Assessing Student Performance in Design Thinking: A Conceptual Framework

Pedro Antunes
Department of Informatics, Faculty of Sciences of the University of Lisbon
Campo Grande, 1749-016 Lisbon, Portugal
padantunes@fc.ul.pt
ORCID: 0000-0002-5411-8798

Gustavo Zurita
Faculty of Economics and Business of the University of Chile
Diagonal Paraguay 257, Santiago, Chile
gzurita@fen.uchile.cl
ORCID: 0000-0003-0757-1247

Manuel Caeiro Rodríguez
School of Telecommunication Engineering, University of Vigo
Campus Universitario de Vigo, 36310, Vigo, Spain
mcaeiro@det.uvigo.es
ORCID: 0000-0002-2784-6060

Abstract

This study examines the literature on design thinking education, focusing on non-professional design from the perspective of student performance assessment. Several theoretical views on design thinking assessment are discussed, distinguishing among competency, organizational capability, creative capability, and divergent thinking. A variety of performance dimensions is also analyzed: factual knowledge, applied knowledge, output assets, process knowledge, team project, behavior, and mindset. The main contribution of the paper is a conceptual framework that organizes these theoretical views and performance dimensions. This conceptual endeavor is complemented by a more practical discussion of assessment items and specific conditions required for assessment. In this way, the paper shows how this conceptual framework supports educators in exploring and articulating multifaceted assessment schemes, making strategic decisions using a set of logically related concepts, and conveying the underlying rationale to students. The study contributes an instrumental tool for disciplined approaches to assessing student performance in design thinking, offers a graphical synthesis of the complexity of DT assessment, and supports requisite variety, visibility, balance, and interdisciplinary awareness.

Keywords: Design thinking education, student performance, conceptual framework, assessment schemes.

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1 Introduction

Design Thinking (DT) is a paradigm centered on how people engage with problem situations and develop creative solutions (Dorst, 2010). However, an important consideration that yields different meanings across research domains concerns practitioners and their operating contexts. Johansson-Sköldberg et al. (2013) and Cross (2023) distinguish two worlds: the world of professional design, rooted in design theory, and the world of non-professional design, more interdisciplinary by nature but still keeping creativity alive.

This study concerns DT education in the world of non-professional design with a focus on assessment. A general understanding of DT in this world is that it fosters breakthrough innovation, adaptation to new technologies, and responsiveness to technical and societal challenges (Leifer & Meinel, 2016; Mayer et al., 2021). This understanding permeates DT education in engineering, information technology, business, and other domains, whether through courses dedicated solely to the topic or more eclectic courses. The purpose is not to make every student a designer but to develop knowledge, skills, and dispositions for finding unconventional answers to complex problems (Beligatamulla et al., 2019; Thuan & Antunes, 2024).

Research in DT education has been developing models for integrating DT into the world of non-professional design (Henriksen et al., 2020; Panke, 2019; Verganti et al., 2021). The assessment of student performance[1] is also a central research topic in DT education. For educators, it is essential to develop assessments that align with the nature of DT and the context in which it will be practiced.

However, the literature on this topic is scarce. Prior reviews on DT, such as those by Bathla et al. (2024), Magistretti et al. (2021), and Auernhammer and Roth (2021), do not address student performance assessment, and curricular approaches often only provide a few hints about assessment (Monllor et al., 2024; Taheri et al., 2018; Taimur et al., 2022).

One complication in DT assessment is the diversity of views and performance dimensions educators can consider, encompassing individual, team, and organizational skills, as well as processual, behavioral, and attitudinal outcomes (Auernhammer & Roth, 2021; Dunne & Martin, 2006). To complicate this matter even further, one of the core challenges in DT assessment, the evaluation of creativity, remains particularly challenging (Long et al., 2022; Rawlings et al., 2025). Creativity is inherently multifaceted, context-dependent, and difficult to operationalize (Acar & Runco, 2019), requiring educators to carefully attend to the conditions that enable creativity to be properly developed and judged (Long et al., 2022).

Presently, educators wishing to explore DT in their courses will have to rely more on tacit than on consolidated explicit knowledge to account for the variety of views and assessment elements while addressing conceptual and practical roadblocks. We address this problem by proposing a conceptual framework that aligns diverse theoretical views and performance dimensions for DT assessment, integrating aspects of task, routine, experience, and way of thinking. The framework supports the identification of options and conditions, reflection, and exploration, providing coherence to assessment schemes and making them more understandable and shareable (less tacit and more explicit).

[1] We use the term ‘performance’ in a broad sense, considering the accomplishment of work and associated perceptions, thoughts, and decisions (Koh et al., 2015a). Later, we identify specific DT performance dimensions.

The framework brings four contributions: foster requisite variety by articulating the variety of assessment schemes that educators can use to shape the educational experience; improve the visibility of elements used in assessment schemes (e.g., creativity elements); balance the different performance dimensions, theoretical views, and assessment criteria; and foster interdisciplinary awareness through integration of theoretical views. Within this broader approach to DT assessment, the framework incorporates creativity as one important aspect of student performance, helping educators consider how it may be reflected not only in output assets but also in process knowledge, team projects, behaviors, mindsets, assessment criteria, and contextual conditions.

The framework is demonstrated through a set of cases that offer qualitative insights into its value. Cases are a popular approach to illustrate the use of conceptual frameworks (e.g., Jabareen, 2009). Framework construction is also a recognized method in educational research (Antonenko, 2015; Watson & Webster, 2020). In particular, frameworks can be a form of research contribution (Antunes et al., 2025), encapsulating and integrating theoretical perspectives, clarifying thought on complex phenomena, and providing flexible conceptual structures that can be adapted to different contexts and goals.

The paper is structured as follows. First, we review the discourse on DT education and practice and discuss some repercussions for assessing student performance. We then synthesize the prior literature, emphasizing both theoretical views and performance dimensions. The concepts extracted from the review are integrated into a conceptual framework. The framework is then used to analyze a set of courses. Finally, we provide some discussion points.

2 Background and Research Goals

2.1 DT theory, practice, and performance

DT theory characterizes the phenomenon as a particular form of reasoning and agency in contexts that require a designer's eye from experts who regard themselves as non-professional designers (Cross, 2023; Johanssen et al., 2018). This characterization often employs a variety of dualisms, such as thinking and doing, process and output, diverging and converging, abduction and deduction/induction, materiality and discursivity, organizational and personal, and technology and people (Kimbell, 2012). These dualisms highlight the complexity of the phenomenon.

Characterizing DT performance is complicated by these dualisms. For instance, we cannot view performance solely as the product of design (an output perspective), but also as a process involving, e.g., empathy, creativity, critical thinking, collaboration, and co-creation (Bathla et al., 2024; Brown, 2008). And we cannot view performance solely from an organizational perspective centered on change (Çınar et al., 2017; Eloranta et al., 2024), but also from a personal perspective that considers cognitive talents such as originality and flexibility (Dilekçi & Karatay, 2023).

2.2 DT practice in education

Centering on DT practice in education, we identify three major concerns: what is taught, how it is taught, and what is assessed.

2.2.1 What is taught

Three complementary perspectives have been proposed to characterize DT: as a process, a toolkit, and a mindset (Brenner et al., 2016).

The **process perspective** emphasizes patterns of action. For instance, the pattern proposed by Brown (2008) holds that DT is accomplished by metaphorically moving between three action spaces, inspiration-ideation-implementation, which demarcate complementary goals. Other popular patterns are divergence-convergence (Brenner et al., 2016) and mystery-heuristic-algorithm (Martin, 2010), which organize DT into phases, from exploratory (divergence, mystery) to consolidating (convergence, heuristic), and systematizing (algorithm).

The **toolkit perspective** underscores DT's practical, experimental, and intuitive nature (Chongwatpol, 2020; Micheli et al., 2019). Complex problems are ambiguous, can be viewed and explored in different ways, and solutions emerge through experimentation and abductive thinking (Dorst, 2010; Micheli et al., 2019). What may look like a hit-and-miss approach is supported by various methods and tools selected by decision-makers to play around with ideas and possibilities (Dorst, 2010). Such methods and tools constitute the DT toolkit. The systematic review by Parizi et al. (2022) identifies 83 techniques spanning the problem space (e.g., brainstorming and empathy maps), the solution space (e.g., pitching and prototyping), and working across both spaces (e.g., mind mapping and storyboarding).

The **mindset perspective** underlines principles, sensibilities, and attitudes that influence problem-solving (Fraser, 2011; Howard et al., 2015). These include, e.g., openness to different perspectives and desire to make a difference (Dosi et al., 2018). Mindset shapes the individual's actions, self-awareness, and organizational culture.

Teaching DT requires integrating these perspectives when approaching complex problems (Dunne & Martin, 2006). In particular, the mindset should not be neglected as it concerns "playing the long game," and fostering mastery, confidence, and delight in problem-solving (Panke, 2019).

2.2.2 How it is taught

It is widely recognized that theoretical knowledge of DT alone is insufficient; it must be combined with practical experience (Beligatamulla et al., 2019; Panke, 2019). The epistemology of action supports this view, suggesting that complex problems can only be meaningfully addressed through active engagement. Experimenting with potential solutions helps deepen the understanding of the problem itself (Schön, 1983). This hands-on process promotes reflection-in-action: the ability to apply existing knowledge and simultaneously generate new insights while actively working toward solutions. Additionally, finding and implementing a solution encourages reflection-on-action (Yanow & Tsoukas, 2009), where learners analyze their experiences retrospectively to extract lessons and develop transferable knowledge.

DT education relies on learning by doing, as students iteratively test ideas and solutions. This action-oriented perspective leads educators to abandon traditional, analytical approaches (Pande & Bharathi, 2020). While informative, instructional strategies such as lectures, case studies, and formal exercises tend to emphasize analysis over experimentation. In contrast, approaches like problem-solving challenges, project-based learning, and real-world design sprints embody the

principles of action-based learning and align with the experiential nature of DT (Meyer & Norman, 2020).

2.2.3 What is assessed

A central question for educators is to evaluate how students engage with, integrate, and apply DT in practice (Benson & Dresdow, 2014). Learning outcome assessment is recognized as a means to answer this question (Abdellatif & El-Wakeel, 2025; Benson & Dresdow, 2014). However, it is challenging in the DT context (Henriksen et al., 2020; Koh et al., 2015b). Given that DT combines process, toolbox, and mindset and entails an epistemology of action that favors sophisticated challenges and rich learning environments, the assessment of student performance is wide-ranging. Furthermore, important cognitive abilities, such as divergent thinking, can be complicated to assess without imposing certain conditions (Acar & Runco, 2019). As our review later shows, few papers specifically address the assessment of student performance in the DT context. Although multiple case studies on DT education are available, they primarily focus on course contents and educational methods, leaving assessment out of the discussion (e.g., Auernhammer & Roth, 2021; Chongwatpol, 2020; Sunley et al., 2019).

2.3 Research question and goals

The research question this study addresses is: Considering the diversity, interdisciplinarity, and complexity of student performance in DT education for non-professional designers, what should educators consider when defining a DT assessment scheme? Assessment is an important challenge for educators, who need to continuously improve the quality of education and meet the expectations of institutions and society (Benson & Dresdow, 2014). The concern is *not* that educators cannot devise assessment schemes related to DT. The current success of DT courses indicates *they can* (Auernhammer & Roth, 2021). However, this is largely done through tacit knowledge, which makes it difficult to accumulate and share explicit knowledge. A set of constructs that provides not only coherence but also requisite variety, visibility, balance, and interdisciplinary awareness is missing. Such constructs would be beneficial not only for educators seeking to explore and articulate multifaceted assessment schemes and to make decisions using a set of logically related concepts, but also for students seeking to understand the rationale behind them.

Considering this background, the present study defines the following goals:

1. Review the literature to identify relevant theories and dimensions for assessing student performance in DT education (encompassing the diversity, interdisciplinarity, and complexity of perspectives on the topic)
2. Structure the identified elements into a coherent framework (aligning the diversity of theories and assessment dimensions)
3. Demonstrate the use of the framework in analyzing several courses (in diverse contexts)

3 Literature Review

3.1 Approach

Multiple literature searches were done on Scopus and Web of Science (WoS) to identify related studies. These databases were selected because they provide quality control and have been used in studies on DT (e.g., Auernhammer & Roth, 2021; Schulten & Chounta, 2024). To focus on

quality, searches in both databases only considered journal articles. Since DT is a well-established discourse, we concentrated the WoS searches on the core index rather than the expanded or emerging indexes.

Various search strings were tested using the term ‘design thinking’ as an invariant, combined with terms like assessment, evaluation, and performance. One extra search was conducted to identify literature reviews on DT. The process converged on three searches yielding 1156 total items.[2]

The results were imported into a reference management tool (Zotero). Next, 170 duplicates were removed. The remaining 986 items were then screened for relevance to this study based on the paper’s title and abstract. This narrowed down the set to 52 items. All 52 articles were then examined in detail. Manual backward searches were conducted in parallel to identify missing essential articles, adding 28 articles to the set. In summary, the literature review is based on 80 articles.

3.2 Identified performance dimensions

The qualitative analysis of the selected papers focused on identifying commonalities and differences among assessment schemes, and gradually developing a classification scheme that isolates certain patterns. As noted by Miles and Saldana (2014, p. 29), there is the risk of forcing a certain order, but the purpose is to find coherence and explanation within complexity and diversity. We identified seven dimensions in the literature related to assessing student performance.

3.2.1 Factual knowledge

Measuring the acquisition of factual knowledge is a traditional method for assessing student performance. It is associated with “the notion that if students have knowledge, they have the capability” (Beligatamulla et al., 2019, p. 99). This aligns with academia’s emphasis on grounding its mission on knowledge units (Lerro et al., 2025). Specific factual knowledge about DT involves understanding a variety of creative processes across different fields and recognizing how to reconcile imagination with interpretations, needs, and outcomes (Cross, 2023). Assessment methods include examinations, assignments, discussions, case studies, and class participation (Odeh & Patanakul, 2024). Assessment criteria concern the retention of knowledge units (Benson & Dresdow, 2014).

Focusing assessment schemes on factual knowledge has several downsides. One is the potential lack of understanding of the context surrounding the utilization of factual knowledge (Beligatamulla et al., 2019). DT comprises the application of knowledge in complex, uncertain, and resource-challenged situations (Benson & Dresdow, 2014). Thus, it requires exploration, reflection, and opportunities that go beyond analytical reasoning (Laptev & Shaytan, 2022). It requires situated learning, in which students encounter real contexts, engage in authentic activities, and explore multiple roles and perspectives (Berglund, 2024; Herrington, 2006).

[2] The search ("design thinking" AND ("student assessment" OR "student evaluation" OR "learning assessment" OR "assessment of learning")) returned 408 items. The searches TS=(“design thinking” AND “assessment”) and TS=(“design thinking” AND “literature review”) returned 530 and 218 items, respectivelly. The ‘TS’ field indicates that a search was done on title, abstract, and keywords rather than the full articles. This was done to contain the number of resulting items.

3.2.2 Applied knowledge

Applied knowledge concerns the manifestation of practice in the execution of creative tasks and effective engagement with methods (Herrington, 2006; Laptev & Shaytan, 2022). Assessment involves evaluating task execution, considering knowledge acquisition, reflection, and integration. Assessment methods include discussions with educators and communication events (e.g., pitches and demos) (Benson & Dresdow, 2014; Çınar et al., 2017; Laptev & Shaytan, 2022). Typical assessment criteria include perspective, goal orientation, information needs, critical thinking, and independence (Grohs et al., 2018; Laptev & Shaytan, 2022).

The literature highlights that the assessment of applied knowledge depends on various conditions, including engaging tasks, students' motivation, and mentors' feedback (Lerro et al., 2025; Monllor et al., 2024; Wenninger, 2019).

3.2.3 Output assets

A standard view over DT is that it is a creative process that "takes a problem as input, which captures needs, values, constraints, and other factors," and "generates a solution, which captures innovation, impact, and other elements that may be considered relevant" (Thuan & Antunes, 2024, p. 1884). This leads to an assessment approach centered on output assets. Common assets include models and maps (e.g., empathy maps), storyboards, mockups, and prototypes (Auernhammer & Roth, 2021; Chongwatpol, 2020; Magistretti et al., 2021; Monllor et al., 2024). Typical assessment criteria include creativity, function, meeting objectives and requirements, effectiveness, convincingness, and clarity (Hong & Choi, 2011; Monllor et al., 2024).

Focusing the assessment exclusively on output assets has several deficits. One is that DT outcomes also include intangible elements such as the ability to address the problem context and associated ambiguity, creative thinking, engagement in reflective practices, empathy with the affected community, and collaboration (Guaman-Quintanilla et al., 2023; Hong & Choi, 2011; Karunarathne & Calma, 2024). Another deficit is the emphasis on convergence, when divergence (envisioning and exploration) is also critical (Magistretti et al., 2021). Focusing on output assets also singles out success over failure, overlooking that risk-taking, failing, and learning from failure are inherent in DT (Bathla et al., 2024; Dosi et al., 2018; Guaman-Quintanilla et al., 2023; Hennessey & Mueller, 2020; Thuan & Antunes, 2024). Finally, constructive tenets emphasize a holistic understanding of real-world problems and potential solutions that can be difficult to convey through output assets (Guaman-Quintanilla et al., 2023).

3.2.4 Process knowledge

Assessing DT process knowledge helps overcome deficits in output assets (Wenninger, 2019). It involves an appreciation of the flow of activities, feedback, and intermediate decisions that lead to productive thinking (Auernhammer & Roth, 2021). These are often reported using logbooks, peer assessments, and self-assessments (Bathla et al., 2024; Wenninger, 2019). They expand the range of expected outcomes and emphasize the formative dimension of DT (Wenninger, 2019). Typical assessment criteria include process performance, problem solving, and strategic thinking (Auernhammer & Roth, 2021; Bathla et al., 2024).

The literature suggests that "students must be assessed more on the process than the outcome" (Bathla et al., 2024, p. 350). However, it has certain drawbacks. One is the emphasis on procedure and instrumentalism. The "uncritical promotion of instrumentalist approaches to creativity" is considered the "shadow side" of DT process knowledge (Zidulka & Mitchell, 2018,

p. 749), as it marginalizes alternative, idealistic, and radical forms of creativity (Eloranta et al., 2024). Excessive proceduralism also constrains creativity and reduces confidence in moving away from codified practices towards less comfortable self-directed pathways (Sunley et al., 2019).

3.2.5 Team project

Learning through team projects is a popular DT pedagogical model, as it "moves away from an over-dependence on passive teaching approaches" (Glen et al., 2015, p. 184) and creates opportunities for real-world contextualization and legitimacy (Beligatamulla et al., 2019). Team projects are usually structured around problem-solving (Dunne & Martin, 2006; Laptev & Shaytan, 2022), with an emphasis on difficulty and uncertainty (Kress & Sadler, 2013) and an urge to be effective (García-Castanedo et al., 2024).

Team projects generate output assets and can thus be assessed using that dimension. However, they promote diverse goals, opportunities, choices, and creative activities that teams can openly investigate (Herrington, 2006). Team projects evolve dynamically through exploration, collaboration, and hands-on experience; this performance dimension concerns how teams organize and enhance their abilities along the project (Laptev & Shaytan, 2022). This can be appreciated through progress reports, discussions, peer evaluations, 360-degree feedback, and presentations (Auernhammer & Roth, 2021; Bathla et al., 2024; Laptev & Shaytan, 2022). Typical assessment criteria include progress, collaboration, team dynamics (e.g., mutual support and effort), and mastery (in matching problem and solution) (Bathla et al., 2024; Beligatamulla et al., 2019; Ericson et al., 2009; Kress & Sadler, 2013; Schlott, 2024).

Several concerns have been raised regarding project-based assessment. One problem concerns the configurations set by educators, in which an excessive reliance on predefined goals may reduce creativity (Hennessey & Mueller, 2020). Another concern is that project-based performance is context-specific and depends on unique mental frames and cognitive behaviors, which can be challenging to judge (Hawthorne et al., 2014; Kress & Sadler, 2013).

3.2.6 Behavior

This dimension differs from the others in that it descends from the macro to the micro. This is where DT intersects with cognitive science, combining solution-oriented macro processes with micro-level processes that lead to creative ideas (Pinkow, 2023).

Cognitive scientists have been developing instruments for measuring creative behavior, including the popular Torrance Test of Creative Thinking (Runco & Acar, 2012). Regarding student assessment, the literature reports the use of expert judgment (Chen et al., 2024), progress checks, peer feedback, group pitches, and demos (Laptev & Shaytan, 2022; Taimur et al., 2022; Wenninger, 2019). Typical assessment criteria include inventiveness, failure handling, viability, motivation, fluency, flexibility, originality, elaboration, and divergence (Acar & Runco, 2019; García-Castanedo et al., 2024; Rawlings et al., 2025; Schlott, 2024).

The literature suggests this assessment dimension is challenging because micro processes can be idiosyncratic, highly dynamic, and socially interactive, making it difficult to evaluate performance objectively (Bandera et al., 2020). Also, there may be a tendency to emphasize certain behaviors, such as fluency (generating many ideas), which are easy to assess, rather than the combination of micro-processes put forward by DT (e.g., flexibility, originality, and

elaboration) (Dilekçi & Karatay, 2023). Finally, this dimension may lack support in certain educational contexts due to a lack of institutionalization, e.g., where analytic work prevails over craft (Barry & Meisiek, 2015; Taylor, 2019).

3.2.7 Mindset

Mindset is a concept that seeks to explain how people behave in terms of principles, beliefs, and attitudes, such as empathy, resilience, integrative thinking, novelty, and risk-taking, which determine problem-solution understanding and action (Lavrsen et al., 2024; Thuan & Antunes, 2024).

The literature suggests that creating a DT mindset is an essential educational goal (Dosi et al., 2018; Vallis & Redmond, 2021; Vignoli et al., 2023). The nature of DT requires combining skills with guiding beliefs and attitudes (Vignoli et al., 2023) while structuring situations, goals, and alternatives, a process in which mindset is essential to align the different elements in play (Lavrsen et al., 2025). A DT mindset is also "crucial for addressing complex challenges" (Bathla et al., 2024, p. 338). Therefore, it has been suggested that assessing student performance should include a mindset component (Chongwatpol, 2020).

Researchers have used interview methods and questionnaires to assess DT mindset self-awareness (Dosi et al., 2018; Howard et al., 2015; Schweitzer et al., 2016; Vignoli et al., 2023). However, these instruments examine the effect from a research perspective; they are challenging to operationalize for student assessment. Because they rely on self-awareness, students could provide false answers (Fuechtenhans & Brown, 2023). They regard the DT mindset as a long-lasting impact (Schweitzer et al., 2016), which educators cannot determine in a single course. Howard et al. (2015) categorized mindset elements into *way of life* and *way of work*. The former consider how people perceive DT at the strategic level, and the latter concern how people apply DT at the tactical level. The second category helps delimit the mindset assessment to the students' tactics during the course, which can be appreciated using methods such as observation, analysis of records, reports, and reflective journals (Karunarathne & Calma, 2024; Vignoli et al., 2023). Typical assessment criteria include collaborative attitude, exploratory attitude, transformative mindset, and making things different (Beligatamulla et al., 2019; Groeger & Schweitzer, 2020).

3.3 Theoretical views

Our qualitative analysis also identified several theoretical views that help distinguish and compare different processes or constructs researchers use to characterize DT assessment.

3.3.1 DT competency

Competency is typically characterized as the integration of knowledge, skills, and dispositions (mindsets or attitudes) in task situations (Dall'Alba, 2009; Thuan & Antunes, 2024). This integration enables students to act on knowledge by mobilizing, adapting, and applying the resources needed to face difficult situations and perform well in various contexts (El Asame & Wakrim, 2018).

Educators must decide how to build capacity to act on knowledge, creating task situations that require DT principles and methods while empowering students with skills supported by DT mindsets (Beligatamulla et al., 2019; Taheri et al., 2016). Regarding assessment, educators

should focus on evaluating applied knowledge, considering multidisciplinary perspectives, challenges, and situations (Benson & Dresdow, 2014).

3.3.2 DT as an organizational capability

DT has emerged as a response to increasing complexity, competition, and technological changes in organizations (Hawthorne et al., 2014; Karunarathne & Calma, 2024). Organizations are expected to bring DT into their routines to identify innovation opportunities (Auernhammer & Roth, 2021). Routines express the idea that organizations operate on repetitive, recognizable patterns of action (Pentland & Hærem, 2015). Routines provide structure to operations. By turning DT into a routine, organizations can continuously practice DT, building a significant competitive advantage (Magistretti et al., 2021).

Educators must decide how to frame DT as an organizational routine, build learning situations aligned with organizational needs, and focus on innovation and transformation (Magistretti et al., 2021). Therefore, the assessment should focus on process knowledge and output assets.

3.3.3 Cognitive capability

Researchers note that cognitive capability plays a fundamental role in providing deeper explanations of what makes DT successful (von Thienen et al., 2018). One important capability is creative thinking, which combines the capacity to generate unique ideas (divergent thinking) with the capacity to select optimal solutions (convergent thinking) (Pinkow, 2023; Rawlings et al., 2025).

Cognitive capability closely aligns with constructivist pedagogy and experiential learning, in which students construct knowledge through personalized problem-solving experiences (Guaman-Quintanilla et al., 2023; Monllor et al., 2024; Vallis & Redmond, 2021). Educators must define situated experiences that allow students to generate unique ideas while considering their usefulness (Herrington, 2006; Monllor et al., 2024). Problem complexity, unique links to external clients, and potential impact considerations are essential (Kress & Sadler, 2013).

Individuals influence groups, and groups influence individuals (Pinkow, 2023). Therefore, it is reasonable to consider that cognitive capability assessment should integrate the team, behavioral, and mindset dimensions.

3.3.4 Divergent thinking

Several reviewed papers highlight the central role of divergent thinking in DT (Acar & Runco, 2019; An et al., 2016; Runco & Acar, 2012). Four important microprocesses are usually identified: fluency (many ideas), flexibility (different perspectives), originality (uncommon ideas), and elaboration (expansion of ideas) (Said-Metwaly et al., 2024).

Divergent thinking leads individuals to take unconventional, paradoxical (e.g., serious versus playful), and even extreme directions (Acar & Runco, 2019). Educators can foster divergent thinking by promoting openness, intuition, quick feedback, and opportunities for failure (Laptev & Shaytan, 2022). Given these elements, the assessment should focus on behavior and mindset.

4 DT Assessment Framework

After identifying the dimensions discussed above (theoretical views and performance dimensions) and their respective categories in the literature, we performed another round of

qualitative analysis, accompanied by the framework construction. The analysis involved identifying clusters linking categories across the two dimensions. Clustering is a well-known strategy in qualitative analysis that helps to understand phenomena by grouping related elements, conceptualizing them, and then moving to higher levels of abstraction (Miles et al., 2014). The results from this process are shown in Figure 1.

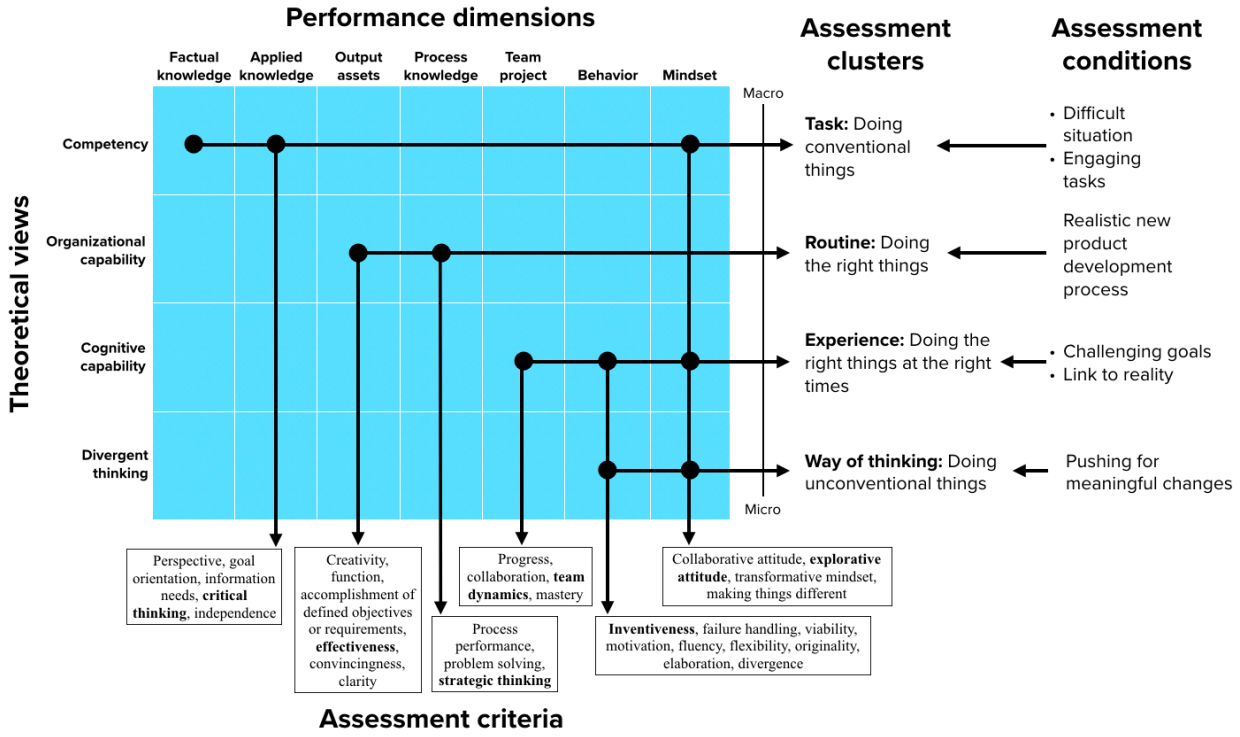


Figure 1. DT assessment framework

One aspect that emerged from the analysis was an arrangement of clusters at different levels, from the macro to the micro, where macro refers to the more general and broad, and micro refers to the specific and narrow. At the macro level, what matters most is the **task**, doing conventional things based on learned models and best practices. Immediately below, the focus is on the **routine**, assessing if students do the right things, from an organizational standpoint. Still going down, the focus shifts to the students' **experience**, considering whether they do the right things at the right times (in the right contexts). Finally, at the micro level of understanding, what matters most is the **way of thinking,** seeing whether students do unconventional things or not. These clusters help characterize DT assessment through simple metaphors that evoke distinctions and possibilities (Miles et al., 2014).

We also noted during the analysis that we could not arrange the clusters by performance dimensions, but instead, we could associate specific performance dimensions with the identified clusters. This situation reflects the view that DT is holistic and intersubjective and cannot be educated and assessed in a stepwise manner, tackling a single performance dimension at a time (Dall'Alba & Sandberg, 1996). This kind of emergent, rather than planned, approach to clustering is common and considered valuable in qualitative analysis (Dall'Alba & Sandberg, 1996).

As the clusters consolidated the performance dimensions, we identified related assessment criteria from the literature. The intention was not to delimit or even standardize how assessments should be conducted within each cluster, but to highlight key criteria and present other options. Next, we detail the identified clusters.

Task: Doing conventional things. This cluster concerns the evaluation of competency in task execution, which requires assessing the combination of factual knowledge, applied knowledge, and mindset. The literature notes that factual design knowledge is multifaceted, problem-oriented, collective, experimentalist, and requires transfer, integration, and application in hands-on situations (Brown, 2008; Dorst, 2010). This leads to assessments that prioritize applied over factual knowledge, provided that tasks are devised to cultivate factual design knowledge through practice (Benson & Dresdow, 2014). In this cluster, we exclude assessment criteria related to factual knowledge to emphasize this priority.

We identify **critical thinking** and an **explorative attitude** as key assessment criteria. The former highlights that students are expected to critically evaluate the task's limitations (Panke, 2019), and the latter emphasizes that students should explore both problems and solutions to accomplish the task.

Routine: Doing the right things. This cluster regards DT as a repeatable pattern concerned not only with generating output assets but also with the appropriate use of process knowledge. They complement each other, reflecting the idea that design is a noun and a verb (Brenner et al., 2016). They provide insights not only into what students accomplish but also into how they accomplish it (Kimbell, 2012).

We suggest that **effectiveness** is a key criterion for assessing output assets, and **strategic thinking** is an exemplary criterion for assessing process knowledge. Effectiveness suggests readiness for complex problem-solving. Strategic thinking indicates that students understand DT as a coherent methodology rather than an expedient (Brenner et al., 2016).

Experience: Doing the right things at the right times. This cluster is about how individuals and teams generate ideas with potential to succeed. To cover both individuals and teams, we intersect the team project, behavior, and mindset performance dimensions. This selection can be criticized for not including process knowledge, as doing the right things at the right times is not purely intuitive and instead requires design knowledge, e.g., regarding the divergent-convergent stages (Pinkow, 2023). However, we choose to emphasize the distinction between routine and experience, narrowing down process knowledge (on how to do the right things) to routine. This aligns well with the framework's integrative nature, which excludes an either-or attitude.

We consider three exemplary assessment criteria. One is **team dynamics**, which assesses how the team leverages individuals. Another criterion is **inventiveness**, which is at the core of creative thinking. Finally, we also consider **explorative attitude** as an exemplary assessment criterion related to the mindset of creative and divergent thinkers (Howard et al., 2015).

Way of thinking: Doing unconventional things. This cluster intersects with the behavior and mindset dimensions, but not the team project. The main reason is that a good DT experience is a well-rounded achievement that integrates project execution with behavior and mindset, whereas divergent ways of thinking are more delineated and less dependent on project success or failure

(Çınar et al., 2017). Therefore, we propose **inventiveness** and **explorative attitude** as key assessment criteria.

Having recognized these clusters, we also identified assessment conditions in the literature that should be satisfied for adequate assessment. Linked to the task, we found two conditions: assignments should involve difficult situations and engaging tasks, e.g., by bringing problems from external parties. Considering routine, assignments should focus on realistic new-product development processes, ideally anchored in actual organizational practices. Regarding experience, assignments should have challenging goals and be linked to reality, e.g., with feedback from external parties. Considering the way of thinking, assignments should aim for meaningful changes to existing business models, disrupting the status quo (Zidulka & Mitchell, 2018).

5 Using the Framework: Self-Reflective Case Studies

Research uses a variety of forms to justify propositions, including validation, exemplary cases, demonstration, and self-reflection (Antunes et al., 2025; Franks, 2016). In this study, we combine demonstration, cases, and self-reflection to show how educators can use the framework to reflect on assessment schemes. Each author used the framework to analyze one DT course that they have created and taught. The authors' backgrounds are diverse, spanning computer science (Case 1), business (Case 2), and telecommunications engineering (Case 2), indicating that the framework can be applied across disciplinary contexts.

5.1 Case 1: Product and Service Design

This course is offered to master's students in business as part of an international educator exchange program. The program seeks to strengthen a global perspective of contemporary business topics with a particular focus on DT and software services. The course is designed to foster collaboration between software and business developers, with a focus on Agile practices brought from the software development domain. The course covers DT, Agile methods, and BizDevOps (Antunes & Tate, 2024). It is organized into two modules. The first module focuses on opportunity identification and problem exploration (divergence), while the second module concentrates on solution development and testing (convergence). Students work on projects in teams of two. All work is exclusively in class. All assessments are related to project execution.

The course includes assessment on:

- Task: There are only two tasks: exploring a problem and developing a solution prototype. The extent to which students critically analyze the problem and solution is the selected assessment criterion.
- Way of thinking: Students are expected to have aha moments regarding both the problem and the solution (Ovington et al., 2018). The educator, operating as a mentor, constantly pushes for those moments, and teams are asked to share them immediately with the educator. The educator assesses in class (expert assessment) how far teams go in pursuing aha moments.

Regarding assessment conditions, the following is noted:

- Task: Students identify opportunities in collaboration with the educator to ensure the project is challenging and engaging.
- Way of thinking: All work is done in class, following the studio model. There are established moments for peer feedback. As already noted, the approach depends on mentoring.

Figure 2 outlines the assessment scheme, which invites several reflections. First, the assessment is significantly more restrained than the framework suggests. The omission of several assessment clusters reflects the adopted studio model, which allows the educator to immerse themselves in what the teams do, build a deeper understanding of how they think, and implement a type of assessment that would be difficult to implement without such immersion.

Routine is not covered in the assessment scheme, which may be surprising, given that the course is taught in a context where the currency is promoting business-ready routines. Cognitive capability was also not considered in favor of divergent thinking. These were deliberate choices, stemming from the educator's experience in teaching professional design in an arts school, where routinization is discouraged in favor of nonconformity and aha moments.

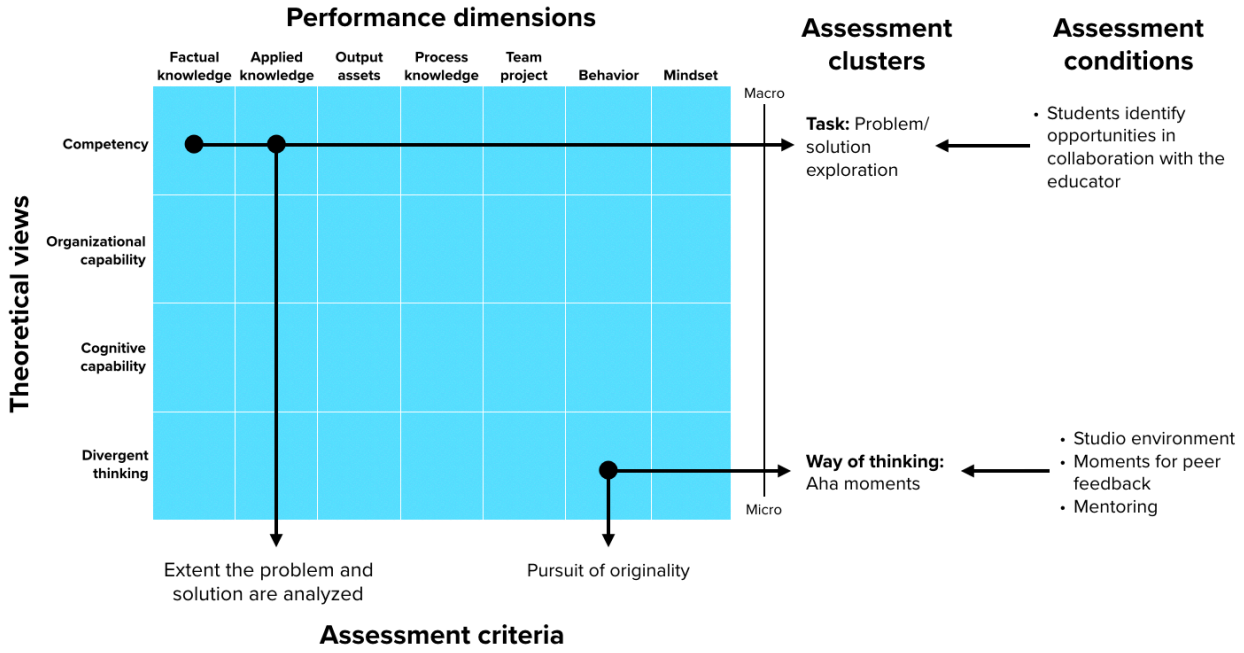


Figure 2. Overview of the "Product and Service Design" assessment scheme

Overall, the framework highlights an assessment configuration that could be difficult to justify without it, especially in a business program. The framework does not constrain strategic choices about what is assessed, but highlights them and helps build a coherent narrative that can be explained to students and faculty. The framework also highlights the conditions the course must fulfill for adequate assessment.

5.2 Case 2: Business and IT

This course is offered by an undergraduate program at a business school. The course aims to develop the students' ability to understand and apply IT strategically and operationally to

support, redesign, or create new business models. DT plays a central methodological and evaluative role, particularly in the semester-long team project, which accounts for 30% of the final grade and is structured into two interdependent parts: P1, in which students individually define problems and solutions; and P2, in which students work in teams to elaborate on solutions. In P2, teams share individual problems/solutions, use divergent (e.g., SCAMPER, brainstorming) and convergent (e.g., NUF Test, PINC Filter) tools to select problems/solutions, and finally apply the DT methodology to elaborate, prototype, and test a solution.

Different assessment approaches are used for P1 and P2. P1 assesses the task, focusing on the quality of the problem/solution definitions. One adopted criterion concerns applied knowledge and evaluates the depth and relevance of the problem and solution definitions, with particular emphasis on the student's ability to distinguish between symptoms and root causes. Another criterion concerns the student's mindset toward problem-solution exploration. P1 includes formative feedback loops based on live presentations and peer reviews that help evaluate mindset.

P2 has a focus on routine. Students use Stanford's DT process (Hasso Platner Institute of Design at Stanford, n.d.), structured according to empathize, define, ideate, prototype, and evaluate tasks, to deliver two well-known output assets: a business model canvas and a prototype. These two assets are assessed using a set of requirements. The prototype should offer a user-centric, functional, and technically feasible solution that features at least one emerging technology (e.g., IoT, VR, AR) and incorporates an e-commerce modality (e.g., B2C, C2C, M-Commerce). The business model canvas should deliver a relevant digital transformation.

Finally, P2 also covers experience, assessing two elements. One is autonomy in exploration, revealed through collaboration with other teams, which is expected to occur multiple times. Collaboration must be documented in MIRO so the educator can examine it in detail. The other assessed element is the student's mindset, focusing on the explorative attitudes in developing the solution. Students are given autonomy to explore solutions, technologies, and business models relevant to their professional interests or social concerns. Explorative attitudes are assessed by closely examining MIRO discussions.

Figure 3 outlines the adopted assessment scheme. A distinctive assessment requirement is to document all work in MIRO and share it with the educator. This enables the educator to assess the project in detail using the criteria discussed above.

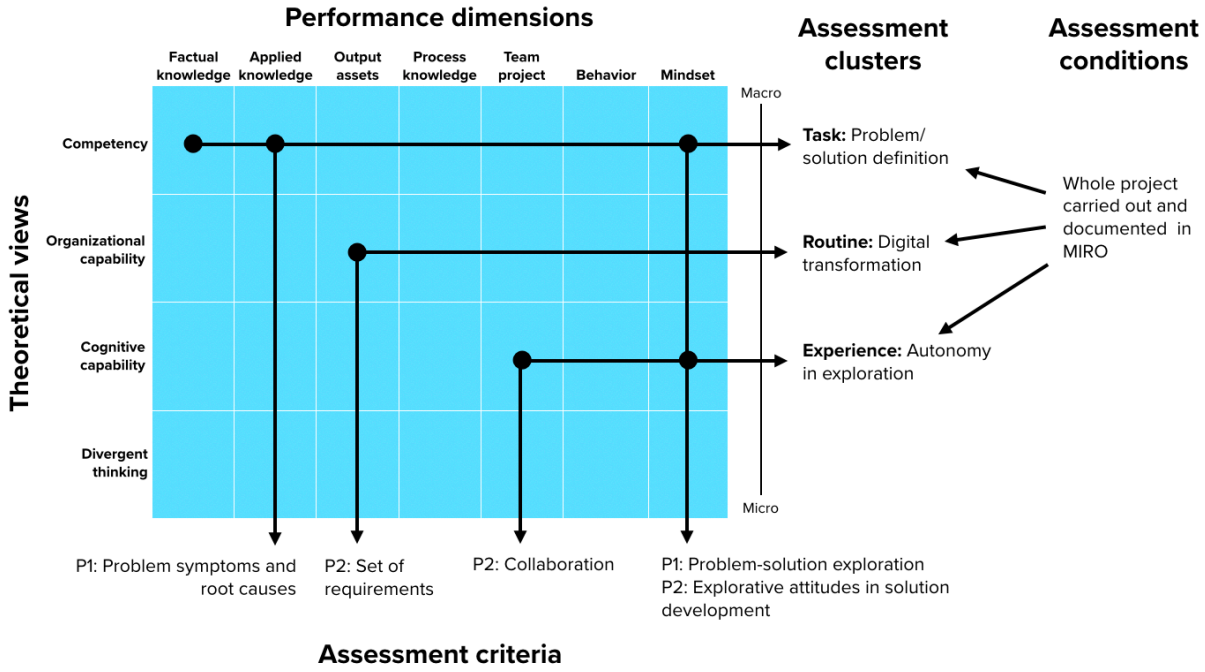


Figure 3. Overview of the "Business and IT" assessment scheme

The course assessment encompasses three assessment clusters, which are operationalized through five assessment criteria split into two stages. This exercise consolidated the various assessment stages, dimensions, and criteria set by the educator, helping to tame complexity, define and justify the logic behind their selection, and improve the alignment between the assessment and the educational goals. It also highlighted the instrumental role of MIRO in supporting the assessment scheme, as it allows in-depth analysis of the students' decisions, without which several assessment criteria would be difficult to operationalize.

5.3 Case 3: Telecommunications Engineering

This course is part of a Master's degree in Telecommunication Engineering. It is positioned at the intersection of engineering education, project management, and entrepreneurship. Rather than focusing solely on technical mastery, the course aims to develop entrepreneurial competencies increasingly required of engineering graduates. Students are encouraged to conceive practical applications of emerging technologies to address real-world problems and deliver meaningful services to society. In this sense, engineering is presented not as an isolated technical endeavor, but as an entrepreneurial activity embedded in broader organizational, social, and market contexts. Within this educational framework, students apply the DT methodology to identify and address a specific challenge relevant to their field of study.

The educator carefully arranges students into teams to maximize diversity in technological backgrounds and personal traits (introversion and extroversion). Each team assumes responsibility for gathering and analyzing relevant information related to the selected challenge, adopting a structured yet flexible approach typical of early-stage venture development. Particular emphasis is placed on empathy and user-centered analysis, enabling students to explore different scenarios and user needs. Based on this analysis, teams generate and refine ideas that lie beyond current technological capabilities. This allows students to experience key phases of

entrepreneurial project development, from problem identification to ideation and concept development, within a controlled educational setting.

The course project spans the entire semester and contributes 50% of the final grade. Students are asked to provide a final presentation of the entire project, considering both the process and the output. The assessment is divided into two parts: P1, which executes the DT methodology, and P2, which evaluates the proposed solutions. In this setup, the educator assesses P1, while P2 relies on peer assessment (from other teams).

The course includes assessment items related to:

- Task: Focuses on how effectively students engage with problems and solutions. The assessment criterion considers the depth and relevance of the problems, with particular emphasis on the coherence between the identified needs, the insights gained during the project, and the proposed solutions.
- Routine: The project is structured around five steps and respective output assets: 1) opportunity identification; 2) problem exploration and interpretation; 3) ideation and experimentation; 4) evolution; and 5) presentation. The educator assesses the process and outputs in P1. Particular attention is given to the alignment between the outputs and specific DT methods such as empathic interviews, brainstorming, rapid prototyping, and storytelling.
- Experience: Proposed solutions are evaluated by peers during presentations. Teams are asked to provide photos and stories (e.g., about user feedback) that help clarify the solution and its context. In P2, the assessment considers criteria such as the capacity to address complex problems and make judgments based on partial or limited information, the ability to understand ethical responsibilities (e.g., toward users), professional ethics, and the need for scientific thinking.
- Way of thinking: Peers assess the way of thinking in P2 using two criteria. The first is that the work explores edge technologies in new ways. The second one is that the work delivers a compelling, attractive, and creative solution.

Regarding assessment conditions, the following is noted:

- Task: The course schedule is pre-defined; success depends more on how students manage their information needs than on how they complete the task.
- Routine: A routine is defined by the course schedule, and teams are forced to follow it. Performance assessment in P1 depends on output assets and team presentations.
- Experience: Assessment in P2 fully depends on team presentations. Mentoring is required to position the solution in context.
- Way of thinking: Teams are organized to maximize diversity.

Figure 4 outlines the main points that result from applying the framework to the course. Considering these points, several reflections arise. First, the assessment scheme is divided into two parts: educators (P1) and peers (P2). The framework helps establish clear relationships between these parts and the assessment criteria. It also helps divide the assessment between the educator and the students. P1 centers on the project's robustness, considering the maturity of the problem and solution, how they are articulated within the project, and the adequate use of methods, and is therefore the educator's assessment domain. P2 is mainly concerned with the

perceived approach to the challenge and is delegated to the students. Of the performance dimensions considered by the framework, mindset is the only one not assessed. However, this is balanced by a significant emphasis on students' behavior.

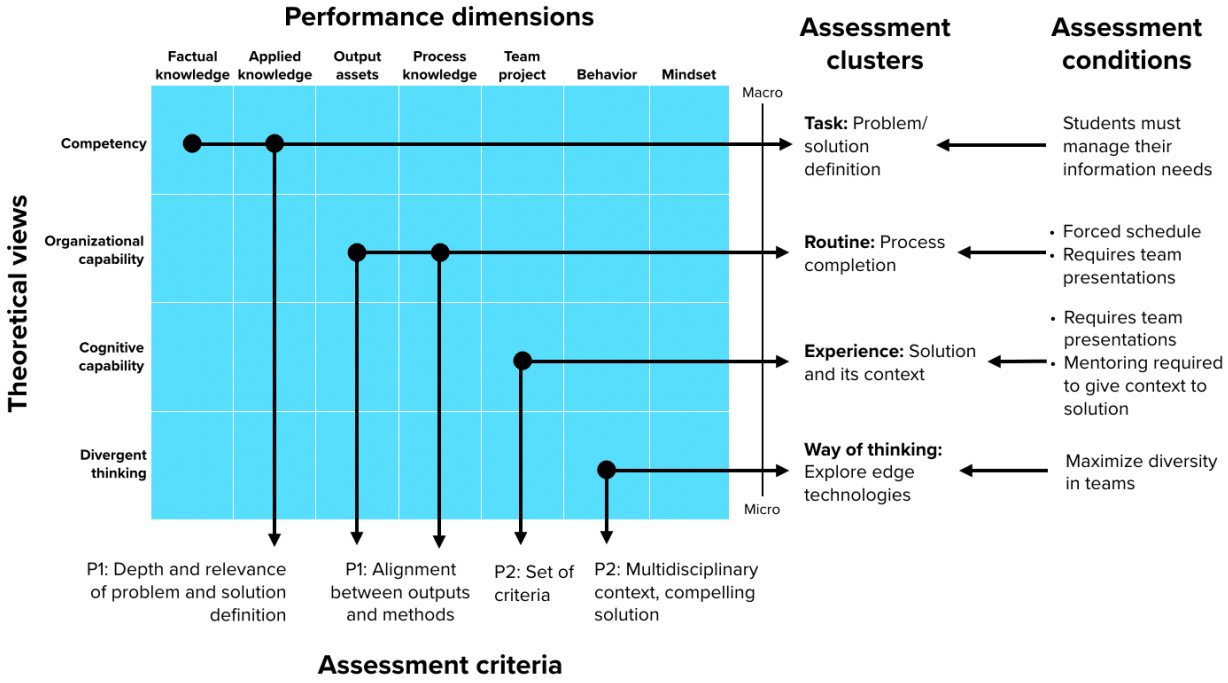


Figure 4. Overview of the "Telecommunications Engineering" assessment scheme

6 Discussion and Conclusion

The major contribution of this study is a framework with four fundamental characteristics: requisite variety, visibility, balance, and interdisciplinary awareness.

Requisite variety. The Law of Requisite Variety (LRV) provides a metaphor for explaining the relevance of the framework developed in this study. LRV states that the complete control of a complex system requires regulators that can be mapped to the variety of possible behaviors (Ashby, 1991). We can regard DT education as the system, the students' involvement in the course as the system behavior, and assessment schemes as the mechanisms for regulating the system. DT is a complex educational system due to the variety of theoretical views and performance dimensions educators can explore. The framework functions as a map that helps make decisions about what to see in the world (Davis et al., 1993). It distinguishes the different elements of complexity from an assessment perspective (ontological commitments). And it also helps define (regulate), through a focusing effect, the educational destinations students are expected to undertake. For instance, assessment choices may enable or constrain creative activities, depending on the criteria and conditions emphasized by educators.

Visibility. The LRV suggests that assessment schemes should be commensurate with the complexity of DT education; otherwise, some DT behaviors will get out of control. For instance, without a means to assess the way of thinking, students may not be motivated to develop creative thinking, and educators may not know whether they are. The framework articulates four

assessment clusters that help educators fine-tune assessment schemes and make them more visible for students.

Balance. Educators have habits, preferences, and the capacity to make contextualized decisions, which can be combined using the framework to select and configure assessment schemes. Some educators may be particularly inclined toward specific theoretical views and performance dimensions, ignoring others. Some assessment criteria may be less traditional than others in certain educational contexts. Also, one should not ignore practicality. DT may account for only a small part of a course; thus, the effort required to assess all DT-related aspects may not be justified. Regardless of the educators' choices influenced by culture, habituation, preference, and practicality, the framework strikes a balance between flexibility and guidance: it provides a theoretically grounded conceptual structure that helps clarify and consolidate individual choices.

Interdisciplinary awareness. The framework brings together conceptual elements from different domains. It does not impose particular elements; instead, it promotes interdisciplinary awareness among educators and students. Within its broader approach to DT assessment, the framework makes creativity-related considerations visible across the four clusters of task, routine, experience, and way of thinking. On the one hand, the approach risks failing to address the breadth and depth of research on design, creative cognition, entrepreneurship, and related subjects. On the other hand, it is inclusive and open, inviting future extensions. Taken as is, the framework already provides a core structure for assessing DT across domains while addressing important matters related to theory (theoretical views) and practice (e.g., assessment conditions).

The proposed framework has some limitations. As a conceptual artifact, demonstrated through self-reflective cases, the framework still lacks strong empirical support. The framework was built on a body of literature focused on design in non-professional design domains, predominantly in education. This may constrain the discussion of some theoretical views, performance dimensions, and assessment criteria. Our effort to link theoretical views and performance dimensions using predefined clusters may be perceived as a rigid scheme rather than an investigative, reflective, and open exercise in understanding the nature of DT assessment. The integrative nature of the framework advances knowledge in a certain way, focusing more on the mediation of concepts (as in semiotics) (Peirce, 1878) than causes and effects. Therefore, its use requires reflexivity and accommodates flexibility and contextual adaptation.

The examination of the framework in the described case studies should be put in perspective, considering that the insights are contextual and may be difficult to relate to the wide range of knowledge domains, pedagogies, and practices in which design thinking can be assessed. The case studies explore the framework less in terms of conformity and more in terms of inviting: asking 'if', 'why', 'why not', and 'how to' questions at different levels, from the macro to the micro.

The framework's main contributions include: structuring a range of concepts dispersed through the literature, offering a graphical synthesis of the complexity of DT assessment, and supporting requisite variety, visibility, balance, and interdisciplinary awareness. The arrangement of assessment clusters from the macro to the micro, and how it shapes educators' strategic thinking, as shown in the case studies, should also be emphasized as an important contribution. The contribution to the field of design creativity is the conceptualization of the macro-micro continuum, which highlights that creativity is a collection of processes operating in parallel at different levels. Educators using the framework will be attentive to which processes they intend

to make explicit to students. Future work could investigate how educators amend and adapt the framework to their specific contexts and interests, with particular attention to macro-micro arrangements.

Statements and Declarations

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The authors declare they have not used generative AI in this work.

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