Bloom's Taxonomy as a Lens to Explore Student Learning of Design Thinking in Software Engineering Education and Training

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ABSTRACT

Background: Design Thinking (DT) has been widely adopted in Software Engineering (SE) for its emphasis on creativity, user understanding, and iterative problem-solving. However, in the context of SE Education and Training (SEET), there is a lack of empirical research exploring how students internalize, engage with, and perceive DT-related content. **Aims:** Our research aims to understand how SE students perceive and internalize DT concepts during their training. **Method:** We conducted semi-structured interviews with nine students who had previous contact with DT through an SE course. We used Bloom's Taxonomy as a foundation, as it offers a structured framework to assess the cognitive levels students reach when learning a given topic. This approach allowed us to explore how students process, retain, and apply DT-related knowledge. We analyzed the data using Grounded Theory procedures. **Results:** Analyzing through the lens of Bloom's framework, we found individual differences in the depth of learning and consolidation of DT concepts. Three participants demonstrated analysis-level abilities, four reached the synthesis level, and two attained evaluation-level skills. Our findings also reveal that students associate DT with creativity, user understanding, freedom to explore options, and goal orientation. They also recognized the value of DT techniques for organizing data, guiding technical decisions, and supporting the software development process. Based on our findings, we propose an empirically-based conceptual model that structures students' perspectives on the use of the DT in SE. **Conclusions:** We hope our contributions can assist educators in developing strategies to help students better retain DT content, with emphasis on SEET, as our results offer a structured understanding of how students internalize DT in SE.

KEYWORDS

Software Engineering Education and Training, Requirements Engineering, Design Thinking, Cognitive Aspects

1 Introduction

Design Thinking (DT) is a human-centered approach that has gained increasing attention in Software Engineering (SE) due to its emphasis on creativity, experimentation, and deep user understanding [10]. DT presents three complementary perspectives [2] – mindset, process, and toolbox – and each has its distinct role in supporting innovation and problem-solving in SE. In the context of Requirements Engineering (RE), DT offers practical methods that integrates with traditional RE practices, and can enhance the requirements elicitation process by promoting the adoption of user-centered processes and fostering creative exploration of solutions [20].

Despite the increasing use of DT in SE education and the recognition of its potential to enhance creativity and user-centered design practices [1, 12, 13, 17, 22, 26, 28], little is known about how students perceive and internalize DT techniques within educational contexts. Prior research has primarily focused on evaluating outcomes such as creativity or teamwork [1, 12, 28], but, to the best of our knowledge, no studies have explored students' learning progression or cognitive development when exposed to DT. With no clear understanding on how students perceive, engage with, and internalize DT content, SE programs may not align pedagogical strategies with students' needs, limiting DT value as part of SE education.

To explore how students process, retain, and apply DT-related knowledge, our research aims to investigate students cognitive progression across Bloom's Taxonomy [3] levels when learning and applying DT concepts, as the taxonomy offers a structured framework to assess the cognitive levels students reach when learning a given topic. Besides that, we also intend to uncover how students understand and internalize DT concepts for SE processes. Therefore, we aim to provide insights on how students learn and appropriate DT concepts within SE Education and Training (SEET) context by answering to the following Research Questions (RQ):

- **RQ1** What cognitive skills do SE students demonstrate when learning and applying DT in SE?
- **RQ2** Which concepts of DT do SE students consolidate and internalize?

We introduced DT concepts during RE classes in a SE course, joining theory and hands-on practice within DT techniques. Then we assigned the students to carry out a practical assignment in which they should elicit requirements for different systems using

DT techniques to assist this process. During this time, they interacted with real users and potential stakeholders. To assess the extent to which DT concepts had been retained and internalized over time, after finishing the practical assignment, we waited a 3 months before inviting students to participate in our research. We conducted and recorded semi-structured interviews within 9 students who volunteered to join our study. We grounded our interview script based on Bloom's Taxonomy [3], allowing us to cover a range of cognitive levels. Upon transcribing the interviews, we analyzed how they demonstrated cognitive progression through their interview answers. We analyzed the data following Grounded Theory (GT) procedures [25].

In our findings, we observed strong cognitive retention at the foundational levels (knowledge and understanding), with all participants recalling core DT concepts and most demonstrating a clear grasp of its purpose and application. Although fewer participants demonstrated skills related to higher cognitive levels such as application, analysis, synthesis, and evaluation, this may reflect the natural progression of learning and the limited opportunities to apply DT beyond the classroom. We also developed a conceptual model that summarizes students' perspectives on DT. Students reported that DT supported technical decision-making and enhanced creativity, user understanding, and exploration of alternative solutions throughout the software development process. They also highlighted strategies for consolidating DT learning, including hands-on practice, interactive lectures, and the use of supporting tools for technique selection.

As our contributions, we expect our insights can assist educators on tailor their pedagogical approaches for promoting a more practical engagement within DT concepts, allowing students to both retain knowledge and advance toward higher-order cognitive skills. As for our conceptual model, we expect it to assist educators and researchers on how to improve DT teaching strategies for SEET by offering insights into how novice engineers engage with user-centered and creative problem-solving approaches at different cognitive levels. Such contributions fill a literature gap, as to the best of our knowledge, no previous studies have proposed a structured representation of students' perspectives on DT in the context of SEET.

2 Background

In this section, we define DT, its characteristics and use on both SE and SEET context. Then, we discuss related work to our research.

2.1 Design Thinking

DT is a human-centered approach focused on innovation that combines design sensitivity, technological feasibility, and business viability to generate solutions that meet real user needs [2, 9]. This approach stimulates creativity through divergent and convergent thinking, values experimentation with prototypes, and promotes constant iteration based on testing with end users [2]. It presents three complementary perspectives [2]: (1) mindset, which incorporates principles such as empathy, experimentation, and focus on users' explicit and latent needs; (2) process, structured in iterative stages; and (3) toolbox, composed of interdisciplinary techniques with focus on different design aspects.

DT is recognized for its interdisciplinary nature that practitioners use to explore innovative solutions in different contexts [11, 19]. For SE, DT stands out as a human-centered approach that promotes creative, collaborative solutions aligned with real user needs, being applied in different stages of the software development process [20]. Its integration with agile methods, such as Scrum, can enrich meetings and practices with empathy, ideation, and prototyping techniques, contributing to a more feedback-sensitive and change-aware iterative process [8]. This approach has been applied in contexts where complex and ill-defined problems demand a deep understanding of the user and collaborative action, favoring creating user-centered solutions with high innovation potential [5, 9].

In RE, DT can act as an assisting approach for eliciting user needs, strengthening communication with stakeholders, and addressing complex problems with flexibility and a user-centered focus [4, 20]. In this sense, DT expands the traditional RE toolbox by incorporating techniques that emphasize a human-centered perspective, introducing methods that aim to elicit and understand user needs through empathy, creativity, and iterative exploration of the problem space [9, 10]. By focusing on the context of use and producing non-technical artifacts such as empathy maps, user stories, and low-fidelity prototypes, DT complements the technical nature of conventional RE approaches and enhances the understanding of stakeholders' perspectives [5, 10]. DT techniques are also effective in requirements elicitation activities, where they help ensure that the resulting solutions are aligned with real user needs [20].

These tools and practices encourage development teams to adopt a user-centric mindset, making the RE process more flexible, creative, and responsive to complex or ill-defined problems [19]. As such, DT techniques enhances RE by guiding practitioners through structured yet adaptable methods that support identifying, analyzing, and validating requirements in ways that prioritize user needs and foster innovative software solutions [4]. On creating a DT culture among software development, it contributes to developing creative and user-centered solutions [7].

2.2 DT in SEET

For SEET, using DT can support developing skills that go beyond traditional technical knowledge, as it integrates technical and social aspects of SE practice, fostering collaborative skills related to teamwork, empathy, communication, and critical thinking [1, 12, 28]. DT offers a user-centered approach that supports a deep understanding of real needs and stimulates creativity and innovation in problem-solving [22, 26], promoting a paradigm shift from technocentric design to human-centered design, and encouraging students to adopt empathic and iterative postures when designing solutions [26].

RE is another field that benefits from using DT. Activities such as requirements elicitation are fundamentally human, making establishing effective relationships with stakeholders and users essential [16]. It requires interpersonal skills such as empathy, active listening, and clear communication [4]. In this way, developing cognitive, interpersonal, and technical skills becomes indispensable for training a software engineer with mastery of RE processes. DT's iterative and practice-oriented structure aligns with RE needs, promoting a reflective learning environment that assists developing such skills in software engineers [12, 22].

Despite advances in identifying benefits from using DT in SEET, to the best of our knowledge, no studies seek to understand in a structured manner how SE students perceive and appropriate the elements that compose this approach. For RE education and training in particular, the lack of structured, student-centered investigations is especially relevant, given that the field seeks for contributions with strong empirical foundations [27]. Our work aims to fill this gap by assessing students learning through Bloom's taxonomy lens and proposing a preliminary conceptual model that represents the perspective of in-training software engineers on using DT. In the following subsection, we compare our research with other papers.

2.3 Related Work

Abich et al. [1] conducted a case study with 22 SE students to investigate how DT can foster collaborative skills in educational projects. The study lasted 18 weeks and adopted the Double Diamond model as its methodological basis. To assess collaboration, the authors used the 3C model (Communication, Coordination, and Cooperation), analyzing artifacts the students developed and applying structured questionnaires. As their results, DT promoted high levels of communication and cooperation among students, although coordination proved challenging.

Marques et al. [12] conducted an experimental study with 77 graduate students in SE to investigate how DT can support soft skills development through practical classroom experiences. The authors proposed a dynamic based on the phases of the D-School model, integrating DT techniques such as personas, user stories, brainstorming, prototyping, and user evaluation. Their analysis of students' perceptions indicated the development of skills such as critical thinking, creativity, teamwork, and client expectation management.

Valentim et al. [26] conducted an empirical study with 17 graduate students to identify their perceptions regarding the learning and application of DT in the context of mobile application design. The study followed the Inspiration and Ideation phases of the model proposed by Brown, using techniques such as Personas, Empathy Maps, Brainstorming, and Co-creation Workshops. Their findings revealed DT's potential to promote empathy, creativity, and collaboration, but also challenges related to understanding users and team interaction.

Challiol et al. [6] proposed a conceptual framework that integrates experiential learning cycles into the teaching-learning process of DT to foster its acquisition as a thinking process by Computer Science students. The authors applied their framework in two workshops with graduate students, in which participants experienced activities based on the Double Diamond model and developed their projects using DT. The participants could apply the acquired knowledge in new contexts, selecting and adapting resources autonomously.

The main difference of our work lies in the use of Bloom's Taxonomy as an analytical lens, which allowed us to explore students' learning progression across different cognitive levels. Thus, our conceptual model offers a structured representation of DT as a technical repertoire capable of enhancing SEET. Therefore, we seek to provide support in fostering the development of pedagogical strategies that promote better retaining knowledge on DT. To conduct our research, we introduced students to DT concepts during SE classes, which we detail in the following section.

3 Methodology

In this section, we present the pedagogical approach for introducing DT in SE classes. Then, we present details on how we conducted the interviews with students.

3.1 Teaching Approach

Our classes occurred during a SE course within 59 students that covered four main modules: (1) SE Principles, (2) Agile Methods, (3) Requirements Engineering, and (4) Software Verification, Validation, and Testing. For this research, we focused specifically on the RE module. During the RE classes, we introduced DT content to support the requirements elicitation process. We aimed to introduce students to how DT techniques could enhance students' ability to identify, understand, and communicate user needs, thereby complementing traditional RE practices. During the RE module, students attended two sessions on DT content, in which we presented its main concepts and practical relevance to SE. Each session lasted about 2 hours, and we describe each as follows:

- **First session:** We introduced DT as a human-centered and collaborative approach to problem-solving, emphasizing its characteristics such as iteration, time constraints, action orientation, and interdisciplinary teamwork. We also discussed its three perspectives [2], highlighting its flexibility and potential to enrich requirements elicitation activities. The session covered well-established DT process models, including the Double Diamond and the cyclical model proposed by IDEO, and presented a set of techniques from the DT toolbox, such as Brainstorming, Personas, Empathy Map, Affinity Diagram, Card Sorting and CSD Matrix. Then, we conducted a hands-on workshop to encourage students to explore and apply DT techniques, enhancing their learning through practice. During it, we instructed them to unite in groups as they would interact within techniques for gathering relevant information on the system they would work within the practical assignment, such as Card Sorting, CSD Matrix and Affinity Diagram.
- **Second session:** We followed up the hands-on workshop, and instructed the students to interact within DT techniques for understanding its users, such as Brainstorming, Personas and Empathy Maps. They generated practical artifacts for understanding the end user's needs that would be useful for providing support during future requirements elicitation activities.

3.2 Practical Assignment

Before the DT lectures took place, we assigned the students a team-based practical assignment focused on requirements elicitation. The main goal was to allow them to practice requirements elicitation processes by engaging with real-world problems and diverse stakeholders [1]. Each group, composed of 3 to 6 students, was required to define a project scope and submit it for approval for the professor and two teacher assistants. In this scope, they should specify the problem they would address through a software system, including the expected value for ending users and the user profiles.

Throughout the assignment, they were also tasked to apply at least three elicitation techniques they would select based on their relevance to the project context. To support the selection and use of appropriate techniques, we introduced the students to the Selection Universe [14], a repository of DT techniques that distributes them into ten categories based on their purposes, such as stakeholder identification, data collection, information organization, idea generation, and requirement specification [2]. By consulting this resource, students could select which techniques to employ depending on their goals, stakeholder profiles, and project constraints.

We encouraged the students to apply elicitation techniques directly with real stakeholders, such as potential users or clients affected by the proposed systems. This engagement aimed to enrich their learning by combining theory with practical application in authentic scenarios. The interaction with real people and contexts allowed students to understand user needs better, identify functional and non-functional requirements, and interact with human-centered techniques.

Upon finishing the DT content, the students could focus on work within the practical assignment. They had 22 days to carry out their practical assignments. Upon finishing the work, they presented their results during the following three class sessions. These sessions followed a workshop-like format, in which each team had up to 20 minutes to present their project outcomes, including the refined system scope after requirements elicitation, the generated artifacts, and a non-functional prototype representing their proposed minimal viable product. At the end of each presentation, teams received constructive feedback from the professor and their peers. This format provided an opportunity for collective learning through peer discussion.

3.3 Interview Planning and Execution

Seeking to explore the retention of DT concepts over time and to provide a more realistic view of what learning outcomes persisted beyond short-term exposure, we waited 3 months upon finishing the SE course before inviting students to participate in our research. Our rationale for conducting the data collection after the end of the course was to assess whether and how students had internalized and consolidated DT content. Therefore, leaving some time after the instructional activities and the practical assignment, we could capture more reflective and lasting impressions on their learning.

As for our instruments [3], we developed an **interview script** whose questions we based on Bloom's taxonomy [3]. This taxonomy defines a conceptual framework that allows the assessment of student learning, and its use in SE focuses on assessing students' learning and designing SE courses [3]. We used the taxonomy's cognitive levels as the basis to design our interview script, which would allow us to capture data on whether and how students perceive the use of DT for SE. In this sense, it would provide a holistic view on their perspectives. Table 1 summarizes each of the cognitive levels and its respective interview question, and we provide our full interview script in our supplementary material.

We also developed a **consent form**, that would allow us to ensure that participants were fully informed about the nature and objectives of the study. The form clarified that participation was voluntary, outlined the procedures involved, and guaranteed confidentiality and the right to withdraw at any time without any consequences. This step was essential to comply with ethical research standards and to promote transparency in the data collection process. The Research Ethics Committee approved this study under protocol number *CAAE: 79890324.2.0000.5020*. We collected contextual data on students' prior experiences through a **characterization form**, which included questions on their prior experience with Requirements Elicitation and DT before taking classes. In summary, most participants had little to no prior knowledge of either DT or Requirements Elicitation.

We first conducted a pilot study within a subject to evaluate our interview script. Upon conducting the pilot study, we were able to improve our instrument before effectively executing interviews within our participants [15]. We contacted the students to join our study via email, on which nine volunteered to participate, and we proceeded scheduled individual interview sessions based on each participant's availability. At the beginning of each interview, we asked them to read and sign the consent form, ensuring they were informed about the study's purpose and their rights. Then, we asked for permission to record the conversation, which was essential for allowing transcribing and analyzing. Once consent was obtained, we proceeded with the interviews, following the predefined script. The interviews lasted approximately 10 to 20 minutes each.

3.4 Analysis and Interpretation

Upon recording each interview, we began transcribing the audio data verbatim to ensure accuracy and preserve the participants' original expressions. We conducted our analysis primarily in Portuguese to ensure fidelity to the participants' original wording and to avoid potential misinterpretations during the analysis. We translated into English only the final excerpts included in our paper. To analyze the interview data, we adopted GT procedures [25], specifically the process involved the stages of Open Coding and Axial Coding. Although GT's use, our intention was not to generate a formal theory. Rather, it served as an analytical foundation for interpreting our data [24].

Our analysis began with a thorough reading of the transcribed interviews, followed by an open coding process that allowed us to identify and label relevant excerpts with descriptive codes. These codes were then organized into preliminary categories. As different categories emerged, we organized them in a way that captured recurring patterns and key dimensions in the participants' response. Then, we proceeded with axial coding to examine how these categories related to one another, allowing for exploring connections among the conceptual axes. Our analysis provided insights into how students perceived and internalized the DT content, as well as how they connected it to their perception for SE processes.

[1] The practical assignment specification and DT presentation are available in our supplementary material
[2] https://sites.google.com/view/universodeselecao
[3] All the instruments are available in our supplementary material

Table 1: Interview Questions Aligned to Bloom's Taxonomy Levels

Cognitive Level	Skill	Interview Question
Knowledge	Retrieve relevant knowledge from long-term memory	What do you remember from the Design Thinking classes? You can mention the words that come to your mind.
Understanding	Build meaning through language	In your perception, what is Design Thinking for? When is it applied?
Application	Use principles to complete a task with minimal supervision	Have you had the opportunity to apply Design Thinking somewhere else out of the practical assignment scope? It can be in academic or industrial settings.
Analysis	Distinguish applications of learned concepts analytically	Did you study any of the techniques after the course? Or did you compare the techniques you used to understand which context one might be better?
Synthesis	Combine elements to form a coherent and functional whole	Have you had the opportunity to evaluate the result produced by Design Thinking? These results refer to the artifacts generated at the end of a process or from applying a technique.
Evaluation	Make judgments based on criteria	Is there any detail you would like to improve among the techniques you used? It could even be modifying a technique to make it more consistent with your expectations or knowledge.

To analyze our data through the lens of Bloom's Taxonomy and assess whether students demonstrated skills associated with each cognitive level, we reviewed their responses and classified each on a binary scale as either "Yes" or "No." A "Yes" classification indicated that the student exhibited skills corresponding to the cognitive level in question, whereas a "No" indicated the absence of such skills. This additional layer of analysis provided a structured interpretation of students' cognitive engagement with the DT content. All coding and Bloom-level assignments were discussed among three researchers and resolved by consensus to ensure consistency in interpretation and classification.

4 Results

In this section, we present our findings related to the students perspectives on DT for SE, and their learning cognitive aspects.

4.1 DT in SEET Conceptual Model

As Figure 1 presents, our analysis resulted in a conceptual model that captures the main categories and relationships emerging from the students' perspectives on DT. The central construct, **Students perspectives on DT for SEET**, is composed of two interconnected categories: (1) **DT Techniques Properties** which include six types of properties, such as Understanding the user, Creativity and idea Generation, Organizing data, Exploring options, Goal-oriented and Decision making; and (2) **Perceptions on learning DT**, supported by Strategies for Consolidating DT Content. Due to the page limit, in the Figure we highlighted from one to two codes per category in gray color, and we provide an overview of our complete conceptual model in the supplementary material [4].

Our findings reflect learning behaviors aligned with different cognitive levels of Bloom's Taxonomy, as our instrument for gathering qualitative data was grounded by this framework. Therefore, the identified categories and codes are structured to represent how students retained DT concepts throughout their learning process. We describe our findings in the following section, and to facilitate understanding, we highlighted in bold the codes identified within each category.

[4]Our full conceptual model is available in our supplementary material

4.1.1 DT Techniques Properties. **DT techniques are interdependent** was one of the factors P01 highlights, stating that *"they have to be used together because if you keep going back to modify a certain technique, you might end up removing the function of another."* **DT techniques complement each other** is another property aligned with P09's perspective, who claims that *"they all complement each other and fill a portion of the whole."* These properties highlight that people can use DT techniques together since they can complement each other, a relevant characteristic of DT [23].

DT techniques work iteratively is a factor that P04 perceived when commenting that *"it seems like it always comes back. The person goes there, applies the technique, and then reaches a conclusion. Continues developing 'x thing' and then returns to that again. It is the perception I have, that it is in a cycle."* In this way, DT is understood as an iterative and incremental process, as it is possible to use a technique and enhance its results with new information.

Another property is that **DT techniques are equally important**, as P06 reports that *"all DT techniques are important. None of them is more than another."* In the sense that all techniques are important, **The difference between DT techniques is where to fit them**, as P06 declares that *"What differs [DT techniques] is where it fits, you know? For something, 'this one' might be better than using 'that one.'"* Another property of DT techniques is that the **Practice helps to fit them better**, as P06 highlights when reflecting on the desire to *"be able to specify better where I fit each technique, you know? We had the class, but I believe these things come with practice."* In this way, we can observe that there is no silver bullet when using DT in software development. Different factors turns to be relevant on selecting across a wide variety techniques [14]. Thus, understanding factors related to the system's context becomes highly relevant when selecting appropriate DT technique according to the project's needs.

In this sense, another recommendation includes **Using DT techniques according to the need**, as P05 asserts that *"the use of each technique was exclusively based on our choice, on our needs at the*

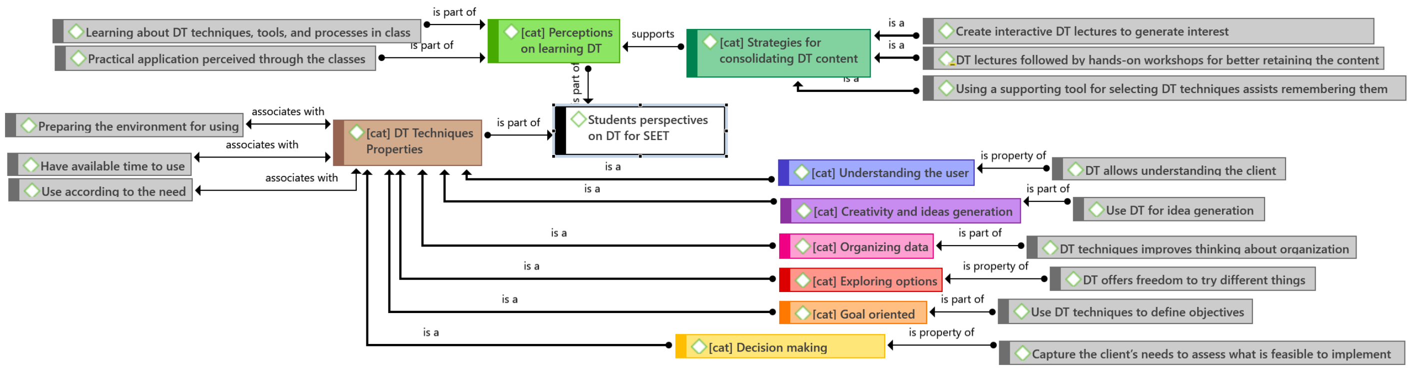

Figure 1: Conceptual model based on student perceptions of DT in SE.

time." Additionally, it is also necessary to **Have available time to use DT techniques**, as P05 considers using them *"when you have a certain available period, right, to be able to use them, because, whether you like it or not, they take a while to use. So, if you have a very tight deadline, applying techniques that take much time is complicated."* Therefore, on using DT techniques, it is necessary to consider the existing need to use a it and whether the available time is suitable for its application.

Finally, **Preparing the environment for using DT techniques** originates from P09 reflection on commenting on their experience using Brainstorming within their group. In this sense, they highlight feeling that *"the technique is having an effect on the people themselves, and that affects the project [...] so, as it [the technique] is affected by the environment in which it is applied, maybe it would be interesting to take an approach in that environment as well. Since it affects the technique, maybe shaping the environment according to the technique."* It reflects the need to prepare an appropriate environment for using DT techniques, as this process involves people, and their outcomes can impact the software under development. Thus, it is necessary to understand how to create an ideal environment that enhances each DT technique's outcomes.

> **Finding:** DT techniques are iterative and interdependent. Its use depends on aspects such as needs, time availability, and an appropriate environment.

4.1.2 Understanding the User. We highlight that there is **Interest in DT techniques that deal with the user**, which P08 reflects upon that *"many of the DT techniques that I find interesting are mainly those dealing with the user."* This interest is enhanced by the fact that **DT allows understanding the client**. P01 emphasizes this by stating that DT *"is used for you to understand the client, and in that moment of understanding so that later you can start thinking about how the system will be and everything else, the technical part."* This point is supported by the fact that students explored users' needs using DT techniques to support requirements elicitation.

In this way, techniques such as **Personas allows defining the target audience**, which P09 mentions as *"that categorization of the user itself. You define who the 'target audience' is, so to speak. And then you start categorizing their characteristics."* Another highlighted factor was that **The CSD Matrix also allows understanding the client**, as P01 points out that *"the [CSD matrix] can serve to help you understand the client."* These pieces of evidence highlight that the DT toolbox offers tools that support identifying user needs.

> **Finding:** DT assists in an user-centered elicitation process, and students demonstrated interest in techniques focused on identifying ending-user needs.

4.1.3 Creativity and Ideas Generation. **DT can provide space for generating new ideas**, as P06 highlights that its use involves *"listening to all the people in the team and giving space for new ideas."* This perspective extends as a recommendation to **Use DT for idea generation**, which P04 emphasizes that they believe *"DT is mainly used to generate ideas."* By bringing together these aspects, DT is considered an approach composed of well-structured processes and techniques that stimulate creative thinking.

In consequence, **DT techniques are also focused on creativity**, which P02 highlights that *"they are techniques geared toward a more creative side."* Techniques such as Brainstorming emphasize such creative side, whose use **Allows idea generation**, as P05 contextualizes by saying they began using *"the most useful [technique] for us, which was Brainstorming since we did not know anything. Since we needed to develop ideas, we thought of 'brainstorming.'"* Field Studies also assists in **Providing new information**, which P05 adds that their group *"managed to separate the points we wanted to evaluate. We were able to separate well and find some new information."* These pieces of evidence demonstrate that it is possible to use DT techniques to stimulate creativity in generating ideas and identifying new information with potential relevance in ideation processes.

> **Finding:** DT techniques assists creative thinking, idea generation, exploring new information and develop solutions.

4.1.4 Organizing Data. We highlight that **DT combines creativity and organization**, a factor that P02 recognizes in DT as it *"combines both creativity and organization."* We also denote that **DT allows understanding how to generate and organize artifacts**, as P08 highlights their perspective that *"part of DT is about understanding how to generate the artifacts."* These factors emphasize DT as an approach with the potential to support executing processes related to artifact generation in a structured and organized way.

In addition, another perspective we identified is that **DT techniques improves thinking about organization**, which P07 describes that *"all the DT techniques helped us to think better, right? To group things."* Within the range of DT techniques that support organization, we highlight that **Card sorting allows data organization**, a factor that P05 details that *"we used card sorting, 'we have many ideas now... how could we bring this information together in a way that helps us better situate it?' We thought, 'Let's choose a technique to organize the data,' which was that one [card sorting]."* By analyzing these perspectives, DT positions as a driving force capable of stimulating organization through its techniques.

Therefore, we recommend **Using DT to organize many options**, which P02 explains when talking about using it *"when you have many options, and you basically want to take all of that and organize it in a way that is easier to digest, a way that is easier to organize."* This recommendation is supported by the evidence highlighted in the previous paragraphs, which shows how DT can bring organization to processes and support the management of data.

> **Finding:** DT techniques help structure and organize data, while supporting artifact generation and the development of organizational thinking.

4.1.5 Exploring Options. We highlight that **DT offers more freedom than traditional techniques**, as P02 states that *"it is something much more free than traditional techniques."* In this sense, **DT offers freedom to try different things**, which P02 explains by saying that DT is *"something that gives a little more freedom for you to try different things."* We can observe that these perspectives recognize DT as an approach that offers more flexibility in its techniques than those traditionally used in the elicitation process. It aligns with the fact that DT expands the RE toolbox by offering techniques capable of complementing such a process [9].

Thus, we conclude that **DT provides the opportunity to explore all available options**, which P02 describes they consider DT to *"give many opportunities for you to explore all the options you have."* The experimentation of multiple options is a predominant characteristic of DT since its techniques related to prototyping allow testing ideas quickly, emphasizing DT's experimental nature [10].

> **Finding:** DT encourages experimentation through its techniques, offering greater freedom than traditional techniques.

4.1.6 Goal Oriented. As for DT's capability to support keeping a goal-oriented mindset, we highlight that **DT techniques provide a holistic view that supports achieving objectives**. In this sense, P06 emphasizes that *"those maps, those personas made me realize things that I would not have noticed if I had just said: 'This is the project, this is the assignment, and I think it is like this and that.' There was a lack of a full view, you know? To complete that assignment and achieve what it was supposed to."* In this context, we recommend **Using DT techniques to define objectives**, as P06 describes that *"at the beginning of an assignment, I think we do not really know where to start. Moreover, the DT techniques are a turning point for us to know at least what we want and where we want to get."* These points help us understand that it is possible to use DT techniques to comprehend the system under development, facilitating tracking of its goals and outlining strategies to achieve them.

On recommendations for using DT in a goal-oriented way, we recommend **Using DT when you do not know what to do**, which aligns with P02's perspective, who stated that *"it [DT] is more applicable when I do not know what I want to do, and when I have many options."* This highlights that students may consider DT as a valuable tool to guide a project when there is no defined strategy for which direction to take it. We also recommend **Using DT to clarify uncertainties**. P09 highlights it when answering when DT is applicable, declaring that it is *"to clear doubts about what will be done and so on."* P02 has a similar perspective, stating that its use is suitable when *"what you want to create, what you want to develop, is not that clear."* These perspectives emphasize DT's capacity to guide the resolution of uncertainties within a project, a relevant factor in defining the objectives to be achieved by the system under development.

> **Finding:** DT techniques supports a holistic understanding of what needs to be achieved, as it helps to clarify uncertainties and define objectives.

4.1.7 Decision Making. We identified some factors that consolidate the usefulness of DT to support technical decision-making from the student's perspective. The first factor is that **DT is a set of techniques for eliciting requirements.** This factor associates with P05's perspective, who states to comprehend DT as *"a set of techniques we are going to use to elicit requirements."* This perspective aligns with the primary use of DT techniques during the practical assignment as tools for eliciting requirements.

Besides that, it is possible to **Capture the client's needs with DT to assess what is feasible to implement**, as P01 states to use DT for *"capturing the client's need and see what is feasible or not to be implemented later."* In this sense, techniques such as prototyping can be capable of **Simulating decisions** and **Visualizing DT's decision-making**. P01 explains that *"when our prototype was ready [...] we could see that all our decisions about what it had to have, how we understood the clients, were materialized there. Obviously, it was not implemented, but we had a whole simulation of what it would be [...] There, it was possible to see that the decisions we made during DT worked, and some did not."* In this way, we can understand that DT may assist in asserting which client needs are feasible to implement and to simulate such decisions through prototypes.

Finally, the idea that **DT techniques target aspects of the application's design** also associates with P01's perspective, which claims that *"all [DT techniques] target a certain aspect of the application's design."* The design of an application, in turn, is associated with the system's structure and the definition of its functionalities. In this sense, techniques such as the CSD matrix can **guide technical functionalities** and **guide technical doubts about what a system should have**, as P01 comments on how *"The [CSD matrix] could also serve to guide technical functionalities of the system [...] it can solve many technical doubts about what the system should or should not have."* We can conclude that students understand the use of DT techniques to support defining which functionalities to implement in a system.

> **Finding:** DT assists in decisions making, helping identify feasible functionalities and simulate design choices.

4.1.8 Perceptions on Learning DT. In the subsection, we highlight perceptions that emphasize the main aspects students point out regarding their learning about DT. The first perception is related to **Learning about DT techniques, tools, and processes in class**, as P04 recalls remembering *"the techniques that were presented, the tools we can use, in which processes we can use them."* Complementarily, the **Practical application of DT was perceived through the classes**, which aligns with P03's view, who claims *"really being able to see where it [Design Thinking] was applied, for example in projects or even assignments that I had already done in college. I was able to understand where those ideas and plans could be applied"* when recalling DT classes. In this way, the DT content taught in class allowed students to understand DT methods and processes.

A factor that expands the idea of the perceived practical application of DT is that the **Teaching approach of DT techniques allows students to visualize its use in industry**. This perception aligns with the perspective of P09, which contextualizes that *"since I do not work, I do not have that. I have not yet found that useful in the academic environment. That is all. However, it is not like, 'Oh, I hate DT'. It is just that I have found no way. Maybe it is possible to use it. It certainly is possible to. However, there are many factors for not to. So, I think the way DT was approached is more interesting for the industry."* In this way, the adopted teaching approach allowed the application of DT in the software industry to be visualized by students like P09.

> **Finding:** DT lectures accompanied by hands-on workshops engages students, as it allows them to recognize how to use DT in real context.

4.1.9 Strategies for Consolidating DT Content. Regarding strategies educators can employ to enhance the learning of DT content, we highlight **Applying DT techniques to reinforce learning** as the first one. On the relationship between applying DT techniques and the perceived learning of DT content, P08 comments that *"...all these DT techniques that I went and applied something with them stayed in my mind."* In this sense, P08 adds that *"I would have liked, regarding DT, to have practiced more with the techniques. Because in my mind, at least, when I practice, it gets fixed."* We can observe that practicing DT techniques can make students retain the content. Another strategy we highlight is to **Create interactive DT lectures to generate interest**, as P03 highlights that the lectures *"had much interaction. I remember liking these interactions"*. The interaction aspect, within both the professor or among other students may enhance collaboration, which is a fundamental aspect of DT [1].

On providing suggestions to improve DT lectures, P05 suggests adding *"something more practical [...] during the lecture itself, to practice. To do something that can make it retain better"*, while P03 highlights that *"exercise lists and this kind of thing stick better in my mind, maybe an activity like that would have made these things stay longer in my mind."* Such suggestions, when added to the two strategies listed above, associate with a third emerging strategy, which is **DT lectures followed by hands-on workshops for better retaining the content**.

Participants reported appreciating lectures with a certain level of practice within DT techniques, as P07 reports that *I think that lectures with this level of practice, of really practicing it [Design Thinking] in the classroom so that we could ask questions right away, were what helped me the most to understand the shown techniques."* Regarding the techniques practiced during lectures followed by hands-on workshops, P07 adds that *"[...] the ones that stuck the most were precisely the ones we practiced. I saw some others for the assignment. However, the ones we practiced in class were a strong point."* It highlights how practicing DT techniques in the classroom can strengthen students' learning of DT content.

We also identified that **using a supporting tool for selecting DT techniques assists remembering them**, as P08 highlights to *"[...] remember a lot about the project that has several DT techniques there on that website. If I am not mistaken,'selection universe,' or something like that... And I remember a lot of what is there, for example, of the techniques. The simpler ones we have, like questionnaires, right? Interviews. Moreover, others like 'fly on the wall,' right? The idea of 'the fly', observing who your audience is. And a lot of this part of elicitation comes from that. From the selection universe..."* and *The 'fly on the wall', for example, I found very interesting, or others [techniques] in the selection universe."* We can observe that part of the remembered DT content occurred due to using the Selection Universe [14] as a supporting tool for selecting techniques.

> **Finding:** Hands-on workshops, interactive lectures, and the use of assisting tools helps students to retain DT content.

4.2 Analysis of Cognitive Aspects

As Figure 2 presents, students show strong cognitive retention at the lower levels of Bloom's Taxonomy. At the **Knowledge** level, all participants recalled key DT factors. P04 shared to "remember the techniques that were presented, the tools we can use, in which processes we can use them." Such outcome indicates solid retention of core DT concepts, reflecting students' ability to retrieve relevant knowledge from memory months after the course had ended.

At the **Understanding** level, Students demonstrated a clear understanding of DT's purpose and application. P01, for instance, described DT as a way to "understand the client, and from there think about how the system will be and everything else," indicating the ability to interpret the role of DT in bridging user needs and system design. Likewise, P05 referred to DT as "a set of techniques that we are going to use to elicit requirements [...] we are going to use them depending on our needs." demonstrating both an understanding of DT's function in the requirements elicitation process and an awareness of the contextual nature of technique selection. Therefore, such responses illustrate students' ability to reflect comprehension beyond memorization, as they could explain DT concepts in their own words.

At the **Application** level, P08 claims to have used DT in a project *"related to an application that would have an educational use [...] One of the things we did was requirements elicitation [...] for that, we used a DT technique which was the user story."* Although students had opportunities to interact within DT through the hands-on workshop and the practical assignment on requirements elicitation, not many were able to use DT outside the classroom. It suggests that the transition from conceptual understanding to practical application remains limited, possibly due to a lack of real-world opportunities to use DT.

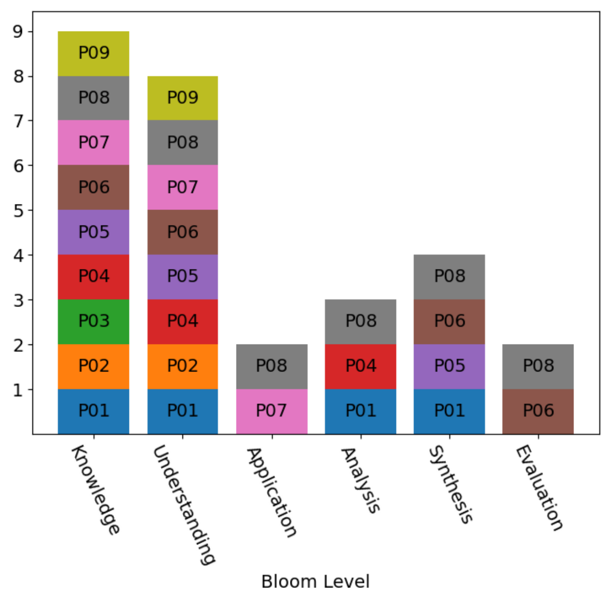

Figure 2: Distribution of participants across the cognitive levels regarding their demonstrated skills.

At the **Analysis** level, some students demonstrated initial signs of analytical thinking when reflecting on the effectiveness and fit of different DT techniques. P04 attempted to evaluate which techniques were more appropriate in their context, highlighting that "most of the techniques that we could use, we applied and tried to incorporate into our project. Some worked, others did not." As Analysis relates to the ability to break information into parts and examine relationships between components or outcomes, this reflection suggests a capacity to distinguish between techniques based on their results.

At the **Synthesis** level, P05 reflected on the overall outcome of the DT techniques they had applied, stating to be "unsure if we used [the techniques] correctly, but the results themselves were clear to see." As synthesis skills reflects the capability to combine elements into a coherent whole, P05's comment reflects on how they could recognize the value of the results despite uncertainties, which suggests an initial development of synthesis-level thinking.

Similarly, at the **Evaluation** level, we found indications of evidence towards evaluative thinking. P06, for instance, wants to "be more specific with the techniques, or the organization that best fits what I want. For the project I want. For the size of my group," reflecting on their ability to choose techniques that align with different project demands. As evaluation skills relates to make judgments about the value or applicability of ideas and techniques based on specific criteria, this insights demonstrate the P06's emerging ability to assess which techniques are most useful and applicable on their context.

In summary, our findings indicate that our pedagogical approach assisted students in retaining DT concepts as it supported retention and understanding of DT content, and that the practical assignment provided a valuable context for application. Although many students presented strong retention on foundational levels such as knowledge and understanding, fewer could present skills related to the highest cognitive levels, which can relate to fewer opportunities to use DT outside classroom. However, as we found suggestive evidence that students are capable of demonstrating higher-order skills, promoting targeted opportunities for reflection, practice, and application may reinforce these competencies and support deeper cognitive engagement with DT concepts.

5 Discussion

Regarding Bloom's Taxonomy, its use aligned with the educational nature of our research and provided insights into students' learning progression related to DT content within the context of SEET. As we found strong retention at the foundational levels, it suggests that students developed a solid base of knowledge and understanding on DT principles. Such retention reflects positively on their learning outcomes, indicating that our pedagogical approach assisted their demonstrated skills. Although we also presented DT as an iterative process, which is one of its perspectives, we did not assessed students' understanding of iteration.

Our instructional approach aimed at practical engagement with DT during the course, Although students had limited opportunities for interacting within DT in real-world context, a few ones demonstrated capabilities related to application, analysis, synthesis and evaluation skills. It suggests that our pedagogical approach was effective in assisting their learning progression. Therefore, providing extended opportunities to engage with DT beyond the classroom could further support the internalization of its concepts and foster the development of high-order skills.

These findings help us answer RQ1 by showing that students demonstrated solid skills regarding the foundational levels of Blooms' Taxonomy – knowledge and understanding. A few students also exhibited signs of higher-order cognitive skills – such as application, analysis, synthesis, and evaluation – especially when those who got to use DT beyond the classroom. Therefore, our pedagogical approach created favorable conditions for deeper learning. Although the cognitive assessment was individual, the learning occurred in a collaborative setting, as DT emphasizes teamwork and peer learning.

As students emphasized the need for more interactive lectures and hands-on workshops, we can denote that active learning strategies, such as in-class exercises and guided practice, contribute to a deeper engagement with DT concepts [28]. Our pedagogical strategy seeked to bring theory closer to practice on providing students the opportunity to interact within DT techniques through in-class training and a practical assignment. Therefore, rather than treating DT as a separate topic, it is possible to adopt DT as complementary to traditional RE methods [9]. In SEET context, this combination can enrich students' learning [28].

Interacting within real stakeholders possibly enhanced students' understanding of user needs. Such experiences may bridge theory and practice, reinforcing the value of DT in addressing real-world challenges [29]. Also, having access to assisting tools can support students in selecting appropriate DT techniques according to their needs [14, 18, 22], as they reported that having access to resources like the Selection Universe helped in choosing techniques that matched their needs.

Students viewed DT as useful for organizing ideas and guiding technical decisions, which positions DT as a decision-making aid in SE projects [5]. It connects with its growing use in industry, where DT has been adopted to foster innovation and align with SE practices [19]. These findings suggest that introducing DT in educational settings bridges the gap between academic preparation and the demands of SE industry, equipping SE students with the necessary skills. In summary, regarding RQ2, we found that students internalized DT as a supporting approach for creativity, user understanding, decision-making, and structured problem-solving. DT assists in idea generation, freedom to explore alternative solutions, and structure requirements elicitation processes.

6 Limitations

Although the small number of participants may limit the generalizability of our findings, this is not the goal of qualitative research, which seeks to generate contextualized insights rather than statistical generalization [21]. We provided a detailed description of the educational context, the pedagogical approach employed, and the procedures of the empirical study, allowing other researchers to replicate it in similar settings.

The limited opportunities students had to engage with DT in real-world contexts beyond the classroom stands as a limitation. Therefore, we designed the practical assignment to simulate a real project, where students could interact within possible stakeholders. We also conducted the interviews 3 months after the course ended, aiming to capture longer-term reflections on students' learning on DT concepts and identify those who had the chance to use DT in other settings.

As we carried out data collection after the end of the course, it may introduce students' recall bias. However, by using Bloom's taxonomy as the basis for our interview guide, we could capture nuances of how students consolidated the DT content after the end of the course across different cognitive levels. To mitigate potential researcher bias during qualitative analysis, three researchers discussed and resolved all coding decisions and Bloom-level assignments by consensus. Finally, the conceptual model resulting from the analysis is still preliminary and has not yet been validated in other contexts. Thus, our model represents an initial contribution, and we intend to conduct empirical studies that may expand our findings.

7 Conclusion

In this paper, we assessed students' cognitive engagement within DT content for SE across Bloom's Taxonomy levels, and explored how they perceive and appropriate its content. We introduced DT within a RE module of a SE course, combining lectures and hands-on sessions. After students completed a practical assignment using DT techniques to elicit requirements from real stakeholders, we conducted semi-structured interviews within nine who volunteered to join our study. Our analysis allowed us to assess students' cognitive engagement across Bloom's Taxonomy levels and to develop a conceptual model that structures their perspectives on DT.

Regarding students' demonstrated skills related to Bloom's cognitive levels, all students retained foundational knowledge and most developed a solid conceptual understanding of DT, evidencing the effectiveness of the instructional approach in supporting early stages of learning. While higher-order skills were less frequently observed, students who engaged with DT beyond the classroom exhibited emerging signs of such. Thus, students may benefit from extended practice to consolidate their learning. Regarding students perceptions on DT, our conceptual model summarize our main findings. It includes DT potential to foster creativity, organize information, understand user needs, and support technical decisions. Thus, our findings contribute to a more comprehensive understanding of how SE students internalize and operationalize DT.

As for our insights on cognitive aspects, we expect our findings provide support for educators to understand how students engage with DT concepts, from foundational knowledge retention to the gradual development of higher-order skills. Therefore, it may assist in developing pedagogical strategies that promote a deeper learning of DT. We also expect our conceptual model to fill the gap of empirical evidences on student-centered investigations for RE education and training [27]. We hope it acts as a pedagogical resource that assists educators to design DT-focused instructional strategies by highlighting aspects students find most valuable.

As for future work, we intend to explore complementary strategies that extend students' engagement with DT beyond the classroom, allowing us to observe how such experiences can support the development of higher-order cognitive skills. For our conceptual model, we intend to incorporate more evidences into its categories, allowing us to strengthen its explanatory and pedagogical value. We also plan to identify and classify strategies DT educators employ on teaching DT in SE courses, to serve as a foundation for developing evidence-based guidelines for integrating DT into SE curricula.

ARTIFACT AVAILABILITY

To improve our research verifiability, we provide all our instruments. It is available at this hyperlink.

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