't like having to click on 'more' to see the nine objectives*", P12 - "*the page is very poorly laid out and made. I suggest using tools like Mobirise if you can't program the page. Then you can host it on GitHub, GitLab, or Heroku for free*," and P15 - "*I didn't like the initial screen because it doesn't direct to the divisions of techniques. I felt a bit lost on it*."

Improvement Suggestions: As suggestions for improving the Selection Universe, participants reported that it would be beneficial to improve the layout of the approach and include a side menu instead of a top menu, provide more examples, add a link to forums or something more collaborative, incorporate back or forward buttons on pages, and have examples displayed on the same page rather than as a link to an external repository, as suggested by the participants: P3 - "*I believe placing the objectives in a fixed left side menu would be better*", P11 - "*forums or something more collaborative could be interesting, sharing information*", P12 - "*the website layout could be simplified and could use a Single Page Application (SPA) architecture, making it more modern and more accurate*", P14 - "*application examples for automation and hardware areas*," and P15 - "*1. on the home screen, links to the categories could be added; 2. at the end of each category, back or forward buttons could be added to other categories or even back to the home; 3. examples of techniques could be on the same page, but as hidden material, similar to the 'show more' in YouTube video descriptions; 4. if possible, videos of use cases could be added for more information.*"

This study conducted with industry professionals revealed that the web version of the Selection Universe approach can be used as support during the requirements elicitation phase, as it provides a better understanding of the techniques, facilitating the selection of them. It was also noted that participants suggested improvements in the layout of the approach, such as placing back buttons on all categories.

We did not cross-reference the data between participants, but our analysis revealed that more experienced participants found the approach helpful in understanding the techniques, as it presents

the relationship between the methods and their objectives, thus improving the selection process. They also highlighted that the approach condenses many techniques, compares them, and provides centralized information on their usage. In contrast, less experienced participants mentioned that the approach helps them better understand the problems to be solved and facilitates the selection of appropriate techniques by providing an overview of what is commonly used in Design Thinking.

4.2.5 Threats to Validity. In this study, the threats to validity include (1) the problem of specification of the material used, (2) the participants' familiarity with the Selection Universe, and (3) the sample may not be representative of the population studied. To mitigate threat (1), pilot studies were conducted to evaluate and improve the material to be used. To mitigate threat (2), training on the use of the Selection Universe; (3) a amostra pode não ser representativa para a população estudada. Para mitigar a ameaça (1) foram realizados estudos pilotos visando avaliar e melhorar o material a ser utilizado. Para mitigar a ameaça (2) foi realizado treinamento sobre o uso da abordagem Selection Universe. Para mitigar a ameaça (3), o estudo foi realizado na indústria de software com profissionais de dois projetos de desenvolvimento de software que ocupam diferentes cargos, entre eles: Designer, testadores, desenvolvedores de software, desenvolvedores de hardware e mecânico.

5 FINAL CONSIDERATIONS

In this paper, we present the evolution of the Selection Universe approach. The approach consists of DT techniques that can be used in requirements engineering, especially during the requirements elicitation phase.

We conducted two empirical studies to evaluate the Selection Universe web version. The first study employed two techniques, a focus group and a card sorting session. The focus group aimed to verify participants' perceptions about the use of the approach and suggestions for improvement, and the card sorting aimed to evaluate the categorization of DT techniques. As a result of the focus group, we found out that the approach was well received by the participants and facilitated the process of selecting DT techniques for requirements elicitation of the proposed systems. As a result of the card sorting, two categories were removed. The techniques from these categories were grouped into a new category called Data Collection. During the focus group results analysis, improvements were identified in the Selection Universe. After we completed the improvements suggested in the focus group, we conducted another study with 15 industry professionals. This study revealed that the Selection Universe can support the requirements elicitation stage, as the approach provides a better understanding of the techniques, which facilitates the selection of the DT techniques by the software engineers.

The main practical implications of the results of this study include: For Professionals: (1) Facilitation of Adequate Technique Selection: assists in choosing the most appropriate DT techniques for ER, making the process more user-centered, and (2) Promotion of Innovation: stimulates innovation by allowing exploration of different approaches and solutions to project challenges. For Researchers: (1) Experimental Validation of the Approach: experimental studies validate the proposed approach, demonstrating its utility in SE, (2) Encouragement of DT Integration in SE: the results may inspire greater integration of DT in software development, aiming for higher user satisfaction and better project outcomes, and (3) Contribution to the Literature: findings enrich the literature with a practical and proven methodology for applying DT in ER, offering valuable insights for future research.

The Selection Universe is updated whenever new works citing DT techniques that can be used in requirements elicitation emerge. The new web version of the approach features 46 DT techniques.

Future work aims to evolve the approach to version 3.0, where DT techniques that can be used in requirements engineering identified in the MSL by Parizi et al. [15] will be analyzed. A total of 85 techniques will be analyzed. After evolving the approach, replication of the experiments conducted in this work with industry professionals will be carried out to expand the use of the results obtained in this research and thereby evaluate version 3.0 of the approach.

6 DATA AVAILABILITY

The dataset and material used in this research are currently maintained as an open-source project accessible at:

https://figshare.com/s/5fa72236e1459e0efd79

To avoid leakage of sensitive data and ensure privacy, we choose to anonymize all personal information provided in this paper.

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