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Developing design mindset: how individual and contextual factors influence the development of design mindset through method teaching

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ABSTRACT

Method Teaching is an essential approach for training novice designers to think and act like designers. Methods are commonly used in design education, yet with varying outcomes and experiences for students. There is a need to better understand how individual and contextual factors influence the effectiveness of *Method Teaching*. In this quasi-experimental pre-post-intervention study, we investigate how group composition, motivation, *Design Mindset* (D-Mindset0.1), *Self-efficacy* (GSES), *Ambiguity tolerance* (TAS), and *Sensation-seeking* (BSSS) influence students' learning through *Method Teaching*. Our results show that *Method Teaching* increases *Design Mindset* scores and that the effectiveness of *Method Teaching* is influenced significantly by the three personality traits and the level of prior *Design Mindset*.

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Design education; method teaching; design mindset; personality traits

1. Introduction

Design education is not merely about knowing facts; it emphasises '… the importance of practical, embodied, and experiential ways of knowing and being, which are essential to the profession … ' (Shreeve 2015, 83). Design methods can play a crucial role in facilitating this process, so much so that much design education is often structured around the training in, usage of, and reflection on design methods, in what has been termed *Method Teaching* (Daalhuizen, Person, and Gattol 2014). In *Method Teaching*, students are taught, through the practical use of design methods and reflection on the usage, to embody the behaviours and mindset associated with good design practice (Andreasen 2003; Daalhuizen, Person, and Gattol 2014; Jones 1992; Newstetter 1998; Shreeve 2015). However, due to the varying outcomes and experiences of students, several authors have questioned the effectiveness of design methods as teaching tools for training designers (Andreasen 2011; Curry 2014; Daalhuizen, Person, and Gattol 2014; Dorst 2008; Jensen and Andreasen 2010).

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Method Teaching is a situated and highly contextual phenomenon (Curry 2014; Daalhuizen and Hjartarson 2022), entailing a complex interaction between method, method-user, and context of use (Dorst 2008; Hjartarson and Daalhuizen 2021). Furthermore, method use is a skill in itself, influenced by individual differences, the context of use, and the learning situation (Andreasen 2003; Curry 2014; Daalhuizen and Hjartarson 2022; Hjartarson and Daalhuizen 2021), and is not straightforward to develop. Design education, and in particular *Method Teaching,* thus needs to develop the students' *Design Mindset* and support them in internalising the beliefs and attitudes that align with proper design practice. However, little is known about how different variables influence *Method Teaching* and the development of *Design Mindset*. In other words, we need a better understanding of the factors influencing learning and adoption of *Design Mindset* through method usage.

1.1. Research question

Therefore, we ask:

> How do individual and contextual factors influence the development of Design Mindset through Method Teaching?

Starting from this question, we investigate the influence of the individual factors of *Design Mindset*, motivation, and the personality traits: *Self-efficacy, Ambiguity tolerance, and Sensation-seeking,* as well as context factors related to group composition, on the efficacy of *Method Teaching* in developing *Design Mindset* in students. In doing so, we aim to provide insight into the intricacies of developing *Design Mindset* through method usage and the factors influencing the process.

1.2. Hypotheses

Generally, we hypothesise that *Design Mindset* develops through *Method Teaching.* Additionally, following our research question, we have identified ten variables related to individual and contextual factors: initial *Design Mindset* scores, *Sensation-seeking, Self-efficacy, Ambiguity tolerance, Excited about course, Will use tools, Gender ratio in group, Facilitator ratio in group, Avg. Design Mindset score in group,* and *Avg. facilitator Design Mindset in group,* which we hypothesise will positively impact the learning outcome as represented by positive changes in *Design Mindset*. The proposed relationship between the variables is illustrated in Figure 1.

The following sections provide the theoretical foundations and the overall argument for the relevance and inclusion of the variables.

2. Understanding method teaching

Design methods play two central roles in *Method Teaching*. Firstly, design methods are central to structuring the learning situation by scaffolding the project/problem-based and cooperative learning (Royalty 2018). Secondly, design methods function as exemplars of design practice, guiding students' behaviours and, through usage, helping students to embody a *Design Mindset* (Cross 2008).

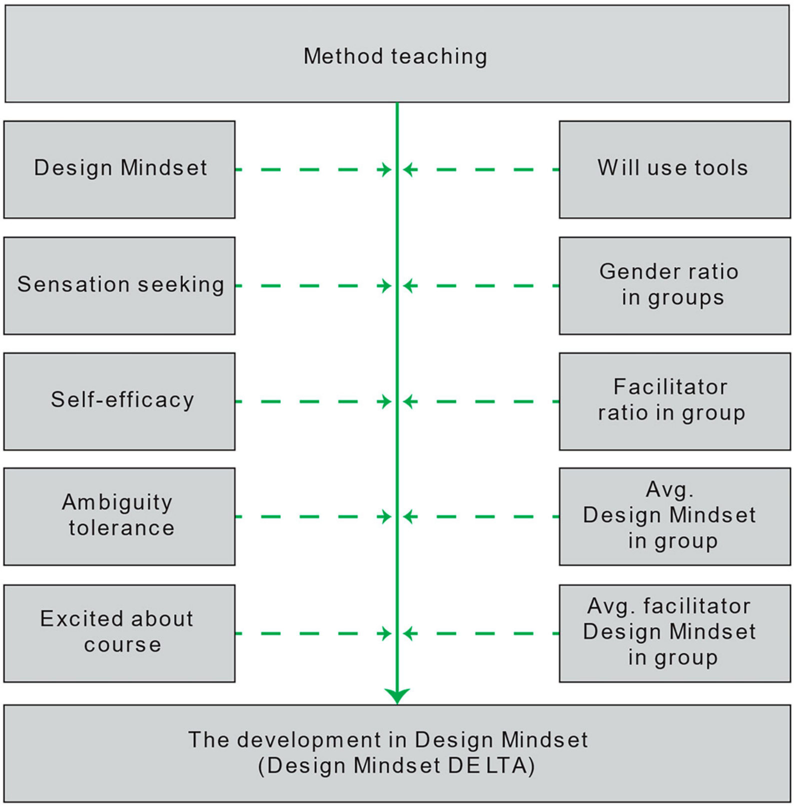

Figure 1. Interaction between Method Teaching (intervention) and the variables hypothesised to influence the development of Design Mindset (dependent variable).

2.1. Scaffolding the learning situation

Projects are an essential source of learning for designers (Lawson and Dorst 2009). Design methods provide a structure to projects and the underlying activities in *Method Teaching* (Curry 2014; Daalhuizen, Person, and Gattol 2014; Hjartarson and Daalhuizen 2021; Lawson and Dorst 2009; Newstetter 1998; Royalty 2018). They help students break down the project into specific activities by stringing methods together into a design process (Cross 2008; Gericke et al. 2020), thus structuring the learning situation, reducing uncertainty, and making projects more manageable (Curry 2014). Scaffolding the learning situation supports improved performance and promotes learning (Newstetter 1998), andenabling the students to handle a project that matches the complexity of real-world design problems without paralysing them and stifling their learning (see Sulman 2005).

As is the case with any educational scaffolding (see Savery 2006), the aim of *Method Teaching* is not to teach the students to use the methods but rather to teach them to think and act like designers so that the scaffolding can be removed over time.

2.2. Method usage and mindset

Design methods have been defined as '… formalised representation of a design activity that functions as a mental tool to support designer to (learn how to) achieve a certain goal, in relation to certain circumstances and resources available' (Daalhuizen et al. 2019, 37). As such, design methods are carriers of procedural knowledge (Blessing and Chakrabarti 2009; Cantamessa 2003; Daalhuizen and Cash 2021).

However, method usage is not straightforward. Mindlessly following prescribed procedures does not guarantee a good design solution (Curry 2014; Daalhuizen, Person, and Gattol 2014). Method users have to interpret and assess the appropriateness of a method in their specific situation, taking into consideration, e.g. the overall goal of the project, the stage in the design process, the social organisation of the project team, and other stakeholders in the project (Badke-Schaub, Daalhuizen, and Roozenburg 2011; Daalhuizen and Hjartarson 2022; Gericke, Kramer, and Roschuni 2016; Lavrsen et al. 2022; Newstetter 1998).

Ideally, a design method contains all the necessary information for implementation (Daalhuizen and Cash 2021; Jagtap et al. 2014). However, knowledge essential for correct implementation is often implicit or omitted in the formalisation of methods (Jänsch, Birkhofer, and Walther 2005). Furthermore, methods are often removed from their original context of use and the experiential knowledge of using them (Andreasen 2003; Dorst 2008; Hjartarson and Daalhuizen 2021; Johansson-Sköldberg, Woodilla, and Çetinkaya 2013). Even if the method contains the necessary information, the user has to understand it and recognise its affordance in achieving their goal (Newstetter 1998).

Consequently, the effective use of design methods requires an alignment between the method and the method user's experience, values, and beliefs (Andreasen 2003; Andreasen, Hansen, and Cash 2015; Daalhuizen and Cash 2021); a so-called *Method Mindset* (Daalhuizen, Person, and Gattol 2014). A method mindset includes the knowledge and experiences required to effectively employ a method and, ultimately, preferences for one method over alternatives (Daalhuizen, Person, and Gattol 2014).

While mindset influences how tasks, contexts, and methodology are interpreted and understood in relation to one another (Andreasen, Hansen, and Cash 2015), it is worth noting that method usage also shapes the development of mindsets. Design methods act as mental tools, stimulating designerly thinking and behaviours (Cross 2008; Daalhuizen and Hjartarson 2022), helping students to behave as professionals (Royalty 2018), and embody good practice (Andreasen 2003; Daalhuizen, Person, and Gattol 2014; Jones 1992; Shreeve 2015; Sulman 2005). This is reflected by the tendency of more experienced designers to rely less on formalised methods as procedural knowledge becomes internalised and behaviours embodied (Daalhuizen and Hjartarson 2022; Lavrsen et al. 2022; Lawson and Dorst 2009).

Transcending method usage and delving into design practice more generally, what we have referred to as *Design Mindset* is the mindset that aligns with the beliefs, attitudes, norms, and practices of appropriate and efficient design practice (Lavrsen, Carbon, and Daalhuizen in press; Lavrsen, Daalhuizen, and Carbon 2023). In the context of *Method Teaching*, the development of *Design Mindset* can thus be seen as the core learning outcome (see Figure 2).

2.3. Learning through method usage

Experiential learning theory holds that learning occurs in a cycle of experience, reflection, conceptualisation, and experimentation (Kolb 2015; Kolb and Kolb 2022). In *Method Teaching*, this learning cycle is facilitated by using design methods, as shown in Figure 2. Design methods inform the concrete experience of designing by imposing an initial

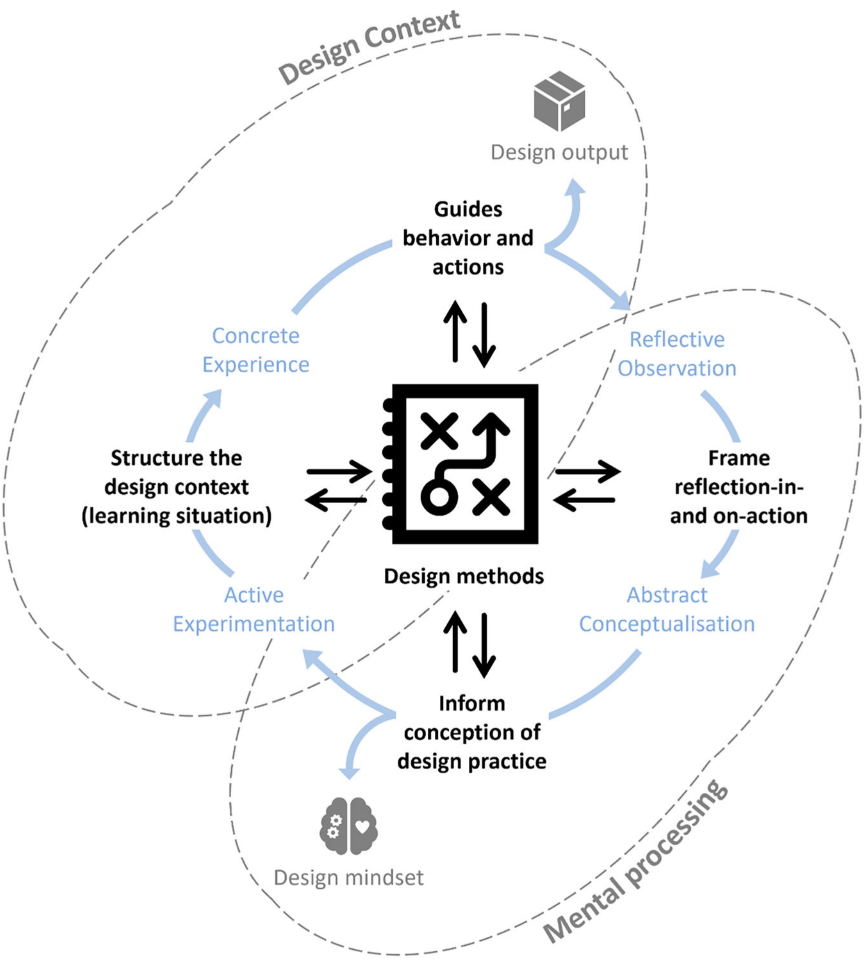

Figure 2. Method Teaching: How design methods inform the experiential learning process.

structure to the design context and providing guidance on how to behave and act in that context.

As an exemplar of design practice, the methods also inform the reflective process necessary for translating experiences into learning. Schön (1983) distinguishes between *reflection-in-action* and *reflection-on-action*. Design methods function as a reference for reflection-in-action in the design process and retrospectively as a reference for reflection-on-action (Hjartarson and Daalhuizen 2021). They provide a baseline for making sense of the situation and design activities in relation to it. The reflective process is usually triggered by encountering something unexpected or getting stuck (Kolb and Kolb 2022). Here, prior experiences, theoretical knowledge, and the method's portrayal of design practice are considered to reevaluate the students' understanding of the situation and make sense of it. New conceptualised insights can then be tested and refined through experimentation, for example, by tweaking the method's implementation or trying another, more promising method. If the new conceptualisation improves the understanding or control over a situation, it can become part of how learners think and act (Kolb 2015). Through this process, unique approaches to solving design problems can be developed (Lawson and Dorst 2009).

2.4. Group competencies and composition

Like other forms of project-based learning, *Method Teaching* relies on cooperative learning (see Johnson, Johnson, and Smith 2014). Designing, as well as design learning, is a social process shaping both the learning outcomes and the context of learning (Newstetter 1998). In *Method Teaching*, learning happens as the students engage with the problem, the methods, and each other. Leveraging each other's knowledge, insights, and unique expertise, the students work together to solve the problem and learn collaboratively. When the students negotiate their understanding of the problem, what they need to do, what methods to use, and how to use them, they share their knowledge, opinions, and perspectives, enhancing their learning opportunities (Hjartarson and Daalhuizen 2021; Johnson, Johnson, and Smith 2014; Scager et al. 2016). More diverse groups can stimulate a more nuanced reflection in the group, which is central to the learning process and professional practice (Hjartarson and Daalhuizen 2021; Scager et al. 2016; Schön 1983). Furthermore, more experienced students can help the group make more appropriate use of methods and increase the chances of a positive experience using them (Daalhuizen and Hjartarson 2022; Johnson, Johnson, and Smith 2014; Lavrsen et al. 2022; Sanders and Stappers 2008). In this study, the groups were secured some design methods and processes expertise through student facilitators, who are tasked with facilitating the overall teamwork and the use of the specific methods (see Section 3.2).

Based on the role of diversity in group-based learning, we hypothesise that having a higher ratio of females in the otherwise male-dominated groups (*Gender ratio in group*) will positively influence changes in *Design Mindset*. We also hypothesise that having more facilitators in a group (*Facilitator ratio in group*) will increase learning by providing extra experience with and support in applying design methods. Similarly, we hypothesise that higher *Design Mindset* scores of the facilitators (*Avg. facilitator Design Mindset in group*) and the groups overall (*Avg. Design Mindset score in group*) will positively influence the group members learning.

2.5. The student and individual differences

As already established, individual differences and preferences influence the experience and effectiveness of method usage and learning and, thus, the effects of *Method Teaching*. In this section, we outline some of the individual factors that might influence the learning outcomes of *Method Teaching*.

2.5.1. Motivation

Engagement in the learning situation is dependent on the student's motivation. Motivation determines the extent to which individuals engage in the learning process, persist in facing challenges, and seek learning opportunities (Bandura 1997; Zimmerman, Bandura, and Martinez-Pons 1992). Motivation is influenced by how a situation is interpreted, which again depends on several factors, including personality traits. Generally, there are two types of motivation: intrinsic and extrinsic. In an educational context, intrinsically motivated students are motivated by the task itself, while extrinsically motivated students are motivated by the reward or grade (Scager et al. 2016). Structural factors like group interdependence, autonomy, and the challenge of the assignment also influence motivation (Scager et al. 2016).

Consequently, we hypothesise a positive relationship between the changes in *Design Mindset* and the variables related to excitement about the course (*Excited about course*) and the perceived usefulness of the course (*Will use tools*).

2.5.2. Ambiguity tolerance

Most design situations can be described as ambiguous (Mahmoud, Kamel, and Hamza 2020). Ambiguous situations '… cannot be adequately structured or categorised by the individual because of the lack of sufficient cues' (Budner 1962, 30). Ambiguity tolerance determines whether ambiguous situations are perceived as desirable or threatening (Budner 1962) and how one responds to them (Furnham and Marks 2013). Low tolerance for ambiguity tends to be expressed in a '… tendency to view ambiguous situations rigidly in black or white' (Rosen, Ivanova, and Knäuper 2014, 62), rejection and avoidance of such situations (Budner 1962; Furnham and Marks 2013; Rosen, Ivanova, and Knäuper 2014), and emotional reactions such as uneasiness, discomfort, dislike, anger, and anxiety (Rosen, Ivanova, and Knäuper 2014). On the other end of the spectrum, a high tolerance for ambiguity is associated with creativity—even though the evidence for the connection might be weaker than theoretically or intuitively expected (Merrotsy 2013).

Based on the high levels of ambiguity generally associated with designing (Cash and Kreye 2017; 2018; Cross 1990; Lawson and Dorst 2009; Mahmoud, Kamel, and Hamza 2020), we hypothesise that higher ambiguity tolerance will allow the students to engage more broadly with both the ambiguities of the design context and the general learning situation, resulting in improved *Design Mindset* scores.

2.5.3. Sensation-seeking

Like Ambiguity tolerance, Sensation-seeking relates to individual reactions to the world around them. Sensation-seeking is '… defined by the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience' (Zuckerman 1994, 27). Risky behaviours are likelier among people scoring high in Sensation-seeking, who tend to underestimate the risk associated with their behaviours and, therefore, are also more likely to repeat them (Hoyle et al. 2002). They are, however, not risk-seekers (Zuckerman 1994).

Sensation seekers engage in new situations with openness (Franken 2002; Hoyle et al. 2002). Furthermore, high sensation seekers are prone to divergent thinking (Zuckerman 1994), which Crismond and Adams (2012) identified as an indicator of informed design practice and Guilford (1968) as a necessity for generating creative ideas.

Consequently, we hypothesise that scoring higher on Sensation-seeking will lead to an improved *Design Mindset*, as the openness to new and complex situations and willingness to take risks should result in a willingness to investigate and challenge both the design context and the methods used, facilitating more opportunities for reflection and learning.

2.5.4. Self-efficacy

Self-efficacy is the belief in one's ability to handle a situation (Bandura 1997). Like the other personality traits presented above, Self-efficacy influences people's behaviour. Self-efficacy:

> … influence the courses of action people choose to pursue, how much effort they put forth in given endeavors, how long they will persevere in the face of obstacles and failures, their resilience to adversity, whether their thought patterns are self-hindering or self-aiding, how much stress and depression they experience in coping with taxing environmental demands, and the level of accomplishment they realize.
> (Bandura 1997, 3)

Consequently, Self-efficacy influences learners' engagement, effort, and goal-setting behaviour. People scoring high in Self-efficacy tend to take a future perspective, set bigger goals, and work harder to make them a reality (Bandura 1997), and generally display what Kelley and Kelley (2013) call creative confidence (Jobst et al. 2012). As such, we hypothesise that higher scores in Self-efficacy translate into improved learning outcomes and higher scores in *Design Mindset*.

2.5.5. Design mindset

Lastly, we hypothesise that individual differences in *Design Mindset* influence the effectiveness of *Method Teaching*. Like the *Design-Mindset-based* group variables, we associate individual *Design Mindset* with design-related competencies. Based on its recent operationalisation as a construct (Lavrsen, Carbon, and Daalhuizen in press; Lavrsen, Daalhuizen, and Carbon 2023), we have a limited basis for predicting its influence on the learning outcome of *Method Teaching*. However, based on the expectation that existing competencies might facilitate the navigation of the design context and learning situation, we hypothesise that higher *Design Mindset* scores (*T1_Design Mindset*) will positively influence the learning outcome.

3. Method

This study employs a quasi-experimental pre–post-intervention research design to answer our research questions and investigate how key variables influence the effectiveness of *Method Teaching*. The quasi-experimental format was chosen to reflect the real-life learning context, using an existing course—designed around *Method Teaching*—as the intervention (see section 3.2). Data was collected employing a questionnaire before (T1) and towards the end of the course project (T2). The pre-intervention data (T1) has been employed and discussed in previous research (Lavrsen, Carbon, and Daalhuizen in press; Lavrsen, Daalhuizen, and Carbon 2023), reporting the development of the inventory used to measure *Design Mindset* for this study (see Section 3.3.1).

3.1. Sample

We recruited our participants from a sample of 586 engineering students enrolled in a design and innovation course mandatory for all master students at Technical University Denmark (DTU). The students were asked to fill in the questionnaires as part of the course but had the option not to have their data used for the study. Four hundred seventy-three

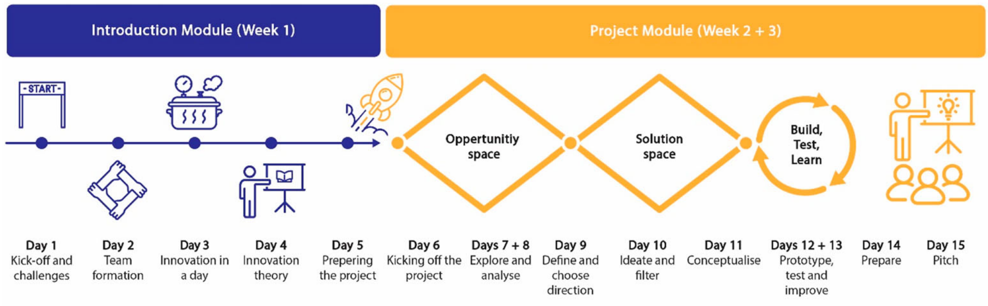

Figure 3. The modules and setup of the course.

completed the pre-intervention questionnaire; of those, 254 completed both the pre-and post-intervention questionnaire, resulting in a response rate of 43%. Of the final sample, 150 (59%) identified as male, 101 (40%) as female, 2 (1%) as other, and 1 opted not to answer.

The participants' backgrounds varied between more than thirty different engineering educations (see Appendix A), with varying degrees of training ($M = 1.8$ courses; $Md = 1$; $SD = 2.42$) and practical work experience ($M = 3.7$ months; $Md = 0$; $SD = 7.17$), with the majority having little to no training or experience with innovation. The age ranged from 20 to 41 years, with an average age of 24.4 years ($SD = 2.54$).

Despite being a sample of convenience, the diversity of disciplinary specialisations in engineering and different levels of exposure to design and innovation theory and practice make the sample representative of engineering students.

3.2. Procedure

We studied *Method Teaching* in the context of two intertwined project-based full-time courses that ran over three weeks. One course aimed at giving students innovation competencies through participation in an innovation project as part of a team. The other focused on facilitating the innovation process for the students in the innovation course, to teach facilitation skills. Despite different learning objectives, the overall structure for both courses was the same, and it was, in practice, taught as one.

The courses consisted of a one-week introduction module and a two-week project module (see Figure 3). The introduction module included an introduction to innovation and design processes, methods, mindset, real-world innovation challenges for the project phase, and team formation. To ensure multidisciplinary teams, the project teams were formed based on the students' case preferences and disciplinary specialisations. The teams consisted of six to ten innovators and one or two facilitators. Four broad cases, including overall challenges and problems, were presented by industry partners. They were centred around: securing renewable carbon for the chemical sector, climate and environmentally-friendly solutions for the maritime industry, sustainable retail focusing on keeping local retail areas relevant and environmentally friendly, and how to make access to nature available for people with cognitive disabilities.

The project module was structured around a predefined and controlled design process based on the double-diamond process (Design Council 2003), including planning and preparation, exploration and research, definition of innovation challenge, ideation, conceptualisation, prototyping and testing, and pitching (see Figure 3).

Students were guided through the design process through scaffolded design activities structured around design methods like *User Observation*, *List of Requirements*, *Weighted Objectives*, and *10 plus 10 Ideation* (see van Boeijen, Daalhuizen, and Zijlstra 2020), and with specific deliverables most days. Within the limits of this structured design process, the facilitators were free to bring in additional methods to support the completion and quality of the deliverables.

Two of the authors were involved in the course's development and teaching.

3.3. Measurements and data collection

We administered two questionnaires: one at the beginning of the course (Day 2; this questionnaire has previously been published in Lavrsen, Carbon, and Daalhuizen in press) and one after completing the project module of the course (Day 14; see Appendix B: Post-Intervention Questionnaire). The questionnaires consisted of four main parts, with instruments measuring *Design Mindset*, *Self-efficacy*, *Ambiguity tolerance*, and *Sensation-seeking*. In addition, the pre-intervention questionnaire included items related to consenting to participate, demographic information, motivation, and experience. As such, the pre-intervention questionnaire consisted of 60 items, and the post-questionnaire consisted of 50.

3.3.1. Design mindset

To measure the learning outcome, we developed the *Design Mindset Inventory* (*D-Mindset0.1*; (Lavrsen, Carbon, and Daalhuizen in press; Lavrsen, Daalhuizen, and Carbon 2023) to measure *Design Mindset*. *D-Mindset0.1* consists of 10 items, all measured on a 7-point Likert scale, ranging from *strongly disagree* (= 1) to *strongly agree* (= 7), and can be divided into four underlying factors: (1) *Iteration*, (2) *Conversation with the situation*, (3) *Co-evolution of problem-solution*, and (4) *Imagination* (Lavrsen, Carbon, and Daalhuizen in press). Based on the pre-and post-intervention scores of *Design Mindset*, we calculated the changes in *Design Mindset* (*Design Mindset_DELTA*) as a measure of learning outcomes (see Figure 2).

3.3.2. Personality traits

We used the General Self-efficacy Scale (GSES; Schwarzer and Jerusalem 1995) to measure *Self-efficacy*. We modified the GSES from a 5-point to a 7-point Likert scale to align it with the other instruments used in the questionnaire and increase the usability of the entire set of employed scales.

We have used the 12-item Tolerance for Ambiguity Scale (TAS; Herman et al. 2010) to measure *Ambiguity tolerance*. Despite initially being designed for cross-cultural research, the TAS has previously been used in connection with design research by Mahmoud, Kamel, and Hamza (2020).

We used the Brief Sensation-seeking Scale (BSSS; Hoyle et al. 2002) to measure *Sensation-seeking*. The BSSS is based on the widely used Sensation-seeking Scale-V (SSS-V; Zuckerman, Eysenck, and Eysenck 1978), but BSSS has the advantage of only consisting of eight items rather than 40 and using the more user-friendly Likert scale as a response format rather than the forced-choice format (Hoyle et al. 2002).

4. Analysis and results

In the following section, we examine the descriptive statistics of the variables, the assessment of the employed *t*-test, the regression analyses, and the evaluation of the resulting models.

4.1. Data processing

Before conducting the analysis, the data was cleaned. Due to the consent form only being part of the pre-invention questionnaire, fifty participants who only responded to the post-intervention questionnaire were removed from the dataset. While a loss of data, these responses would not have been useful for this study due to them missing the pre-intervention responses and, thus, the grounds for comparison of the development in *Design Mindset*. Incomplete entries were also removed. A few participants answered the post-questionnaire twice. We removed their second entry to avoid duplicates and bias.

4.2. Descriptive statistics

Table 1 shows the descriptive statistics for the dependent and the independent variables. It is worth noting that some variables rely on smaller sample sizes. The biggest difference in sample size is between pre-and post-intervention-based variables ($n_{Pre} = 473$; $n_{\text{Post}} = 254$), reflecting a lower response rate for the post-intervention questionnaire than the pre-intervention questionnaire. The group-based variables (*Gender ratio in group* and *Avg. Design Mindset score in group*) are also based on a smaller sample since these variables could only be calculated for respondents in groups where all members participated in the study.

While a Shapiro–Wilk test indicates that the majority of our data is not normally distributed ($p < .05$), our large sample size means that most can be considered so according to Kim's (2013) guidelines ($n < 50$: absolute *z*-scores for both skewness and kurtosis < 1.96; $50 < n < 300$: absolute *z*-scores for both skewness and kurtosis < 3.29; $n > 300$: absolute Skewness < 2 and absolute Kurtosis < 7; see Table 1). The exceptions are *T2_Conversation with the situation (F2), Gender ratio in group, Avg. Design Mindset score in group*, and all the dependent variables except *Co-evolution of problem-solution (F3)_DELTA*. While this influences the reliability of the regression analysis presented later, we consider the analysis robust enough to provide meaningful results.

4.3. The changes in design mindset

The descriptive statistics (Table 1) clearly show an increase in *Design Mindset* from the pre- ($M = 4.41$, $SD = 0.53$) to the post-intervention test ($M = 4.55$, $SD = 0.59$). To test if this increase was significant, we conducted paired sample *t*-tests for *Design Mindset* and each of its sub-constructs: *Iteration*, *Conversation with the situation*, *Co-evolution of problem-solution*, and *Imagination*.

Table 1. Descriptive statistics of all variables at T1 and T2, including independent and dependent variables.

		Valid	*Median*	*Mean*	*SD*	Skewness	*z*(Skewness)	Kurtosis	*z*(Kurtosis)	Min.	Max.
T1 scores	T1_Design Mindset	473	4.45	4.41	0.5	0.034	0.304	0.382	1.705	2.4	6.1
	T1_Iteration	473	4.75	4.75	1.0	−0.562	−5.018	0.711	3.174	1.0	7.0
	T1_Conversation with the situation	473	6.00	6.03	0.8	−0.960	−8.571	1.970	8.795	1.5	7.0
	T1_Co-evolution of problem-solution	473	5.00	4.97	1.0	−0.075	−0.670	−0.129	−0.576	2.5	7.0
	T1_Imagination	473	3.50	3.74	1.1	0.117	1.045	−0.020	−0.089	1.0	7.0
T2 scores	T2_Design Mindset	254	4.55	4.55	0.6	−0.184	−1.203	−0.263	−0.865	2.8	6.1
	T2_Iteration	254	5.00	4.78	1.0	−0.474	−3.098	−0.050	−0.164	1.5	7.0
	T2_Conversation with the situation	254	6.50	6.12	0.9	−1.033	−6.752	0.357	1.174	3.5	7.0
	T2_Co-evolution of problem-solution	254	5.00	5.03	1.0	−0.218	−1.425	0.012	0.039	1.5	7.0
	T2_Imagination	254	4.50	4.29	1.1	−0.208	−1.359	−0.224	−0.737	1.0	7.0
Dependent variables	Design Mindset_DELTA	254	0.18	0.13	0.6	−0.389	−2.542	1.203	3.957	−1.8	1.9
	Iteration_DELTA	254	0.00	−0.02	1.0	−1.077	−7.039	3.803	12.510	−5.0	2.3
	Conversation with the situation_DELTA	254	0.00	0.08	0.9	−1.062	−6.941	2.093	6.885	−3.5	2.0
	Co-evolution of problem-solution_DELTA	254	0.00	0.06	1.2	−0.385	−2.516	0.958	3.151	−3.5	4.0
	Imagination_DELTA	254	0.50	0.59	1.2	0.095	0.621	1.080	3.553	−3.0	5.0
Independent variables	Sensation-seeking	473	4.38	4.35	1.2	−0.082	−0.732	−0.637	−2.844	1.4	7.0
	Self-efficacy	473	5.20	5.18	0.7	−0.299	−2.670	0.681	3.040	2.0	7.0
	Ambiguity tolerance	473	4.50	4.46	0.6	−0.176	−1.571	0.154	0.688	2.2	6.1
	Excited about course	473	5.00	4.73	1.5	−0.519	−4.634	−0.323	−1.442	1.0	7.0
	Will use tools	473	6.00	5.35	1.3	−0.716	−6.393	0.169	0.754	1.0	7.0
	Gender ratio in group	68	0.23	0.28	0.2	0.241	0.828	−1.389	−2.420	0.0	0.6
	Facilitator ratio in group	464	0.11	0.13	0.0	1.823	16.133	2.228	9.858	0.1	0.2
	Avg. Design Mindset score in group	117	4.42	4.44	0.2	−0.268	−1.196	−0.972	−2.189	4.1	4.8
	Avg. facilitator Design Mindset in group	456	4.73	4.76	0.5	−0.142	−1.246	−0.358	−1.570	3.6	5.6

$*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

The *t*-tests (Table 2) revealed that the increase in *Design Mindset* was significant, $t(253) = -3.66$, $p < .001$, Cohen's $d = 0.230$, supporting our hypothesis of *Method Teaching* positively influencing *Design mindset*.

Of the *Design Mindset* sub-constructs, only *Imagination*, $t(253) = -7.93$, $p < .001$, Cohen's $d = -0.498$, shows a significant increase in score from the pre- to the post-intervention test, indicating that it is the primary driver of the increase in *Design Mindset* scores. While the remaining sub-constructs show no significant changes, it is worth noting that *Iteration* decreased from the pre- to the post-intervention test as the only construct.

Both significant results—*Design Mindset* and *Imagination*—fall within what can be considered a medium effect size ($0.2 <$ *Cohen's d* < 0.8; Cohen 2013).

4.4. Variables influencing the development of design mindset

4.4.1. Initial analysis of individual variables

To identify the relationships of each independent variable to the learning outcomes of *Method Teaching*, we conducted separate linear regression analyses for each of the ten variables. Aligning with our model of *Method Teaching* (see Figure 2), we relied on the differences between the pre-and post-intervention scores of *Design Mindset* (*Design Mindset_DELTA*) as a measure for the participants' learning and, thus, as our dependent variable.

The independent variables shown in Table 1, along with pre-intervention scores of *Design mindset* (*T1_Design Mindset*), are used as the independent variables for these analyses. All these variables were collected in the pre-intervention questionnaire.

Table 3 shows the model summaries for all variables and represents the goodness of fit and the contribution of each model (H_1) and their null hypotheses (H_0). The models for *T1_Design Mindset*, $F(1,252) = 40.08$, $p < .001$, $R^2 = 0.137$, *Self-efficacy*, $F(1,252) = 6.97$, $p = 0.009$, $R^2 = 0.027$, *Ambiguity tolerance*, $F(1,252) = 14.46$, $p < .001$, $R^2 = 0.054$, indicate significant improvements in performance compared to their null models. As indicated by the *Adjusted* R^2, the three models explain 13.4%, 2.3%, and 5.1% of the variance of *Design Mindset_DELTA*, respectively.

At the other end of the spectra, *Excited about course* (*Adjusted* $R^2 = -0.004$) and *Avg. facilitator Design Mindset in group* (*Adjusted* $R^2 = -0.001$) both explain less of the variance of *Design Mindset_DELTA* than their respective H_0-models, suggesting they are not suitable for understanding the changes in *Design Mindset* scores.

The one-way ANOVAs shown in Table 4 support rejecting the null hypothesis for the models including *T1_Design Mindset*, $F(1,252) = 40.08$, $p < .001$, *Self-efficacy*, $F(1,252) = 6.97$, $p = 0.009$, and *Ambiguity tolerance*, $F(1,252) = 14.46$, $p < .001$. The result indicates that these three models account for significant variance, while the remaining models fail to do so.

Table 5 displays the coefficients of each of the variable models, and the relationships to the development of *Design Mindset* are illustrated in Figure 4 (green lines indicate a positive relationship, while red lines indicate a negative relationship. The line width shows the strength of the relationship based on the standardised coefficients, and the dashed lines indicate that the results were not statistically significant). The unstandardised coefficients tell us the amount *Design Mindset_DELTA* changes when the independent variable increases by one and anything else is static (e.g. if *T1_Design Mindset* increases by 1, *Design Mindset_DELTA* will decrease by −0.425). As such, Table 5 gives us the directionality of the

Table 2. Paired Sample t-test.

Measure 1		Measure 2	*t*	*df*	*p*	M_Δ	SE Difference	Cohen's *d*	SE Cohen's *d*	95% CI for Cohen's *d* Lower	Upper
T1_Design Mindset	–	T2_Design Mindset	−3.66	253	< .001***	−0.128	0.035	−0.230	0.065	$-\infty$	−0.125
T1_Iteration	–	T2_Iteration	0.29	253	0.615	0.018	0.061	0.018	0.061	$-\infty$	0.121
T1_Conversation with the situation	–	T2_Conversation with the situation	−1.40	253	0.082	−0.081	0.058	−0.088	0.069	$-\infty$	0.016
T1_Co-evolution of problem-solution	–	T2_Co-evolution of problem-solution	−0.87	253	0.193	−0.063	0.073	−0.054	0.073	$-\infty$	0.049
T1_Imagination	–	T2_Imagination	−7.93	253	< .001***	−0.594	0.075	−0.498	0.070	$-\infty$	−0.388

Note. The alternative hypothesis specifies that Measure 1 is less than Measure 2 for all tests. For example, T1_Design Mindset is less than T2_Design Mindset.
Note. Student's *t*-test.
*$p < 0.05$;
**$p < 0.01$;
***$p < 0.001$.

Table 3. Model summaries—Individual variables.

	Model	R	R^2	Adjusted R^2	RMSE	R^2 Change	F Change	$df1$	$df2$	P
T1_Design Mindset	H_0	0.000	0.000	0.000	0.559	0.000		0	253	
	H_1	0.370	0.137	0.134	0.520	0.137	40.08	1	252	$< .001^{***}$
Sensation-seeking	H_0	0.000	0.000	0.000	0.559	0.000		0	253	
	H_1	0.080	0.006	0.002	0.558	0.006	1.60	1	252	0.207
Self-efficacy	H_0	0.000	0.000	0.000	0.559	0.000		0	253	
	H_1	0.164	0.027	0.023	0.552	0.027	6.97	1	252	0.009^{**}
Ambiguity tolerance	H_0	0.000	0.000	0.000	0.559	0.000		0	253	
	H_1	0.233	0.054	0.051	0.544	0.054	14.46	1	252	$< .001^{***}$
Excited about course	H_0	0.000	0.000	0.000	0.559	0.000		0	253	
	H_1	0.005	0.000	−0.004	0.560	0.000	0.01	1	252	0.932
Will use tools	H_0	0.000	0.000	0.000	0.559	0.000		0	253	
	H_1	0.118	0.014	0.010	0.556	0.014	3.55	1	252	0.061
Gender ratio in group	H_0	0.000	0.000	0.000	0.577	0.000		0	48	
	H_1	0.175	0.031	0.010	0.574	0.031	1.49	1	47	0.228
Facilitator ratio in group	H_0	0.000	0.000	0.000	0.560	0.000		0	251	
	H_1	0.088	0.008	0.004	0.559	0.008	1.96	1	250	0.163
Avg. Design Mindset score in group	H_0	0.000	0.000	0.000	0.577	0.000		0	48	
	H_1	0.193	0.037	0.017	0.572	0.037	1.82	1	47	0.184
Avg. facilitator Design Mindset in group	H_0	0.000	0.000	0.000	0.584	0.000		0	159	
	H_1	0.074	0.006	−0.001	0.584	0.006	0.88	1	158	0.351

$*p < 0.05$;
$**p < 0.01$;
$***p < 0.001$.

Table 4. ANOVA—Individual variables.

	Model		Sum of Squares	*df*	Mean Square	*F*	*p*
T1_Design Mindset	H_1	Regression	10.8	1	10.8	40.1	< .001***
		Residual	68.2	252	0.3		
		Total	79.0	253			
Sensation-seeking	H_1	Regression	0.5	1	0.5	1.6	0.207
		Residual	78.5	252	0.3		
		Total	79.0	253			
Self-efficacy	H_1	Regression	2.1	1	2.1	7.0	0.009**
		Residual	76.9	252	0.3		
		Total	79.0	253			
Ambiguity tolerance	H_1	Regression	4.3	1	4.3	14.5	< .001***
		Residual	74.7	252	0.3		
		Total	79.0	253			
Excited about course	H_1	Regression	0.0	1	0.0	0.0	0.932
		Residual	79.0	252	0.3		
		Total	79.0	253			
Will use tools	H_1	Regression	1.1	1	1.1	3.6	0.061
		Residual	77.9	252	0.3		
		Total	79.0	253			
Gender ratio in group	H_1	Regression	0.5	1	0.5	1.5	0.228
		Residual	15.5	47	0.3		
		Total	16.0	48			
Facilitator ratio in group	H_1	Regression	0.6	1	0.6	2.0	0.163
		Residual	78.2	250	0.3		
		Total	78.8	251			
Avg. Design Mindset score in group	H_1	Regression	0.6	1	0.6	1.8	0.184
		Residual	15.4	47	0.3		
		Total	16.0	48			
Avg. facilitator Design Mindset in group	H_1	Regression	0.3	1	0.3	0.9	0.351
		Residual	53.9	158	0.3		
		Total	54.2	159			

Note. The intercept model is omitted, as no meaningful information can be shown.
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

relationship between the different variables and the changes in *Design Mindset*. Perhaps the negative relationship between *Design Mindset_DELTA* and *T1_Design Mindset*, *Sensation-seeking*, and *Will use tools* is most noteworthy in this context, even though the model for the latter is not considered significant. These results suggest that the hypothesised positive relationship between these three variables must be rejected.

4.4.2. Analysis of multiple variables

To investigate the individual and combined effects of the different variables on the learning outcomes of *Method Teaching*, we conducted a forward selection stepwise multiple linear regression analysis for *Design Mindset_DELTA*. We employed stepwise analyses to systematically select the most influential variables for inclusion in the final regression models.

The independent variables *T1_Design Mindset, Sensation-seeking, Self-efficacy, Ambiguity tolerance, Will use tools, Facilitator ratio in group*, and *Avg. facilitator Design Mindset in group* was included in the analysis. *Gender ratio in group* and *Avg. Design Mindset score in group* were excluded to avoid the immense loss of degrees of freedom (48 vs 253) resulting from the number of respondents the variable could be calculated for (see Section 4.2). Neither showed a significant relationship to *Design Mindset_DELTA* on their own (see Table 3, Table 4, and Table 5), and both have a relatively small sample size (see Table 1). Similarly, we

Table 5. Coefficients—Individual variables.

Model			Unstandardised	Standard Error	Standardised	*t*	*p*
T1_Design Mindset	H_0	(Intercept)	0.127	0.035		3.635	< .001***
	H_1	(Intercept)	2.006	0.299		6.720	< .001***
		T1_Design Mindset	−0.425	0.067	−0.370	−6.331	< .001***
Sensation-seeking	H_0	(Intercept)	0.127	0.035		3.635	< .001***
	H_1	(Intercept)	0.291	0.134		2.176	0.030**
		Sensation-seeking	−0.037	0.029	−0.080	−1.266	0.207
Self-efficacy	H_0	(Intercept)	0.127	0.035		3.635	< .001***
	H_1	(Intercept)	−0.514	0.245		−2.094	0.037**
		Self-efficacy	0.120	0.045	0.164	2.640	0.009**
Ambiguity tolerance	H_0	(Intercept)	0.127	0.035		3.635	< .001***
	H_1	(Intercept)	−0.768	0.238		−3.228	0.001***
		Ambiguity tolerance	0.197	0.052	0.233	3.803	< .001***
Excited about course	H_0	(Intercept)	0.127	0.035		3.635	< .001***
	H_1	(Intercept)	0.117	0.123		0.955	0.340
		Excited about course	0.002	0.025	0.005	0.086	0.932
Will use tools	H_0	(Intercept)	0.127	0.035		3.635	< .001***
	H_1	(Intercept)	0.408	0.153		2.668	0.008**
		Will use tools	−0.052	0.028	−0.118	−1.884	0.061
Gender ratio in group	H_0	(Intercept)	0.026	0.082		0.315	0.754
	H_1	(Intercept)	−0.130	0.152		−0.856	0.396
		Gender ratio in group	0.457	0.374	0.175	1.221	0.228
Facilitator ratio in group	H_0	(Intercept)	0.125	0.035		3.538	< .001***
	H_1	(Intercept)	−0.058	0.135		−0.429	0.668
		Facilitator ratio in group	1.439	1.029	0.088	1.399	0.163
Avg. Design Mindset score in group	H_0	(Intercept)	0.026	0.082		0.315	0.754
	H_1	(Intercept)	−2.211	1.662		−1.330	0.190
		Avg. Design Mindset score in group	0.500	0.371	0.193	1.348	0.184
Avg. facilitator Design Mindset in group	H_0	(Intercept)	0.091	0.046		1.971	0.050**
	H_1	(Intercept)	−0.304	0.425		−0.715	0.475
		Avg. facilitator Design Mindset in group	0.083	0.089	0.074	0.935	0.351

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

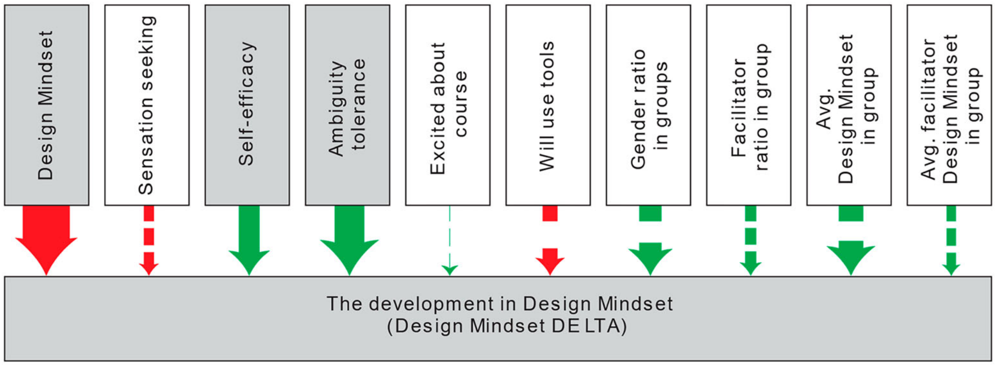

Figure 4. Visualisation of the regression models of the individual variables (colour indicates directionality, line width, the strength of the relationships based on the standardised coefficients and dashed lines non-significant relationships ($p > .05$)).

Table 6. Models summaries—Multiple variables.

	Model	*R*	R^2	Adjusted R^2	RMSE	R^2 Change	F Change	df1	df2	p
Design Mindset_DELTA	1				0.559			0	253	
	2	0.370	0.137	0.134	0.520	0.137	40.080	1	252	< .001***
	3	0.472	0.223	0.217	0.494	0.086	27.768	1	251	< .001***
	4	0.509	0.259	0.250	0.484	0.036	12.154	1	250	< .001***
	5	0.537	0.288	0.277	0.475	0.029	10.193	1	249	0.002**

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

excluded *Excited about course* and *Avg. facilitator Design Mindset in group* due to their negative Adjusted R^2 values (see Table 3), indicating that they do not improve the predictive model.

The significance of *F-change*, displayed in Table 6, indicates that the model provides meaningful information about the changes in *Design Mindset*. The model explains 27.7% of the variance of the changes in *Design Mindset*, as indicated by the *Adjusted* R^2. Additionally, the *p*-value ($p = 0.002$) suggests statistical significance in explaining the variability of *Design Mindset* scores.

The one-way ANOVA shown in Table 7 supports rejecting the null hypothesis. The *p*-values indicate highly significant model fits, while the *F*-values show diminishing returns in explanatory power as less predictive variables are added to the model.

As could be expected based on the initial analyses of the variables, Table 8 shows that *T1_Design Mindset, Self-efficacy, and Ambiguity tolerance* are included in the best model for explaining the changes in *Design Mindset* scores (*Design Mindset_DELTA*). More surprisingly, *Sensation-seeking* is also included in this model, indicating an interaction between the independent variables that increases the relevance of *Sensation-seeking*.

Similar to the initial analyses, Table 8 also shows a negative relationship between the changes in *Design Mindset* and the variables *T1_Design Mindset* and *Sensation-seeking*, contradicting our initial hypotheses.

The relationships are visually summarised in Figure 5 (green lines indicate a positive relationship, while red lines indicate a negative relationship. The line width shows the strength of the relationship based on the standardised coefficients).

Table 7. ANOVA—Multiple variables.

	Model	df	F	p
Design Mindset_DELTA	2	1	40.1	$< .001^{***}$
		252		
		253		
	3	2	36.1	$< .001^{***}$
		251		
		253		
	4	3	29.2	$< .001^{***}$
		250		
		253		
	5	4	25.2	$< .001^{***}$
		249		
		253		

Note. The intercept model is omitted, as no meaningful information can be shown.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

5. Discussion

In this study, we have investigated how individual and contextual factors affect the development of *Design Mindset* through *Method Teaching*. The results show that *Method Teaching* generally improves *Design Mindset* as we hypothesised (see Section 1.2). We find that the changes in *Design Mindset* are best predicted by the individual factors—*Design Mindset, Sensation-seeking, Self-efficacy,* and *Ambiguity tolerance*—rather than the contextual factors. The results also show that several variables were negatively correlated with the development of *Design Mindset*, contrary to our hypotheses (see Section 1.2). Among the variables included in the final regressing model (see Section 4.4.2), both *Design Mindset* and *Sensation-seeking* were found to be negatively correlated with the development of *Design Mindset*.

5.1. Design Mindset and Method Teaching

Considering that neither *Iteration, Conversation with the situation*, nor *Co-evolution of problem-solution* of the sub-constructs of *Design Mindset* was statistically significant, the results indicate that the development of *Design Mindset* was driven mainly by the improvements in the sub-construct *Imagination*. *Imagination* is associated with divergent and hypothetical thinking (Lavrsen, Carbon, and Daalhuizen in press). While both concepts were in play during the course, looking closer at *Method Teaching* in general and the specific case studied here, we would have expected the development of *Design Mindset* to be driven mainly by *Conversation with the situation* and *Co-evolution of problem-solution*. Despite aspects related to both being more explicitly taught and taking up more time in the course than any aspects related to *Imagination*, neither improved significantly. These results might indicate that the specific setup of *Method Teaching* employed in the studied course is skewed towards stimulating development in *Imagination* rather than the other sub-constructs of *Design Mindset*. Alternatively, the beliefs and attitudes related to *Imagination* might be more susceptible to change than the other sub-constructs of *Design Mindset*, at least within the short time frame of the case presented here.

Even though insignificant, it is also worth addressing the negative changes to *Iteration*. The negative development is worrisome since working iteratively is essential to designing

Table 8. Coefficients—Multiple variables.

	Model		Unstandardised	Standard Error	Standardised	*t*	*p*	Collinearity Statistics	
								Tolerance	VIF
Design Mindset_DELTA	1	(Intercept)	0.127	0.035		3.635	$< .001^{***}$		
	2	(Intercept)	2.006	0.299		6.720	$< .001^{***}$		
		T1_Design Mindset	−0.425	0.067	−0.370	−6.331	$< .001^{***}$	1.000	1.000
	3	(Intercept)	1.096	0.332		3.300	0.001^{***}		
		T1_Design Mindset	−0.477	0.065	−0.416	−7.387	$< .001^{***}$	0.977	1.024
		Ambiguity tolerance	0.250	0.048	0.297	5.270	$< .001^{***}$	0.977	1.024
	4	(Intercept)	1.231	0.327		3.761	$< .001^{***}$		
		T1_Design Mindset	−0.481	0.063	−0.419	−7.610	$< .001^{***}$	0.976	1.024
		Ambiguity tolerance	0.317	0.050	0.376	6.307	$< .001^{***}$	0.835	1.198
		Sensation-seeking	−0.095	0.027	−0.205	−3.486	$< .001^{***}$	0.854	1.172
	5	(Intercept)	0.840	0.344		2.439	0.015^{*}		
		T1_Design Mindset	−0.506	0.063	−0.441	−8.082	$< .001^{***}$	0.962	1.04
		Ambiguity tolerance	0.280	0.051	0.332	5.531	$< .001^{***}$	0.792	1.262
		Sensation-seeking	−0.104	0.027	−0.226	−3.877	$< .001^{***}$	0.843	1.186
		Self-efficacy	0.133	0.042	0.181	3.193	0.002^{**}	0.886	1.129

Note. The following covariates were considered for analyses but not necessarily included in the models: T1_Design Mindset, Sensation-seeking, Self-efficacy, Ambiguity tolerance, Will use tools, Facilitator ratio in group, Avg. facilitator Design Mindset in group
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

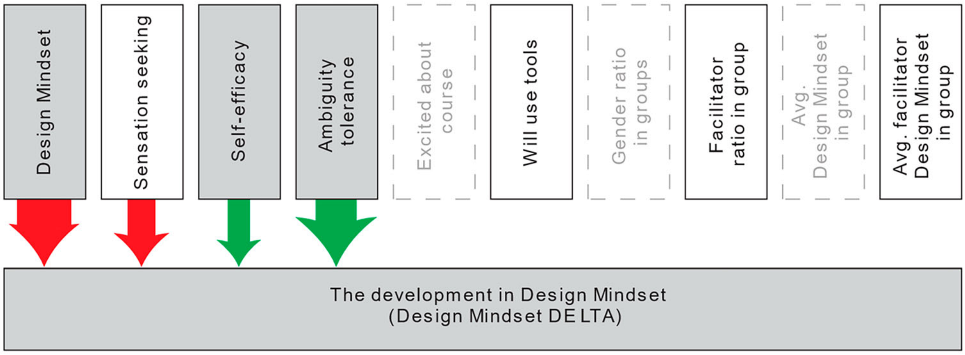

Figure 5. Visualisation of the regression model including multiple variables ($p < .05$; colour indicates directionality and line-width the strength of the relationships based on the standardised coefficients. The muted boxes reflect the variables not included in the regression analysis).

and implementing learning and new insights into the design process (Crismond and Adams 2012; Dorst 2011; Lavrsen, Carbon, and Daalhuizen in press). Not addressing the negative development could result in poorer performance on design tasks and less effective learning in future design situations. These findings generally indicate a need to better understand the relationship between the specific components of *Method Teaching* and the development of *Design Mindset* to improve the effectiveness of *Method Teaching*.

5.2. Variables influencing the effectiveness of method teaching

The results from the regression analyses show that several of the variables included in the multiple regression models had no significant influence on changes in *Design Mindset*. Both of the group factors and the factors related to motivation had insignificant predictive power. The dominant variables across the models are the initial *Design Mindset* score and the three personality traits (see Figure 5).

5.2.1. The influence of initial design mindset on developing design mindset

As shown in Table 3, 13.4% of the variance of the change in *Design Mindset* between the start and end of the course can be explained by the participants' initial *Design Mindset*. It is, therefore, not surprising that it is significant when included with other variables in the regression models investigating the changes in *Design Mindset*. As highlighted in Figure 5, participants' initial *Design Mindset* correlates negatively with the overall change in *Design Mindset*. While the negative relationship suggests that *Method Teaching* is more effective for students starting with a lower *Design mindset* score, it does not necessarily mean that higher scores result in negative development. The negative relationship implies that as the initial *Design Mindset* scores increase, the improvements in *Design Mindset* become smaller. Despite contradicting our initial hypothesis (see Section 1.2), this is not surprising as those participants initially scoring higher might be closer to their maximum potential, making it harder to improve significantly.

Taking together with the limited reliability of *D-Mindset0.1* ($\omega = 0.522$), some of the negative relationships might also be ascribed to the statistical phenomenon: 'regression to the mean.' Regression to the mean suggests that individuals with initially extreme scores, high or low, are more likely to move closer to the mean in subsequent measurements due to random fluctuations. This is supported by the data showing that 67% ($n = 55$) of the 82 participants who experienced a drop in *Design Mindset* scores scored above average in *Design Mindset* in the pre-intervention test (T1). Compared with the group of participants with negative development and scoring below average in *Design Mindset* in the initial test ($n = 27$), who had an average drop of −0.33, the above-average group on average dropped −0.55 in *Design Mindset* scores, a statistically significant difference (Welch's $t(78) = -2.901$, $p = 0.005$, Cohen's $d = 0.619$). These findings suggest the need for caution in interpreting the relationship between initial *Design Mindset* scores and changes in *Design Mindset* and highlight the importance of continually improving the *Design Mindset inventory (D-Mindset0.1)* to mitigate the effects of 'regression to the mean' in future studies.

5.2.2. Influence of sensation-seeking

Despite having no statistically significant relationship to change in *Design Mindset* (*Design Mindset_DELTA*) in the initial analysis of the individual variables (see section 4.4.1), we find *Sensation-seeking* included in the multi-variable model, indicating that it interacts with the other variables in a way that makes it more relevant than when on its own (see section 4.4.2).

Considering that our prior research (Lavrsen, Carbon, and Daalhuizen in press) has found a positive correlation between *Sensation-seeking* and *Imagination* and that the changes to *Design Mindset* in this study seem to be driven by changes to this subconstruct, the negative relationship to the development of *Design Mindset* is interesting. It indicates that while being a sensation seeker is positively correlated with the subconstruct of *Imagination* and likely helps the sensation seekers be more creative (Lavrsen, Carbon, and Daalhuizen in press), in the context of *Method Teaching*, these attributes likely influence the learning negatively. This might be due to sensation seekers being prone to distractions, e.g. if the course is not stimulating enough, sensation seekers might be likelier to daydream (R.E. Franken and Rowland 1990; McDaniel, Lee, and Lim 2001). The negative effect of *Sensation-seeking* might be enhanced by the negative development in *Design Mindset* among participants with high pre-intervention *Design Mindset* scores (discussed above) since the combination of high *Sensation-seeking* and *Design Mindset* scores could suggest an increased risk of boredom due to prior experience with design and innovation.

5.2.3. Influence of self-efficacy

The regression models show a positive relationship between the development of *Design Mindset*, *Ambiguity tolerance,* and *Self-efficacy*, aligning with our hypotheses. The positive relationship with *Self-efficacy* is likely driven by higher *Self-efficacy* providing the necessary confidence to persist in the complex context associated with designing, which is a mainstay of *Method Teaching*. In our previous research, we have suggested a similar argument for the more general relationship between *Self-efficacy* and *Design Mindset* (Lavrsen, Carbon, and Daalhuizen in press).

5.2.4. Influence of ambiguity tolerance

Ambiguity tolerance seems to facilitate reflection in and on action, which requires an acceptance of processes and methods being more like guidelines than strict procedures that must be followed. Accepting this ambiguity as part of the design process likely prompts the students to reflect on their method usage and design practices, stimulating learning. Similarly, Ambiguity tolerance has been related to the unfreezing of mental models (Herman et al. 2010), suggesting that *Ambiguity tolerance* generally facilitates learning and changes in mindset.

5.3. Limitations and future research

While our study design allows us to collect data in a real-world context, it also means we had limited control over the factors influencing the learning environment and the learning. While we have shown that several variables influence the effect of *Method Teaching*, the limited control over the intervention leaves much in terms of determining what aspects of *Method Teaching* are affected by what variables and how *Method Teaching* itself influences the development of *Design Mindset*. Without complete control, a direct measurement of the intervention variable, and a control group, it is difficult to establish a direct causal link between the intervention and the change in *Design Mindset*. Various factors, including the intervention, other unmeasured variables, and time-related effects, may have influenced the relationship between pre- and post-intervention measures. Considering, for example, the short timeframe of the study—twelve workdays—it is impressive that we see significant improvement in Design Mindset. However, this improvement would likely be more pronounced given more time. Similarly, the influence of the different variables analysed might change if the development of *Design Mindset* were measured over a more extended period, such as a semester-length course or even over a whole education. It is not unlikely that time could moderate the effect of several variables, making their influence more pronounced and perhaps even changing the directionality of the influence to match our hypothesis better.

The patterns observed in the relationships between *Sensation-seeking, Self-efficacy, Ambiguity tolerance*, and the changes to *Design Mindset* underscore the complexity of variables influencing mindset development in the context of *Method Teaching*. Future research could delve deeper into these dynamics to investigate the interplay between personality traits, *Method Teaching*, and mindset development, ultimately informing more effective educational interventions and strategies in design education.

Lastly, the quality of the results and their interpretation depends on the quality of the instruments used to measure them. As the measure of the students' learning and the core measure throughout this study, the quality of *D-Mindset0.1* has a great potential to influence the study results, as already indicated in Section 5.2.1. *D-Mindset0.1* was developed for this study and is, thus, still in its infancy. There are still a lot of unanswered questions regarding its reliability and validity (Lavrsen, Carbon, and Daalhuizen in press; Lavrsen, Daalhuizen, and Carbon 2023). While the developmental stage of *D-Mindset0.1* influences the result of this study, it also helps further our understanding of the construct and can, thus, inform the development of the *Design Mindset Inventory*.

6. Conclusion

This study has outlined the concept of *Method Teaching* and provided valuable insights into its effectiveness in enhancing *Design Mindset*. The findings reveal that while *Method Teaching* leads to improvements in *Design Mindset*, the specific variables influencing its effectiveness are complex and multifaceted. The analysis suggests that while *Self-efficacy* and *Ambiguity tolerance* positively influence *Design Mindset* development, *Sensation-seeking* may have a more complex relationship, potentially distracting students from focused learning. Overall, this study contributes to our understanding of *Method Teaching* and its impact on fostering *Design Mindset* while also highlighting avenues for continued investigation and improvement in design education.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendices

Appendix A: Proportions of educational backgrounds in the sample

Educational background	Counts	Total	Proportion (%)
Sustainable Energy	32	254	12.6
Architectural Engineering	27	254	10.6
Biotechnology	22	254	8.7
Civil Engineering	19	254	7.5
Chemical and Biochemical Engineering	18	254	7.1
Industrial Engineering and Management	18	254	7.1
Pharmaceutical Design and Engineering	14	254	5.5
Electrical Engineering	13	254	5.1
Computer Science and Engineering	12	254	4.7
Design and Innovation	9	254	3.5
Autonomous Systems	8	254	3.1
Earth and Space Physics and Engineering	8	254	3.1
Business Analytics	7	254	2.8
Mechanical Engineering	7	254	2.8
Transport and Logistics	7	254	2.8
Materials and Manufacturing Engineering	6	254	2.4
Bioinformatics and Systems Biology	5	254	2
Wind Energy	3	254	1.2
Others	3	254	1.2
Advanced Materials and Healthcare Engineering	2	254	0.8
Applied Chemistry	2	254	0.8
Engineering Acoustics	2	254	0.8
Environmental Engineering	2	254	0.8
Food Technology	2	254	0.8
Human-Centered Artificial Intelligence	2	254	0.8
Biomedical Engineering	1	254	0.4
Mathematical Modelling and Computation	1	254	0.4
Physics and Nanotechnology	1	254	0.4
Technology Entrepreneurship (cand.tech.)	1	254	0.4

Appendix B: Post-intervention questionnaire

DTU

0% completed

Please type in the six digits of your DTU student identification number. Your student ID will only be used for connecting data from the two questionnaires.

Student ID

Next

Jakob Clemen Lavrsen, Technical University of Denmark - DTU – 2021

DTU

50% completed

	Strongly disagree 0	1	2	3	4	5	Strongly agree 6
I avoid settings where people don't share my values.	○	○	○	○	○	○	○
I can enjoy being with people whose values are very different from mine.	○	○	○	○	○	○	○
I would like to live in a foreign country for a while.	○	○	○	○	○	○	○
I like to surround myself with things that are familiar to me.	○	○	○	○	○	○	○
The sooner we all acquire similar values and ideals the better.	○	○	○	○	○	○	○
I can be comfortable with nearly all kinds of people.	○	○	○	○	○	○	○
If given a choice, I will usually visit a foreign country rather than vacation at home.	○	○	○	○	○	○	○
A good teacher is one who makes you wonder about your way of looking at things.	○	○	○	○	○	○	○
A good job is one where what is to be done and how it is to be done are always clear.	○	○	○	○	○	○	○
A person who leads an even, regular life in which few surprises or unexpected happenings arise really has a lot to be grateful for.	○	○	○	○	○	○	○
What we are used to is always preferable to what is unfamiliar.	○	○	○	○	○	○	○
I like parties where I know most of the people more than ones where all or most of the people are complete strangers.	○	○	○	○	○	○	○

	Strongly disagree … Strongly agree
I can always manage to solve difficult problems if I try hard enough.	
If someone opposes me, I can find the means and ways to get what I want.	
It is easy for me to stick to my aims and accomplish my goals.	
I am confident that I could deal efficiently with unexpected events.	
Thanks to my resourcefulness, I know how to handle unforeseen situations.	
I can solve most problems if I invest the necessary effort.	
I can remain calm when facing difficulties because I can rely on my coping abilities.	
When I am confronted with a problem, I can usually find several solutions.	
If I am in trouble, I can usually think of a solution.	
I can usually handle whatever comes my way	

	Strongly disagree … Strongly agree
I would like to explore strange places.	
I get restless when I spend too much time at home.	
I like to do frightening things.	
I like wild parties.	
I would like to take off on a trip with no pre-planned routes or timetables.	
I prefer friends who are excitingly unpredictable.	
I would like to try bungee jumping.	
I would love to have new and exciting experiences, even if they are illegal.	

	Strongly disagree						Strongly agree
It is important to challenge the problem statement before trying to solve the problemy.	○	○	○	○	○	○	○
Problems should be well defined and fully understood before attempting to develop a solution.	○	○	○	○	○	○	○
To make the future better, you should not try to solve today's problems but imagine a new future.	○	○	○	○	○	○	○
You should spend more time on building the solution then understand the question.	○	○	○	○	○	○	○
It is more important to spend time generating many ideas than it is to refine a few.	○	○	○	○	○	○	○
As soon as you have a good idea, you should move from idea generation to idea refinement.	○	○	○	○	○	○	○
Representing ideas in non-verbal ways – using diagrams, sketches, prototypes, dramatization, etc. – are essential in understanding a problem.	○	○	○	○	○	○	○
Sharing ideas with others throughout the process makes them better.	○	○	○	○	○	○	○
It is important to look at a solution from different stakeholder perspectives.	○	○	○	○	○	○	○
Once you have a good idea, you should not waste time figuring out how it might fail.	○	○	○	○	○	○	○
A failed experiment can be as important as a successful one.	○	○	○	○	○	○	○
It is more important to spend time testing continuously than to test the end-result.	○	○	○	○	○	○	○
Even late in the process, you should pivot and rethink a solution if learning something important.	○	○	○	○	○	○	○
If done right, you should not have to revisit past stages of the innovations process.	○	○	○	○	○	○	○
It is more important to follow a process than to adapt to the circumstances.	○	○	○	○	○	○	○
Methods are more a guideline than rules you must follow.	○	○	○	○	○	○	○

Next

Jakob Clemen Lavrsen, Technical University of Denmark - DTU – 2021

DTU

Thank you for completing this questionnaire!

We would like to thank you very much for helping us.

Your answers were transmitted, you may close the browser window or tab now.

Jakob Clemen Lavrsen, Technical University of Denmark - DTU – 2021