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Design Thinking Mindset: Scale Development and Validation

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Expectations from Higher Education institutions are increasing towards the education of professionals able to face complex societal issues. In this context, traditional thinking is losing ground, and scholars agree on the importance of promoting a Design Thinking (DT) Mindset in educational settings to address wicked problems. However, an explanation of and measurement for the DT mindset still needs to be adequately developed. We developed and validated a scale to measure DT mindset to fill this gap. After a comprehensive literature review, quantitative research was performed on two samples of professionals (N=151) and students (N=201). We employed confirmatory factor analysis, which yielded a 31-item scale based on ten dimensions. Overall, this study supports the conceptualization and operationalization of the DT mindset as a second-order factor that reflects uncertainty and risk, empathy, holistic thinking, collaboration and diversity, learning orientation, experimentation, critical questioning, abduction, creative confidence, and impact. Our findings advance knowledge that facilitates new research paths and has practical implications for educational and management fields.

Keywords: design thinking, mindset, assessment, self-assessment, measure

Introduction

Design Thinking (DT), the design practice and competence that relies on a designer's ways of addressing deeply human problems, practiced for and with non-designers (Brown 2008; Johansson-Sköldberg, Woodilla, and Çetinkaya 2013; Liedtka 2015; Micheli et al. 2019), has been developing steadily in the latest years across fields, from Social Sciences to Engineering, to Medicine. Among the Social Sciences, Education is the field that received the most significant scholarly attention, with 505 journal papers in the last 15 years, covering 38% of the overall DT publications. Articles discussing the future of higher education leverage Design thinking (e.g., Coates, Xie, and Hong 2021), and most Universities now include DT as a fundamental approach across courses like digitalization (Colombari and Neirotti 2022), entrepreneurship (Daniel 2016) or

technological development (Balboni et al. 2021). Previous research on DT defines it as a complex theoretical concept comprising a set of elements described as attributes (Micheli et al. 2019) or themes (Carlgren, Rauth, and Elmquist 2016). Scholars progressively distinguished three distinct fields among those elements: tools, actions, and mindset. Tools (Carlgren, Rauth, and Elmquist 2016; Liedtka 2015; Nakata and Hwang 2020) represent the portfolio of instruments that a professional can apply to design (e.g., how-might-we questions, point of view, ethnographic interviews, mock-up production, etc.). Actions (Nakata and Hwang 2020; Razzouk and Shute 2012) describe diverse activities that collectively form a progression of steps used during design (problem reformulation, iteratively convergent and divergent work, solution synthesis vs. evaluation, generation and exploration, etc.) and are sometimes expressed as sequential DT phases. Mindset ‘has to do with the beliefs of the individuals, and it is what guides their desires and actions’ (Gaim and Wåhlin 2016 p. 41) in the design activity.

Although tools, actions, and mindset can be identified as distinct ontologies, the DT community has acknowledged their deep interconnection (Nakata and Hwang 2020; Carlgren, Rauth, and Elmquist 2016). In essence, this is the main difference between the multi-plex nature of design thinking and other innovation methodologies that are task-centric (Nakata and Hwang 2020).

Recent studies advanced the effort to identify DT elements (e.g., Micheli et al. 2019; Nakata and Hwang 2020), but studies specifically related to the DT mindset are rare. DT mindset is currently used in different contexts, such as corporate innovation (e.g., Gaim and Wåhlin 2016; Nakata 2020; Nakata and Hwang 2020), life decisions (Howard, Senova, and Melles 2015; Williams, Hutchings, and Phelps 2022), or educational environments (e.g., Gachago et al. 2017; Marks and Chase 2019).

Previous studies have examined relationships between specific dimensions of the DT mindset and other constructs, such as creative confidence (Ulibarri et al. 2014), growth mindset (Yeager et al. 2016), twenty-first century skills (Kickbusch et al. 2020; Marks and Chase 2019; Wright and Wrigley 2019). To understand such relationships better, assessing all the dimensions of the DT mindset is essential.

This research aims to define, develop, and validate a scale to assess DT mindset at the individual level to support researchers and practitioners. An assessment tool is crucial to determining the boundaries of the theoretical definitions of mindset and defining a possible validated measure. With such an assessment, teachers, coaches, and professors could assess the development of a DT mindset in pedagogical interventions.

Theoretical Framework

Mindset has been at the center of DT discourse since Brown (2008) listed the design thinker traits, and DT mindset was claimed imperative for DT implementation and performance (Fraser, 2007; Carlgren et al., 2014). Recently, the DT mindset has gained empirical scholars' attention. Rekonen and Hassi (2018) showed that without an appropriate mindset toward the nature of work in the design approach, people fail to acquire DT methods and tools as changing from a decision to a design attitude is 'easier said than done' (p.3). Similarly, Nakata and Hwang (2020) showed that the DT mindset influences action and is an antecedent of innovation success.

In this research, we align with the definition of the DT mindset of Gaim and Wåhlin (2016). 'This [DT] mindset may be considered a habitual mental outlook that determines how one interprets and responds to situations and is separate from the cognitive competence and logic that are highlighted in the process aspects of design thinking. [...]' (Gaim and Wåhlin 2016 p. 41). Adopting this definition allows one to consider the DT mindset as an emerging entity that integrates different elements of

thinking and doing, distinct from the processual and methodological aspects of design thinking but at the same time evolving and influenced by them.

Studies using an empirical approach to define the DT mindset are rare (Blizzard et al. 2015; Nakata and Hwang 2020; Schweitzer, Groeger, and Sobel 2016). Blizzard et al. (2015) developed and empirically validated a scale that measures the five ‘DT traits’ that Brown (2008) listed as significant for a design thinker. However, since 2008 the DT literature has dramatically developed, and several scholars have studied what are or could be ‘DT mindset elements’ that move beyond Brown’s first contribution.

Schweitzer et al. (2016) used an empirical approach to define a DT mindset, employing a literature review and 15 in-depth interviews to identify 11 different constructs that comprise the DT mindset. The authors noted that “not one of the respondents touched on all [elements of the mindset], but usually referred to between four and eight different [elements of the mindset].” Nakata and Hwang’s (2020) contribution conceptualizes design thinking as a multi-dimensional construct that comprises three mindset elements: human-centeredness, abductive reasoning, and learning by failing. These mindsets are based on a limited literature review and, in their study, comprise elements that other authors consider separate as, for instance, risk-taking associated with learning by failing, problem reframing associated with ideation, or learning by failing related to critical questioning. Therefore, it is crucial to define the DT mindset with an extensive literature review and statistical rigor and address concerns that emerged from the first empirical studies addressing the topic.

Methodology

Developing a reliable scale relies on three main stages (e.g., Churchill, 1979; Netemeyer, Bearden, & Sharma, 2003): a preliminary analysis to generate and review items; a quantitative study to refine the scale, and a second quantitative study to finalize

the scale. DT mindset involves the simultaneous combination of several cognitive and behavioral sub-dimensions that are merely manifestations of an overall design thinking approach.

Initial phase - construct definition and item generation.

We developed a literature search on Scopus and Web of Science databases to identify articles mentioning mindset and Design Thinking. To do this, we looked for journal articles in English, published up to the end of March 2021, that have in title, abstract, or among the keywords the words “Design thinking” and “mindset” or “Design thinking” and “mind”. We obtained 101 articles (99 results from Scopus partially overlapping with 58 results from Web of Science). The first step was to focus on the journals belonging to Education, Social Sciences, Business and Economics, Management, Engineering, Computer Science, Arts and Humanities, and Psychology. Out of 101 contributions, we eliminated those specifically linked to other lines of design research, such as the role of design thinking in medicine, mathematics, energy, environmental science, agricultural and biological science, and health professions. We obtained 76 relevant articles across 59 journals.

We went through the abstracts to classify those 76 results across relevant variables. We distinguished papers that refer to Design thinking as the innovation method/approach from the ones that refer to it as ‘the cognitive activity carried out by designers while they are designing’ (Gero and Milovanovic 2020), or so-called ‘designerly thinking’ (Dorst 2011). We then eliminated contributions that just happened to mention design thinking as a side-construct (e.g., contributions on active citizenship or papers that described the adaptation of design thinking to specific contexts, such as information systems or communication). We thus obtained 16 selected contributions that are insightful for the definition of the components of the design thinking mindset.

We classified papers considering the role DT played in the study: eight articles focus on education and present the effects that courses of design thinking have upon specific targets of students by measuring, for example, their creative confidence, creativity, creative problem solving, or other effects; (Chin et al. 2019; Chongwatpol 2020; Gachago et al. 2017; Ge and Leifer 2020; Jordan and Lande 2016; Kickbusch et al. 2020; Marks and Chase 2019; Wright and Wrigley 2019); six papers are focusing on management and innovation and the impact of design thinking mindset in an organizational context (Carlgren, Rauth, and Elmquist 2016; Fraser 2007; Gaim and Wåhlin 2016; Liedtka and Kaplan 2019; Nakata 2020; Nakata and Hwang 2020); two papers present a design perspective exploring design thinking mindset about values, effects and impediments for innovation (Carlgren, Elmquist, and Rauth 2014; Rekonen and Hassi 2018). Some contributions did not study design thinking per se but compared it with other mindsets, such as twenty-first century knowledge, skills and mindset (5 contributions), growth mindset (5), entrepreneurship mindset (3), engineering thinking (2), strategic thinking (2), and in one case design thinking was compared with other innovation forms (e.g., Stage-gate) or hybridized with other techniques (e.g., Business Analysis). The unit of analysis of the studies was, in most cases, Higher Education students, staff, and educators (6), then innovation managers and employees (5), following organizations (3), and K-12 students, staff, and educators (2).

Three researchers independently coded the elements representing the DT mindset from the selected papers, partly inductively derived and partly built on the academic and practitioner literature on design thinking (Strauss and Corbin 1998). We obtained a 130-item questionnaire based on 19 dimensions, as shown in Figure 1.

Insert Figure 1 here

We compiled a panel of six experts from Academia and Corporate with 8+ years of experience in Design Thinking, coming from different countries (e.g., Canada, Germany, Italy, US) to assess clarity, redundancy, and content validity. Each expert judged coherence across items and constructs on a 4-point scale. We retained items with a content validity index greater than 80%, resulting in an 84-item questionnaire.

Study 1 - Scale purification and item refinement

Study 1 was designed to purify and refine the initial DT mindset scale. We rephrased some items after a native speaker check¹ and converted some questions from negative to positive form². We conducted an online survey with a sample of professional designers (N = 151) from the Design Thinking Network, a LinkedIn group interested in learning, developing, and improving the design thinking process. This group's initial population included 134,102 members, so the response rate was 0.11%. Sample characteristics, including gender, age, origin, and experience in design thinking projects, are shown in Table 1.

Insert Table 1 here

¹ Example: "I think in team is preferable, having different competences" became "I think it is preferable to have different competences in a team."

² Example: "I prefer new contexts rather than familiar ones" became "I prefer familiar contexts rather than new ones."

Respondents were asked to indicate their degree of agreement for the 84 DT mindset items using a 5-point Likert scale (1 = “Strongly disagree” and 5 = “Strongly agree”). An exploratory factor analysis using principal component analysis with Oblimin rotation was used to reduce the number of DT mindset items (Anderson and Gerbing 1988; Netemeyer, Bearden, and Sharma 2003), resulting in a ten-factor solution that explained 66.94% of the total variance. The ten factors were consistent with the previous conceptualization. A total of 40 items with loading > 0.60 and cross-loading < 0.30 were retained (see Appendix). All items had satisfactory item-to-total and inter-item correlations (> 0.60) within their factor (Netemeyer, Bearden, and Sharma 2003).

Confirmatory factor analysis

To assess the scale dimensionality and test its validity, a confirmatory factor analysis was conducted on the sample. We applied structural equation modeling to analyze the data using LISREL 9.2 with the covariance matrix as input and the maximum likelihood (ML) as a fitting function. Item loadings, composite reliabilities (CR), and average variance extracted (AVE) were used to assess construct validity.

A scale refinement was necessary to remove items with factor loadings under .50, dropping nine items from the scale (see Appendix).

Dimensionality

After the confirmatory factor analysis, the following factors emerged, as shown in Figure 2.

Insert Figure 2 here

1 - Uncertainty and risk. Dealing with uncertainty and risk means being accustomed to treating ambiguity as a contextual element (Michlewski 2008), where information might be missing or incomplete, solutions are vague concepts, and specific activities needed to reach an outcome are not known a priori (Schweitzer, Groeger, and Sobel 2016). Designers know that uncertainty and risk-taking are necessary conditions for innovation (Fraser 2007; Ge and Leifer 2020; Wright and Wrigley 2019). and see issues and constraints as opportunities (Nakata and Hwang 2020).

2 - Empathy is ‘the ability to see and experience through another person's eyes, to recognize why people do what they do’ (Schweitzer, Groeger, and Sobel 2016 p. 6). Understanding expressed and unexpressed human behaviors, needs, and values is a crucial requirement for the design thinking process (Gachago et al. 2017; Kickbusch et al. 2020; Nakata 2020). Being empathetic includes ‘being open, avoiding being judgmental, and being comfortable with people with different backgrounds and opinions’ (Carlgren, Rauth, and Elmquist 2016 p. 46).

3 - Holistic thinking involves distancing from a specific situation and maintaining an awareness of ‘how different phases of the iterative design process, including a combination of divergent and convergent thinking, can be utilized to respond to changing problem parameters’ (Wright and Wrigley 2019 p. 15). Design thinkers should be capable of widening and challenging the initial problem and adapting the process accordingly (Carlgren, Rauth, and Elmquist 2016; Schweitzer, Groeger, and Sobel 2016).

4 - Collaboration and diversity mean ‘encompassing collaboration in diverse teams, and the integration of diverse outside perspectives throughout the process’ (Carlgren, Rauth, and Elmquist 2016 p. 48) and ‘encourag[ing] collaboration beyond

the usual disciplines to tap into knowledge and experiences' (Schweitzer, Groeger, and Sobel 2016 p. 78). 'Design thinkers are strong collaborators' (Gachago et al. 2017 p. 20) and integrate knowledge to understand problems and create the final solutions through engagement with others (Benson and Dresdow 2014), not necessarily only with users (Beverland, Micheli, and Farrelly 2016).

5 - Learning oriented: innovation is about learning and design thinkers learn through the innovation cycle. They have 'an appetite for learning [...] [and show] a desire to learn, including learning about others, challenging existing frameworks, and seeking new contexts in which to learn something' (Schweitzer, Groeger, and Sobel 2016 p. 78). Learning happens through action, observation, rapid prototyping, and hypothesis formulation (Dym et al. 2005).

6. Experimentation: design thinkers convert concepts into testable prototypes and have an action-oriented behavior with 'a bias towards testing and trying things out' (Carlgren, Rauth, and Elmquist 2016 p. 47). Design thinkers are open to failure as a means of discovering new opportunities and are ready to learn from failure as early as possible (Kickbusch et al. 2020; Marks and Chase 2019; Wright and Wrigley 2019).

7. Critical questioning is the ability 'to keep an open mind about possibilities' (Schweitzer, Groeger, and Sobel 2016 p. 83), using a "beginner mindset" that goes to the problem's origin by not losing sight of what the team is working towards (Kickbusch et al. 2020 p. 33). Design thinkers are adept at the use of questioning techniques to analyze, synthesize and evaluate information (Calma and Davies 2021). They are inclined toward curiosity and the exercise of 'questioning and testing all concepts' (Nakata and Hwang 2020 p. 120).

8. Abduction is 'the basic reasoning pattern in productive thinking' (Dorst, 2011 p. 523). Design thinkers strive for 'what could be rather than see the work "as it is"'

(Gaim and Wåhlin 2016 p. 41) to ‘foster ideation by producing multiple views of what might work’ (Nakata and Hwang 2020 p. 120). They start from what is known to envision possibilities and explore alternative solutions (Fraser 2007; Gaim and Wåhlin 2016; Liedtka and Kaplan 2019).

9. Creative confidence ‘refers to one’s own trust in his creative problem-solving abilities’ (Kickbusch et al. 2020 p. 33) and gives you the trust to tackle problems ‘of which you rather know what you don’t know than what you actually know’ (Jobst et al. 2012 p. 36). ‘Creativity is critical to DT as a mode to explore and express less tangible and more subjective content by making the abstract or non-experienced come to life’ (Schweitzer, Groeger, and Sobel 2016 p. 81).

10. Optimism to create value is the ‘ability to move forward, knowing you will not always be right but optimistic about your ability to experiment and conduct midcourse correction further down the road’ (Schweitzer, Groeger, and Sobel 2016 p. 82). Design thinkers are concerned with changing current situations into preferred ones by finding better alternatives (Simon 1969) and are determined to make a difference by evaluating possibilities and generating value from insights (Marks and Chase 2019).

Reliability and validity assessment

The estimated composite reliabilities of the ten factors ranged from .78 to .88, demonstrating a level higher than the recommended threshold of .70 (Garver and Mentzer 1999) for the latent variables. Goodness-of-fit statistics for all measurement models were high (NFI, NNFI, and CFI \geq .90) (Table 2).

The average variance extracted (AVE) was over 50% for each dimension (Fornell and Larcker 1981; Garver and Mentzer 1999), demonstrating good convergent validity. In sum, the loadings, fit statistics, and AVEs suggest that each scale captures a significant amount of variation in the latent DT mindset dimensions.

Insert table 2 here

Discriminant validity was also determined by comparing the mean of the extracted variance to the shared variance for all combinations of dimension pairs. In all 45 cases, the extracted variance exceeded the shared variance, demonstrating that the scales have good discriminant validity.

The results of the overall measurement model show the estimates reported in previous stages ($\chi^2 = 550.63$ [d.f. = 390]; NNFI = .946; CFI = 0.954; IFI = 0.954; RMR: 0.038) (Table 3). All loadings were high, ranging from .529 to .902, and correlation coefficients ranged from 0.178 to 0.730. These findings confirm item measurement quality and factor solution stability (Segars and Grover 1998).

Second-order factor analysis

A second-order factor model was used to detect the contribution of each dimension to a higher-level DT mindset construct, conceptualized and measured as a composite of the 10 first-order constructs rather than as a bundle of all items in one first-order latent variable (Gerbing, Hamilton, and Freeman 1994). This higher-order modeling approach recognizes the contribution, retains the idiosyncratic nature of each first-order construct, and treats such constructs as facets of the DT mindset, which is considered a second-order construct. Furthermore, this higher-order modeling approach can resolve ‘bloated specifics,’ which refer to the narrow content span of observed variables that curtail the model’s explanatory power (Gerbing, Hamilton, and Freeman 1994), and the degree of multicollinearity within the model (Koufteros, Babbar, and Kaighobadi 2009).

Insert table 3 here

Although most correlations between the latent variables in this study were below .70, a second-order analysis was conducted because there is a theoretical rationale for a higher-order construct (Garver and Mentzer 1999). The second-order model fit the data well ($\chi^2 = 615.12$ [d.f. = 412], NNFI = .939; CFI = 0.944; IFI = 0.944; RMR: 0.045). Within the second-order model, DT reflected a high level of experimentation (EXPER) ($\gamma = 0.852$; $p < .001$) and holistic thinking (HOL_THINK) ($\gamma = 0.867$; $p < .001$) (Table 2).

The fit measures of the second-order model are not better than the first-order fit measures. However, the second model recognized the contribution and retained the idiosyncratic nature of each first-order DT construct. Therefore, it was considered the preferred alternative for testing the nomological validity of the scale (Koufteros, Babbar, and Kaighobadi 2009).

Study 2 - finalizing the scale and assessing nomological validity

Using a different sample of respondents, Study 2 examined the DT scale's dimensionality, ability to discriminate across different respondents, and nomological validity. The questionnaire was administered via SurveyMonkey to 648 Italian university students who took part in educational programs that introduced the design thinking approach in two different universities over three years. The 201 respondents yielded a response rate of 31%. Sample characteristics, including gender, age, and experience in design thinking projects, are shown in Table 1.

Confirmatory factor analysis and validity assessment

A confirmatory factor analysis was conducted to check the measurements' convergent validity by applying a structural equation model using Lisrel 9.2. Item loadings, composite reliabilities, and average variance extracted (AVE) were assessed to retest the construct validity; all these parameters reached satisfactory levels (loadings > 0.600; CR > 0.700; AVE > .500)

Therefore, we assessed the overall goodness-of-fit of the first-order model using a combination of indexes ($\chi^2 = 617.45$ [d.f. = 390]; NNFI = .955; CFI = 0.962; IFI = 0.962; RMR = 0.042) that demonstrated an adequate overall fit of the model (Table 2).

Fit measures for the second-order model also confirmed an adequate fit ($\chi^2 = 703.51$ [d.f. = 425]; NNFI = .951; CFI = 0.956; IFI = 0.956; RMR: 0.047). Consistent with the previous study, DT was associated with a high level of experimentation (EXPER) ($\gamma = 0.967$; $p < .01$), and holistic thinking (HOL_THINK) ($\gamma = 0.855$; $p < .01$) (Table 3).

Nomological validity

The nomological validity of the DT mindset was assessed by testing the relationship between the design thinking mindset and the growth mindset (Dweck 2006). A growth mindset reflects different individual beliefs about the capacity to change our intelligence. It has been measured with a three-item scale developed by Dweck (2006) that assesses the extent to which people believe they can get smarter if they work at it. Since previous research has shown the likelihood of a strong association between growth mindset and DT mindset (Yeager et al. 2016), we tested the relationship between DT mindset, as a second-order construct, and growth mindset. Results confirmed that the correlation between DT mindset and growth mindset is positive and significant ($\gamma =$

0.373; $p < .01$). Goodness-of-fit measures indicated an adequate fit ($\chi^2 = 517.30$ [d.f. = 127, $p < .01$]; NNFI = .958; CFI = .962; IFI = 0.962; RMR = .051), which supported the DT mindset nomological validity (Table 4).

Insert table 4 here

Discussion and Implications

Scholars who create scales assessing constructs related to the notion of “mindset” face recurring barriers. First, mindset components are traditionally considered at the cognitive (thinking), behavioral (doing), and affective (feeling) levels. Still, it is not easy to separate thinking from doing at the measurement level (Schweitzer, Groeger, and Sobel 2016). Second, there is debate regarding whether skills encompassing constructs such as cognitive skills (e.g., abduction) or practical skills (e.g., experimenting) should be included in the definition of a mindset scale (e.g., Davis, Hall, and Mayer 2016). The third barrier involves connecting mindset with personality traits. Some traits, such as optimism or risk-aversion, are classical personality traits. Aware of this debate, we chose a neutral approach by including those elements in the scale in case the literature suggested they were significant dimensions of a DT mindset.

To the best of our knowledge, this is the first conceptualization of the DT mindset’s multidimensionality, based on a scientific review and quantitative self-assessment. Our scale comprises 31 items, grouped into ten elements, that reflect the DT mindset construct. Previous research efforts (Blizzard et al. 2015) developed a self-assessment scale to measure five traits Brown (2008) listed as design thinking traits, using an extensive sample of US college students. By contrast, our study included

both students and professionals. Our finding that the DT mindset positively correlates with the growth mindset (Dweck 2006) scale supports the scale's construct validity, indicating that the DT mindset captures a unique perception of professionals' attitudes about changing their approach to work.

Our results identified the elements that constitute a DT mindset (Figure 2 and Appendix), that leverage the elements previously identified in earlier studies but do not overlap with them. For example, having creative confidence is not a sufficient condition for claiming a design thinking mindset. However, it is interesting that recent studies have examined the use of design thinking training to improve creative confidence (e.g., Ulibarri et al. 2014). Similarly, some design thinking mindset constructs contribute to defining other mindsets. For example, risk acceptance is a common element that lies at the intersection of design thinking and entrepreneurial mindsets (e.g., Davis, Hall, and Mayer 2016).

As shown in Appendix, some mindset elements collapsed into the same factor, although theory presented them as separate. For example, a human-centered mindset overlaps with an empathy mindset; ambiguity is mixed with risk-taking and experimentation with a bias toward action. Other previous empirical studies (e.g. Schweitzer et al., 2016; Carlgren et al. 's, 2016) showed that, despite the literature agreement on specific construct definitions, professionals fail to recognize them as distinct characteristics of the DT mindset.

From a practical standpoint, since design thinking is widely adopted in education (e.g., Dunne and Martin 2006; Jobst et al. 2012; Daniel 2016), and in higher education design of systems, institutions and resources (e.g. Coates, 2020), a tool to self-assess the DT mindset could be very useful for teachers and educators in various disciplines. This tool could help students make greater sense of their design thinking

experiences by allowing them to focus on the relevant attitudes. It could also support them in self-evaluating their DT mindset development, particularly in project-based or entrepreneurship courses.

Additionally, the tool could inform personal or peer reflections on elements that a student needs to improve. Teachers could use those reflections to narrow the focus to specific parts of a pedagogical intervention. For example, Coleman et al. (2020) built on Blizzard et al.'s scale to compare senior and first-year engineering students' perceived design thinking ability and discovered that senior engineering students perform significantly worse than younger students on feedback-seeking and experimentalism instrument items, suggesting that engineering educators should develop feedback seeking and experimentalism traits in their students.

Limitations and Future Research

The study has limitations that must be considered for future research. First, our study may have overlooked some facets of the DT mindset. However, the in-depth theoretical review should have mitigated this limitation. Second, configural invariance was not tested in this study. Further research should assess whether the same structure of factor loadings can be obtained by introducing specific constraints across groups, such as different degrees of DT expertise. Third, regarding predictive validity, future studies should examine the relationship between personality (Martelaro et al. 2015), background studies, or national culture in informing a DT mindset. Fourth, further longitudinal validation is needed to assess measurement invariance based on data collected from the same respondents across multiple time periods. At last, besides the nomological test performed with the growth mindset construct, other tests with entrepreneurial mindset (Daniel 2016) or innovation mindset could reinforce the validity assessment.

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Figure 1. Elements of a DT mindset, analysis from literature.

[illegible]

Figure 2. Resulting factors

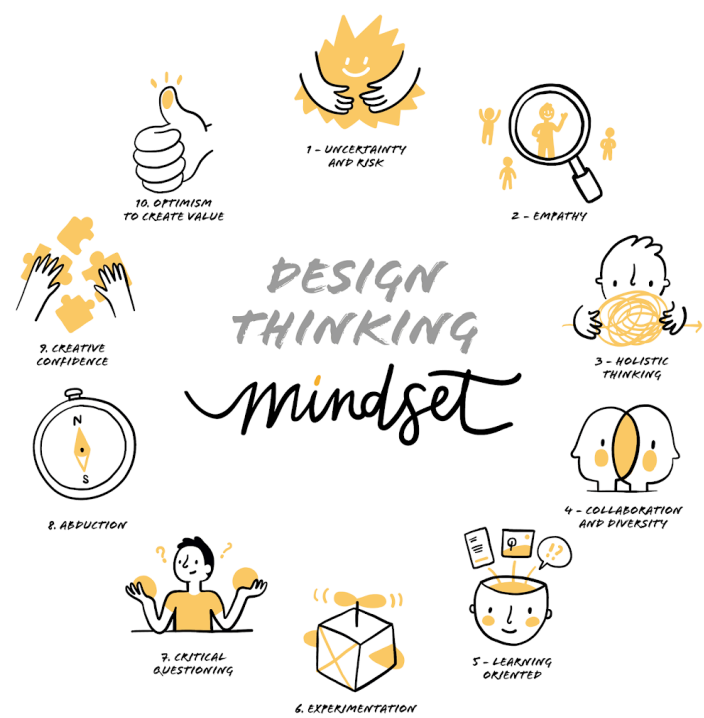


Table 1: Samples description

Professionals		%
Gender	Male	52,0%
	Female	48,0%
Age	18-25	12,4%
	25-45	37,4%
	35-45	27,0%
	45-55	19,5%
	>55	3,7%
Origin	Asia	12,3%
	Europe	39,0%
	North America	35,1%
	South America	9,1%
	Rest of the world	4,5%
Experience (n. of DT projects)	1	23,8%
	2-5	25,6%
	6-10	19,1%
	11-50	25,6%
	>50	4,9%

Students		%
Gender	Male	55.3%
	Female	44.7%
Age	18-25	55.9%
	25-30	29,2%
	30-45	12,1%
Experience (n. of DT educational projects)	1	77,6%
	2	16.9%
	3	4.0%
	>3	1.5%

Table 2. Goodness of fit measures (study 1 and 2)

	Professionals		Students	
	First-order model	Second-order model	First-order model	Second-order model
Absolute fit measures				
χ^2	550.63	615.12	617.45	703.510
Degrees of freedom	390	425	390	425
RMR	0.038	0.045	0.042	0.047
Incremental fit measures				
NNFI	0.946	0.939	0.955	0.951
CFI	0.954	0.944	0.962	0.956
Parsimonious fit measures				
PNFI	0.742	0.794	0.762	0.817
χ^2/df	1.514	1.447	1.583	1.65
AIC	762.627	757.121	829.466	847.515

Table 3. Second-order model parameters (Study 1 and 2)

	Professionals		Students	
	γ	Squared Correlation	γ	Squared Correlation
DT \rightarrow AMBIG	0.551	0.304	0.725	0.525
DT \rightarrow EMPAT	0.500	0.250	0.777	0.604
DT \rightarrow HOL_THINK	0.867	0.752	0.855	0.731
DT \rightarrow COL_DIV	0.626	0.392	0.626	0.391
DT \rightarrow LEARN_OR	0.702	0.493	0.763	0.582
DT \rightarrow EXPER	0.852	0.726	0.640	0.409
DT \rightarrow CRIT_QUESTION	0.633	0.401	0.967	0.935
DT \rightarrow ABD	0.489	0.240	0.542	0.294
DT \rightarrow CONF	0.778	0.605	0.658	0.434
DT \rightarrow IMPACT	0.589	0.347	0.703	0.495

Table 4. Nomological Validity (Study 2)

Linkages		γ	Squared Correlation
Second-order linkages	DT \rightarrow AMBIG	0.723	0.523
	DT \rightarrow EMPAT	0.781	0.610
	DT \rightarrow HOL_THINK	0.850	0.723
	DT \rightarrow COL_DIV	0.639	0.408
	DT \rightarrow LEARN_OR	0.767	0.589
	DT \rightarrow EXPER	0.623	0.389
	DT \rightarrow CRIT_QUESTION	0.970	0.941
	DT \rightarrow ABD	0.534	0.285
	DT \rightarrow CONF	0.654	0.428
	DT \rightarrow IMPACT	0.712	0.507
Main relationship	DT \rightarrow GROWTH	0.373	0.139
Fit indices	χ^2	798.570	
	Degrees of freedom	516	
	NNFI	0.958	
	CFI	0.962	
	RMR	0.051	

Appendix. DT mindset Scale, with EFA coefficients and descriptive statistics

Latent Variables	Items	Professionals					
		Mean	St. Dev.	Factor Load	Eigen Value.	Var. Extr.	Cron. α
1. Uncertainty & Risk	I feel comfortable with what is unknown	4.013	0.950	0.763	10.633	26.584	0.718
	I am comfortable in dealing with problems with which I cannot predict if they will be successfully solved*	4.149	0.862	0.736			
	I like taking many chances also if it leads me to make mistakes	4.058	0.842	0.733			
	I see risks as opportunities to expand my project knowledge	4.273	0.761	0.730			
2. Empathy	During the design activity I dedicate a considerable amount of time to understand what users need	4.552	0.714	0.901	2.882	8.564	0.784
	I can tune into how users feel rapidly and intuitively	4.110	0.897	0.859			
	I am comfortable to see problems from the users' point of view	4.519	0.725	0.734			
	I easily empathize with the concern(s) of other people	4.474	0.769	0.683			
3. Holistic Thinking	I am capable to recognize when there is the necessity to iterate one phase of the process	4.071	0.785	0.776	2.175	5.437	0.796
	I am able to consider what I am doing from a broader perspective	4.266	0.864	0.759			
	I am able to understand which are the impacts on the external environment of the solution we are proposing	4.136	0.776	0.720			
	I am comfortable to insert into the final solution factors coming from a broader vision*	4.169	0.839	0.706			
	I am capable to reframe the initial problem statement*	4.299	0.818	0.610			
4. Collaboration & Diversity	I am comfortable to develop new knowledge with other teammates	4.721	0.530	0.839	2.072	5.180	0.817
	I am comfortable working with people from outside of my organization*	4.591	0.633	0.790			
	I am comfortable to work with people having diverse perspectives and abilities from mine	4.682	0.568	0.735			
	I like to spend time with people doing different work than mine	4.539	0.678	0.640			
	I am open to collaborate with people having different backgrounds*	4.760	0.499	0.612			
5. Learning Orientation	I am comfortable to see a problem like an opportunity to learn	4.649	0.589	0.764	1.721	4.303	0.830
	I am comfortable to implement what I learn*	4.571	0.635	0.742			
	I am comfortable to learn from experiences	4.760	0.444	0.700			
	I am comfortable to learn from observations*	4.708	0.523	0.676			
	I am comfortable to receive feedbacks and learn from them	4.532	0.607	0.669			
6. Experimentation	I am comfortable to make prototypes in order to explore	4.429	0.783	0.734	1.579	3.947	0.761
	I am comfortable transforming ideas into something tangible	4.338	0.769	0.713			
	I am comfortable transforming hypotheses into something to be tested	4.344	0.753	0.651			
	I find useful to create tangible artifacts to discuss with the whole group*	4.286	0.756	0.631			
7. Critical Questioning	I look for something new in a new situation	4.240	0.809	0.790	1.431	3.579	0.779
	I am curious about what I don't know	4.610	0.608	0.629			
	I generally seek as much information as I can in new situations	4.519	0.679	0.625			
8. Abduction	I am comfortable to build conclusions from incomplete information	3.396	1.190	0.893	1.329	3.323	0.754
	I am comfortable to take decisions from a plausible hypothesis	3.695	1.044	0.887			
	I can foresee different outcomes of a project	4.123	0.931	0.639			
9. Creative Confidence	I think I can use my creativity to efficiently solve even complicated problems	4.357	0.806	0.748	1.286	3.215	0.871
	I am comfortable to think something new, different from what already exists	4.396	0.762	0.730			
	I am sure I can deal with problems requiring creativity	4.416	0.764	0.627			
10. Impact	I have the desire to change the status quo	4.422	0.655	0.766	1.122	2.805	0.753

	I desire to create value with the final solution	4.721	0.518	0.697			
	I desire to have an impact on people around me	4.669	0.561	0.669			
	I think I can overcome difficulties*	4.429	0.694	0.619			
N. obs		151					

*Items dropped during the Confirmatory Factor Analysis. These items have not been included for the assessment of construct reliability (Cronbach α)