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Fostering metacognition in the design studio: The effect of minimal interventions on architectural students' metacognitive awareness

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ABSTRACT

This study investigates the role of metacognitive interventions in the design studio and the relationship between metacognitive awareness and design learning through quasi-experimental research. The study was conducted at an undergraduate design studio course with the participation of 80 fourth-year students divided into experimental and control groups. In the study, minimal metacognitive interventions prompting students to reflect on their design project and design process were administered in the experimental group during an academic term embedded in the design course. The Metacognitive Awareness Inventory (MAI) was applied to both the experimental group and the control group as a pre-test and post-test to determine the impact of minimal interventions on metacognitive awareness. In addition, the relationship between metacognitive awareness and design course grade and the type and level of this relationship were analysed. According to the findings, metacognitive interventions significantly enhanced metacognitive awareness levels of students with lower metacognitive awareness. However, interventions did not result in a statistically significant difference in the design course grade. Furthermore, a moderate positive correlation was found between design course grades and pre-MAI scores, i.e., pre-MAI scores explained about 20 % of the variance in the design course grades. In conclusion, minimal interventions are beneficial at least to students with lower levels of metacognitive awareness and potentially more substantial interventions would be even more helpful to these students and other students with a higher level of metacognitive awareness.

1. Introduction

This study investigates the effect of metacognitive interventions in a design studio environment and the relationship between metacognitive awareness and design learning through quasi-experimental research and it questions whether metacognitive awareness levels predict design course grades. The study assumes that improvements in metacognitive awareness have the potential to facilitate design learning, which poses significant challenges for students, as in many other learning fields (Zohar & Barzilai, 2013; Zohar & Dori, 2011).

Design learning is often described as a student-led process because learning in design is primarily dependent on students' abilities

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to plan and monitor their own learning process. The study expands on Mayer's discussion (Mayer, 2004) of the effectiveness of discovery learning highlighting that in a student-led learning paradigm, students must undertake both behavioural activities, i.e., design tasks in the case of design learning, and cognitive activities for long-lasting and deep learning. We contend that metacognitive skills and knowledge have the potential to support such cognitive activities and that studio instructors might benefit from metacognitive indicators to predict students' performances and tailor their studio teaching accordingly.

In the 1980s, Nigel Cross introduced his widely accepted framework on 'designerly ways of knowing' (Cross, 1982). According to Cross, there are unique ways of knowing in design that bring along unique ways of thinking and doing, which are fundamentally different from scientific research and research in humanities as suggested by Archer (1979). These 'designerly ways' highlight specific cognitive, social, and emotional components of design, yet these are only learned through learning by doing (Li & Yuan, 2022; Taneri & Dogan, 2021). Schön (1983) proposes that such learning is facilitated through reflective practices while Kolb (2015) suggests that learning-by-doing could be only effective through cyclic stages of concrete experience, reflective observation, abstract conceptualization, and active experimentation.

Today, there is no agreed-upon method to how to learn these 'designerly ways,' therefore it is a significant challenge for students to acquire these ways in design education and design learning through self-directed strategies (Taneri & Dogan, 2021). Lawson and Dorst (2013) go even further by suggesting that design instructors focus solely on evaluating design products students deliver without hardly ever delving into what students learn. Even if one learns the components of designerly ways of knowing it is still necessary to learn when, where, why, and how to use these, which are the cornerstones of metacognition in creativity. Consequently, through this study, we inquire into whether metacognitive skills can partially ease this difficulty by way of supporting learning-by-doing through metacognitive interventions.

Although the interest in metacognition has increased in various fields in recent years, such as in studies of science education, the number of comprehensive studies on metacognition in the context of design (see Ball & Christensen, 2019) and design learning is still limited (see An & Cao, 2014; Carlson et al., 2020; Clemente et al., 2017; Hargrove, 2013; Kavousi et al., 2020; Kurt & Kurt, 2017). In contrast to studies on design learning, metacognition is extensively studied in science education and its positive impacts are well documented (Zohar & Barzilai, 2013; Zohar & Dori, 2011). Regardless of the advances in the field, Zohar and Barzilai (2013) highlight some significant shortcomings, primarily methodological, of these studies. Taking these shortcomings seriously, we designed a quasi-experimental study integrated into a design studio course, which is the first such study we are aware of in design learning research. Following the findings of these studies, our primary aim in this research is to explore whether metacognitive skills have a similar positive impact on design learning, which differs significantly from science learning concerning its emphasis on material culture and practical knowledge (Archer, 1979).

The study's main theoretical contributions are threefold. First, building on seminal works of scholars such as Schön (1983), it contributes to design learning literature by way of investigating the significance of metacognition in design learning to highlight how some of the challenges imposed on students by purely discovery-based learning could be dealt with. Second, in contrast to few studies on metacognition and design learning, it does this through a quasi-experimental study following other similar research in educational studies as reviewed by Zohar and colleagues (Zohar & Barzilai, 2013; Zohar & Dori, 2011). Finally, it contributes to the general body of work from educational studies, which have not so far taken design learning as its primary focus of research, highlighting the difficulties involved in learning how to be creative and how this could be supported by metacognition.

2. Metacognition and design learning

Design learning remains an implicit learning process, which heavily relies on learning-by-doing (Schön, 1983) or experiential learning (Kolb, 2015). As learning through experience remains implicit students are left alone in realizing what they have learned or even whether they have learned anything in the first place. Both Schön and Kolb realizing that learning cannot be limited to just experience or doing highlight the importance of reflective practices in learning in general and design learning as well, yet their examples and discussions remain descriptive and often not replicable in the design studio environment.

There are many reasons why learning-by-doing solely is insufficient for effective learning in design. First, design is widely accepted as an iterative process (Ball & Christensen, 2019; Carlson et al., 2020). Lawson (2006) characterizes design as consisting of continuous feedback loops, which requires an utmost awareness of the implications of and reflections on design moves for further actions and decisions. According to Ledewitz (1985) and Hillier et al. (1972), design is often based on conjectures because it involves creating something new, which inherently involves uncertainty and risk. When designers create something new, they are working with incomplete information and making educated guesses about what might work best based on their knowledge and experience. Creativity, like design, is often conjecture-based because it involves exploring new possibilities and making connections between unrelated ideas or concepts (Guilford, 1967).

Regardless of the complex nature of the design process, however, the design learning environment often falls back on an implicitly followed analysis-synthesis model of problem-solving for lack of a better alternative (Ledewitz, 1985; Taneri & Dogan, 2021), according to which one first analyses the problem sufficiently enough before jumping to synthesis. In the linear progression from analysis to synthesis, Ledewitz (1985) claims that students are left with no option but to make a "leap in the dark" (p.4) without much scaffolding; and that instructors implicitly follow this model because of the ease with which it can be applied in the studio regardless of its shortcomings. These are expected to be resolved through one-on-one interactions between instructors and students during desk crits as exemplified in Schön's seminal work (Schön, 1983). When, however, these interactions are not structured enough or when convergence of meaning between the student and the instructor does not happen, students may still be at a disadvantage to emulate what it is that they need to learn.

While design needs an iteration between problems and solutions (Dorst & Cross, 2001), creativity needs an iteration between divergent thinking and convergent thinking (Guilford, 1967). The details of the iteration process cannot be explicitly explained or conveyed by the designer verbally or externally (see Quayle & Paterson, 1989; Taneri & Dogan, 2021). Schön (1987) suggests that it is impossible to teach a student what design is, however, it is possible to coach them in the situated action of designing. Coaching, though, as exemplified in the learning interaction episodes of Schön's cases may not always lead to a convergence of meaning.

The management of design moves depends on reflective practices (Schon & Wiggins, 1992). Schön (1983) frequently emphasizes the need for reflection on reflection-in-action and reflection on reflection-on-action to alleviate some of the problems in design learning. He refers to the importance of an iterative reflection, yet his cases do not exemplify in detail how reflection on reflection-on-action occurs or might occur in design learning. We suggest that metacognition might provide new insights into issues where Schön's work remains elusive or incomplete. As studies in science education suggest metacognitive skills foster learning in science education by way of encouraging reflection, therefore, self-regulated learning (Zohar & Barzilai, 2013), indicating that the same set of skills could be helpful for design students as well. Furthermore, again following on Schön's argument that design cannot be taught but can only be learned, it is plausible to argue that design students who take charge of their own learning processes to be learners that are more efficient as it is repeatedly shown in studies on self-regulated learning (Zohar & Barzilai, 2013). Consequently, we advance here that metacognitive skills will help students implement more effective strategies in their learning experiences.

Metacognition was first introduced by Flavell (1979) in the 1970s. Later, researchers such as Blakey and Spence (1990), Welton and Mallan (1999), and Martinez (2006), also contributed to the study of metacognition. Although it has many definitions in the literature, the simplest definition of metacognition is 'thinking about thinking' (Blakey & Spence, 1990) or 'cognition on cognition'. In recent years, studies on metacognition have been conducted in many fields of cognition and learning such as memory (Dunlosky & Metcalfe, 2008), social psychology (Schwarz, 2015), entrepreneurship (Haynie et al., 2010), education (Flavell, 1979; Puryear, 2016), reasoning (Ackerman, 2019; Grohs et al., 2018), and creativity (Grohman et al., 2006; Karwowski et al., 2020; Kaufman & Beghetto, 2013).

Metacognition involves understanding our cognitive strengths and weaknesses, as well as our knowledge and beliefs about how we learn and think. Metacognition is considered to be important in the creativity literature as well. Creative metacognition is described as knowing when, how, and why to be creative and is proposed to have a key importance to being successful in the creative process (Kaufman et al., 2016; Kaufman & Beghetto, 2013). Metacognitive awareness, on the other hand, refers to our conscious awareness of our metacognitive processes (Paris et al., 1983; Schraw & Dennison, 1994). This means that through metacognition, we are aware of our own thinking and learning strategies, as well as our ability to plan, monitor, and evaluate them.

Developing metacognitive awareness is important because it helps individuals become more effective learners and problem-solvers (Blakey & Spence, 1990). Metacognitive awareness helps individuals better identify their strengths and weaknesses and adjust their strategies to improve their performance by understanding their own thinking and learning processes (Gage, 1988). In addition, metacognitive awareness can also help individuals become more self-regulated learners (Veenman, 2016), taking control of their own learning, and becoming more independent and successful learners, which are almost all believed to be essential in the learning-by-doing process of design learning (Lawson, 2006; Schön, 1983).

Given that metacognition constitutes the backbone of learning in general, it could be wise to help students improve their metacognitive skills and knowledge to better manage student-led design learning. Indeed, few studies on the role of metacognitive interventions in design learning all underline the positive impact of these on students' creative performance (Carlson et al., 2020; Clemente et al., 2017; Hargrove, 2013), grades (Kurt & Kurt, 2017), metacognitive skills such as planning (An & Cao, 2014) and monitoring (Kavousi et al., 2020), or metacognitive awareness (Kurt & Kurt, 2017), or creativity (Kaufman & Beghetto, 2013; Sternberg & Williams, 1996).

We propose that knowing where, when why, and how to iterate in design as suggested by the creative metacognition framework offered by Kaufmann and colleagues (Kaufman et al., 2016; Kaufman & Beghetto, 2009, 2013) is important and might improve design learning. Design instructors need to help students develop their metacognitive awareness to especially overcome the difficulties involved in the iterative processes in design and creativity (Carlson et al., 2020), and to help students with when, where, how, and why certain cognitive abilities and strategies could be used (Ku & Morgan, 2006; Sternberg & Williams, 1996). This could help students cope with the difficulties of learning to design and to be creative, which are both ambiguous and non-linear and whose knowledge cannot be conveyed directly and explicitly. Furthermore, many more studies from a science education (Zohar & Barzilai, 2013; Zohar & Dori, 2011) suggest that interventions help boost students' levels of metacognitive awareness and we predict a similar improvement in design students.

Notwithstanding the overall positive impact of metacognitive interventions, it is also known that there are differences in metacognitive awareness levels of individuals just like differences in their cognitive abilities (Hargrove, 2013). As indicated by Schraw and Dennison (1994), individual differences in metacognitive awareness levels lead to different learning experiences and these differences explain why individuals respond differently to metacognitive interventions. According to Runco (1994), the differences experienced by individuals in the learning process may be due to differences in their metacognitive awareness levels, which could be improved through scaffolding, even in the case of design just like any other cognitive ability (see An & Cao, 2014). Kavousi et al. (2020) point out that not all students benefit from metacognition equally and that these benefits are especially evident in high-performing students. This indicates that they are more competent in monitoring and reflecting on the learning task. The effect of metacognitive interventions, therefore, may vary depending on students' initial metacognitive awareness levels and on individual differences. Therefore, it is important to personalize metacognitive interventions and tailor them according to the individual student's levels of metacognitive awareness and we expect that interventions will have a different impact on students with different levels of metacognitive awareness.

Studies on education and metacognition have shown that a high metacognitive awareness level is positively correlated with academic and professional performance in design (Hargrove, 2013; Kavousi et al., 2020; Lawanto et al., 2013) and science learning

(Wilson & Clarke, 2004). Hargrove's study (2013) shows that metacognitive interventions especially repeated metacognitive interventions help boost students' creative performance. Similarly, Clemente et al. (2017) found that metacognitive interventions significantly improved students' creative performance. An and Cao (2014) found that metacognitive scaffolding helps students in their planning skills yet has no impact on their grades. However, Kurt and Kurt (2017) indicate that students' grades improved with metacognitive interventions and increased awareness of their learning process. Based on these studies' findings we predict that an increase in metacognitive awareness will lead to an improvement in academic performance in design studios as measured by design course grades.

Lastly, our final area focus relates to another difficulty in design learning, which primarily concerns studio instructors, as opposed to difficulties concerning students. Design instructors are deprived of relying on many measures such as standardized test and exam scores, and high school GPA in predicting the academic performance of new coming students, which are known to be reliable indicators of course performance in many fields of learning (Meier et al., 2015). There are not many studies in design learning focusing on predictors of design studio performance. In many domains of learning, however, there are studies (e.g., Zohar & Barzilai, 2013; Zohar & Dori, 2011), which shows a correlation between metacognitive awareness levels and students' academic performance. In this study, we propose that understanding students' metacognitive awareness levels at the start of a course might have positive implications for both studio instructors and students. Given the lack of indicators of success in design learning and the positive correlation between metacognition and course grades, we suggest that pre-test levels of metacognitive awareness can predict design course grades and, consequently, provide significant leverage for studio instructors in designing their instructions in design courses.

In sum, our main research question investigates whether the level of metacognitive awareness has an impact on design learning and design course grades, whether metacognitive interventions in the design studio can help students' level of metacognitive awareness, and finally, whether these interventions will be equally helpful to all students regardless of differences in their level of metacognitive awareness. The question is operationalised through a series of sub-questions:

- First, do metacognitive interventions systematically applied to students with different metacognitive awareness levels in an architectural design studio increase students' metacognitive awareness?
- Second, do metacognitive interventions systematically applied to students with different metacognitive awareness levels in an architectural design studio increase students' design course grades?
- Finally, how much and whether students' levels of metacognitive awareness level predict the design course grade?

These questions are formulated to test the following hypotheses:

- Based on the preliminary findings from design studies and on more robust science education studies' findings (e.g., White & Frederiksen, 1998; Zohar & David, 2008), we predict that metacognitive interventions in the studio will lead to an increase in metacognitive awareness levels as in other fields of learning and our first hypothesis in this study tests this prediction.
- Our second hypothesis tests whether metacognitive interventions will have a different impact on students with low and high metacognitive awareness levels.
- Our third hypothesis, which naturally follows the first and findings of studies which link academic performance to metacognition, tests whether an increase in metacognitive awareness levels will translate into an improvement in design course grades.
- Our final hypothesis tests whether, and if so how much, pre-test levels of metacognitive awareness can predict design course grades.

2.1. Types of metacognitive interventions

Research on the role of interventions and how they are used in science education is generally non-experimental or quasi-experimental (Zohar & Barzilai, 2013). In design education literature, there are even fewer controlled studies on the use of metacognitive interventions in design learning (An & Cao, 2014; Clemente et al., 2017; Hargrove, 2013).

Metacognitive intervention refers to various strategies and techniques that aim to increase metacognition and metacognitive awareness. Interventions can be domain-specific (Brown, 1987; Flavell, 1979; Jacobs & Paris, 1987; Nelson, 1990; Schraw, 1998; Schraw & Moshman, 1995; Tobias & Everson, 2002) or domain-general (Blakey & Spence, 1990; Costa & McCrae, 1984; Mayer, 1998;

Table 1
Metacognitive intervention techniques.

Metacognitive Intervention Techniques	Studies
Keeping Diary	(Costa & McCrae, 1984), (Blakey & Spence, 1990), (Hargrove, 2013), (Clemente et al., 2017) (Kurt & Kurt, 2017)
Experience or Learning Portfolios	(Quirk, 2006)
Planning, Monitoring, and Control Sheets	(Costa & McCrae, 1984), (An & Cao, 2014), (Clemente et al., 2017)
Questions that trigger metacognition	(Costa & McCrae, 1984), (Blakey & Spence, 1990)
Think aloud	(Costa & McCrae, 1984), (Kavousi et al., 2020)
Self-evaluation	(An & Cao, 2014), (Kaufman et al., 2016)
Role-Playing	(Costa & McCrae, 1984), (Clemente et al., 2017)
Perspective Taking	(Quirk, 2006), (Clemente et al., 2017)

Sternberg & Williams, 1996). In the literature, tools such as keeping a diary, portfolios, and filling up planning sheets or answering questions are commonly used as metacognitive intervention techniques. The intervention techniques used to develop metacognition in science education and their wide range are listed in Table 1 (Zohar & Barzilai, 2013).

Metacognitive intervention studies in design learning often vary in terms of the format, length, quantity, and setting of interventions (e.g., An & Cao, 2014; Carlson et al., 2020; Clemente et al., 2017; Hargrove, 2013; Kavousi et al., 2020; Kurt & Kurt, 2017). Summaries of these studies are presented in Table 2.

Zohar and Barzilai (2013) drew attention to methodological shortcomings in science education studies and stated that most of these studies do not use controlled designs. They describe the methodological shortcomings of research in the field under two topics. First, most studies do not use control groups and neglect pre and post-test measures. Second, most studies include more than one instructional intervention, making it difficult to isolate the effects of metacognitive interventions. Finally, studies often rely on students' self-reports of metacognitive skills, but this method is a poor indicator of metacognitive strategies.

Taking these shortcomings seriously, we designed a quasi-experimental study integrated into a design studio course. This is the first such study we are aware of in design learning research. As noted above, there are very few quasi-experimental studies focusing on metacognition in design learning. In Hargrove (2013) study, the comparison between experimental and control groups was conducted based on creativity measures rather than measures of metacognitive awareness. An and Cao's (2014) quasi-experimental study was conducted as a stand-alone course on educational technology offered to students in the faculty of education where design was not a major component of their curriculum. Clemente et al.'s (2017) study was conducted in a product design course comparing control and experimental groups. However, similar to Hargrove's study, this study did not measure students' metacognitive awareness levels but instead relied on tests of creativity and critical thinking.

In our study, we compared the performance of the control group with the experimental group in a design learning studio context using pre and post-test measures of metacognitive levels. In line with Zohar and Barzilai's second point, we kept the interventions simple and used only metacognitive interventions, ensuring that there were no other interfering factors. The interventions of our study were defined as 'minimal metacognitive interventions' compared to other studies, as shown in Table 2. These interventions consisted of two different interventions structured by the authors. Furthermore, to avoid the third shortcoming noted by Zohar and Barzilai, we used the Metacognitive Awareness Inventory instead of students' self-assessments of cognitive behaviour.

The rationale for keeping the interventions minimal is the lack of sufficient research data on the positive effects of metacognitive enhancements on design learning. There are few studies in the design learning literature, some of which are observational studies. The educational science literature also does not provide sufficient support with regard to the role of metacognitive interventions in design learning. However, design learning is one of the few learning domains in which student-led learning is prioritized, which makes it a more suitable candidate for investigating the relationship between metacognition and learning than perhaps many other fields such as science learning and mathematics learning. Notwithstanding its uniqueness in enforcing a student-led approach and in emphasizing creativity, many handbooks on learning sciences and educational studies cover little on design learning in contrast to many studies ranging from mathematics to science to the social sciences (see the Routledge Handbooks of Educational Psychology series). This study, therefore, contributes to the educational studies' literature by way of investigating the role of metacognition in a student-led learning environment through a quasi-experimental design.

3. Method

The study employed a quasi-experimental research design comparing a control group to an experimental group. Metacognitive Awareness Inventory (MAI) measurements were used as pre-test and post-test measurements of students' metacognitive awareness levels. The study was conducted during one academic semester (15 weeks long) as part of an architectural design studio course. The interventions, administered only in the experimental group, were designed by authors to be minimal by repeatedly and regularly encouraging students to reflect on their status, progress, and level throughout the term by responding to a series of questions without direct scaffolding on how to improve their metacognitive levels.

3.1. Participants

Eighty fourth-year undergraduate students enrolled in the architectural design studio course at an architecture department

Table 2
Metacognitive interventions combinations in design learning studies.

Study	Format		Length		Quantity		Setting	
	Structured	Unstructured	Long	Short	Single	Multiple	Design Studio	Parallel Course
Hargrove, 2013	x		x			x		x
An & Cao, 2014	x		x			x		x
Clemente et al., 2017	x		x			x	x	
Kurt & Kurt, 2017		x	x		x		x	
Kavousi et al., 2020	x			x		x	x	
Carlson et al., 2020	x		x		x			x
Current Study	**x**		**x**		**x**		**x**	

participated in the study. Fourth-year students were preferred because they are more competent and experienced in the design process and creativity compared to other students. The study was conducted as a between-group study, with two sections of the same course, one as the experimental group and the other as the control group. After being informed at the beginning of the semester that one of the sections of the course would be the experimental group and the other as the control group, the students voluntarily enrolled in the experimental or control groups. All students participating in the study were informed about the purpose of the study, the procedures, and what was expected of them. In addition, it was emphasized that their participation was completely voluntary. It was stated to the students that not participating in the study or withdrawing from the study at any time would not have any negative consequences and would not affect their academic standing. This ensured that the ethical processes of the study were meticulously observed and that the students were not under any obligation or pressure. In addition, precautions were taken to ensure that no bias or problems arose during the participation process, stating that voluntary participation would not affect the results in any way. Irrespective of all the measures taken, we did not measure and test whether being a volunteer in this study, which could be a confounding variable, might have an impact on the results by itself without the presence of any interventions since volunteering might suggest openness to change in the first place and indicate a volunteer bias in the results (see Shadish et al., 2002). We deliberately did not employ random sampling, which might have alleviated some of the problems, given the fact that the interventions employed in the studio were not part of the student's curriculum. As advised by Shadish et al., we used pretest measurements to establish the similarity and dissimilarity between the control and the experimental group. Otherwise, we presumed that since the students from both groups had followed the same curriculum and in prior terms attended the same or similar design courses they could be considered to belong to the same cohort (see Shadish et al., 2002).

Neither the authors nor the instructors of the courses selected the students and assigned them to groups. The groups had different instructors, yet the general outline and content of the courses were the same, had similar syllabi, and their format was similar. There were 48 students ($n = 24$ female, $n = 24$ male) in the experimental group and 32 ($n = 23$ female, $n = 9$ male) students in the control group. In the study, to measure the metacognitive awareness levels and the effectiveness of metacognitive interventions, the experimental and control groups were divided into two groups by the non-hierarchical cluster analysis method according to the Pre-MAI results. These groups were the high metacognitive awareness (HMA) group and the low metacognitive awareness (LMA) group. Based on the clustering analysis, there were 21 people ($n = 21$) in the HMA group in the experimental group, there were 27 people ($n = 27$) in the LMA group, and 19 people in the HMA group in the control group ($n = 19$) with 13 people in the LMA group ($n = 13$). Students in the experimental and control groups were not informed whether they were in the HMA or the LMA group.

3.2. Data collection tool: metacognitive awareness inventory (MAI)

Metacognitive Awareness Inventory (MAI) was developed by Schraw and Dennison (1994) to measure students' metacognitive awareness levels. The MAI is a 52-item Likert-type test. The content of the questions in the inventory is related to knowledge of cognition and regulation of cognition. In the knowledge of cognition category, there are three sub-categories consisting of questions related to declarative knowledge, procedural knowledge, and conditional knowledge, whereas regulation of cognition has five sub-categories consisting of planning, monitoring, evaluation, debugging, and information management. To calculate the metacognitive awareness level of individuals, the total score obtained from 52 questions is divided by 52. Ratios of five or close to five indicate a high level of metacognitive awareness. In this study, the Turkish version of the MAI was used. The validity and reliability of the Turkish version were assessed in the study of Akin et al. (2007). In the Turkish version, the internal consistency and reliability coefficient of the inventory was reported as 0,95 (Akin et al., 2007). For this study, the internal consistency and reliability coefficient of the inventory was recalculated and found to be 0,92. The duration of the application was approximately 15 to 20 min.

Table 3
Categories and sub-categories of questions of MAI and Items in CMAI.

Categories	Sub-categories of MAI	Items in CMAI
Knowledge of cognition	Declarative Knowledge (items no: 5,10,12,16,17,20,32,46)	1. I think my approach/concept to the project is creative. 2. My friends think that my approach/concept to the project is creative. 3. The instructors think that my approach/concept to the project is creative.
	Procedural Knowledge (items no: 3,14,27,33)	6. I can find creative idea/ideas for the project.
	Conditional Knowledge (items no: 15,18,26,29,35)	10. I know when and how to be creative during the design process.
Regulation of cognition	Planning (items no: 4,6,8,22,23,42,45)	5. I think I have worked hard enough to be creative on this project.
	Monitoring (items no: 1,2,11,2128,34,49)	7. I can successfully realize the creative ideas I have found in my project.
	Evaluation (items no: 7,19,24,36,38,50)	4. In class, some students have a more creative approach/concept than me.
	Debugging (items no: 25,40,44,51,52)	9. When I think about architectural projects, different ideas can arise in my mind.
	Information Management (items no: 9,13,30,31,37,39,41,43,47,48)	8. Anything/any concept that is not related to the architectural project can bring up different ideas in my mind.

3.3. Intervention tools

There is research in the literature indicating that questions and questionnaires have a positive impact on metacognitive awareness and, therefore, could be administered as metacognitive interventions in learning environments (Blakey & Spence, 1990; Costa & McCrae, 1984). Indeed, in science education prompts in the form of metacognitive cues, questions, and checklists are the most used intervention techniques (Zohar & Barzilai, 2013). In this study, similarly, the interventions consisted of questions to help boost students' metacognitive awareness levels.

In designing the interventions, we followed the previous research from design learning and the findings from science education. There were two sets of intervention tools, Creative Metacognitive Awareness Intervention (CMAI), and Design Metacognitive Awareness Intervention (DMAI), as mentioned above that were used as prompts to encourage students to reflect on their process and current state of design learning.

3.3.1. Creative metacognitive awareness intervention (CMAI)

Creative Metacognitive Awareness Intervention (CMAI) was prepared by the authors of this study based on the MAI categories and the creativity literature. CMAI prompts students to reflect on the creativity level of their design product. While preparing the CMAI items, the sub-categories of the MAI were used (Table 3) together with the 'four C models of creativity' (Kaufman & Beghetto, 2009), and 'creative metacognition' (Kaufman & Beghetto, 2013). CMAI is a 10-item Likert-type question set (Appendix A) and it prompts students to assess their design individually and in comparison, to their classmates. CMAI was administered three times during the semester and the internal consistency and reliability coefficients were calculated for each application with values of 0,74, 0,76, and 0, 79, respectively. The average coefficient was calculated as 0,76. It took three to five minutes on average to complete CMAI.

3.3.2. Design metacognitive awareness intervention (DMAI)

Design Metacognitive Awareness Intervention (DMAI) was prepared by the authors based on the MAI categories and the design literature. DMAI prompts students to think about their design process. While preparing the DMAI items, sub-categories of the MAI were followed (Table 4). The DMAI items were structured considering the conceptual framework of the items in the MAI. DMAI consists of 10 items and nine of them are Likert-type question sets (Appendix B) while one is an open-ended question aiming to prompt students to think whether there was an important development in their weekly project process. The question set contains items that can evaluate students' perception of the process both individually and in comparison, to his/her peers. In this study, the question set was applied seven times in total. Internal consistency and reliability coefficients were calculated for each application, and values of 0.81 0.88, 0.86, 0.85, 0.87, 0.91, and 0.89 were found, respectively. The average coefficient was calculated as 0,87. The duration of the application was approximately three to five minutes.

3.4. Procedure

At the beginning of the term, both the experimental group and the control group were informed about the research and the data collection process. Metacognitive interventions were administered according to the term calendar given in the course syllabus (Table 5). At the beginning and end of the semester, MAI was applied to both the experimental group and the control group as a pre-test and post-test (Table 6).

After the pre-test, the students in the experimental group used CMAI and DMAI as metacognitive interventions during the whole academic term (15 weeks). Students in the experimental group performed the interventions independently and individually. CMAI and

Table 4
Categories and sub-categories of questions of MAI and Items in DMAI.

Categories	Sub-categories of MAI	Items in DMAI
Knowledge of cognition	Declarative Knowledge (items' no: 5,10,12,16,17,20,32,46)	1. How would you rate the level of your project this week? 2. How would you rate your awareness of what the instructors' expectations were this week?
	Procedural Knowledge (items no: 3,14,27,33)	4. How was your project progressed when you used the strategy(s) to develop your project this week?
	Conditional Knowledge (items no: 15,18,26,29,35)	3. How did you know which strategies would be most helpful to develop your project this week?
Regulation of cognition	Planning (items no: 4,6,8,22,23,42,45)	5. How did you organize your time and information to achieve the goals you set during this week?
	Monitoring (items no: 1,2,11,2128,34,49)	6. How did you do in tracking whether the project achieved its goals this week?
	Evaluation (items no: 7,19,24,36,38,50)	7. At what level do you see your own project in comparison to others' projects in class this week?
	Debugging (items no: 25,40,44,51,52)	8. What was your tendency to seek help from others (friends/instructors) to reach a solution when you thought the project remained unresolved this week?
	Information Management (items no: 9,13,30,31,37,39,41,43,47,48)	9. Were you likely to revisit and make sense of the information/crits you gained after the project crits this week?
Open-ended Question		10. Has there been any development since last week that will enable you to make a positive leap in your project? If there were, could you briefly talk about what, how, and why it happened?

Table 5
Weekly practices and interventions in the experimental group and the control group.

	Experimental Group Syllabus	Control Group Syllabus
Week 1	Introduction + **Pre-test: MAI**	Introduction + **Pre-test: MAI**
Week 2	Site Analysis	Case Study
Week 3	Case Study	Case Study
Week 4	Conceptual Approaches	Conceptual Approaches
Week 5	**Midterm 1** + **CMAI-1**	**Midterm 1**
Week 6	Technical Trip	Desk/Online Crits
Week 7	Desk/Online Crits + **DMAI-1**	Desk/Online Crits
Week 8	Desk/Online Crits + **DMAI-2**	Desk/Online Crits
Week 9	Desk/Online Crits + **DMAI-3**	Desk/Online Crits
Week 10	**Midterm 2** + **CMAI-2**	**Midterm 2**
Week 11	Desk/Online Crits + **DMAI-4**	Desk/Online Crits
Week 12	Desk/Online Crits + **DMAI-5**	Desk/Online Crits
Week 13	Desk/Online Crits + **DMAI-6**	Desk/Online Crits
Week 14	Desk/Online Crits + **DMAI-7**	Desk/Online Crits
Week 15	**Midterm 3** + **CMAI-3**	**Midterm 3**
Week 16	**Final Review Submission**	**Final Review Submission**
	Post-test: MAI	**Post-test: MAI**

DMAI question sets were delivered to students online via Google Forms. Throughout the semester, the instructors reminded the students in the experimental group to participate in the interventions, once every week for DMAI and once after every midterm for CMAI. CMAI was applied after the three midterm reviews when students were asked to evaluate their creative status (product perception) in terms of the progress of their design project. DMAI was applied every week (seven times in total) during the period of desk critics when students were regularly interacting with their instructors one-on-one based on the work they presented. DMAI was used to measure students' self-perceptions of their project progress (process perception) throughout the term when they were actively involved in the designing phase. Thus, students were allowed to reflect on the progress of their projects weekly, through DMAI, and on the status of the creativity level of their work after each midterm submission, through CMAI. In total, DMAI was administered seven times every week during the design phase except the initial four weeks of the terms when students were involved primarily with analysis and the three weeks when they had the midterms. At the end of the study, the students in the control group were also informed about CMAI and DMAI.

3.5. Data analysis

The data was analysed through statistical analysis to determine whether there was a statistically significant difference between the pre-tests and the post-tests with *t*-tests between the experimental group and control group and between students with high MAI levels and students with low MAI levels. Cohen's d effect size calculations were performed for values with statistically significant differences. In addition, the explanation and relationship of design course grades with metacognitive awareness level were examined with simple linear regression analyses.

4. Results

We used the Kolmogorov-Smirnov and Shapiro-Wilk tests to assess the normality, skewness, and kurtosis values of the data. The skewness and kurtosis values of the data belonging to the experimental and control groups are between −1.50 and +1.50, which shows that the data have a normal distribution.

Descriptive statistical tables were created for both the experimental and control group data (Table 7). Using pre-test MAI measures, an independent sample *t*-test analysis was performed to determine whether the experimental group and the control group differ from each other according to the levels of metacognitive awareness. According to the *t*-test result, the p-value is $p = 0.76$ ($p > 0.05$) (Table 8). In other words, the Pre-MAI scores of the experimental and control groups are not significantly different from each other and we concluded that the participants in both groups have similar metacognitive awareness levels.

Table 6
The implementations in the experimental group and the control group.

Experimental Group	Control Group
- Pre-test: MAI	- Pre-test: MAI
- Design Studio Coursework	- Design Studio Coursework
- Metacognitive Interventions:	
. CMAI (3 times after the midterm reviews)	
. DMAI (7 times during designing weeks)	
- Post-test: MAI	- Post-test: MAI
	- Lecture on CMAI and DMAI

Table 7
Descriptive statistic table for experimental group and control group.

Group		Data	N	Max.	Min.	Mean	SD
Experimental Group		Pre-MAI	48	239	134	184.85	22.28
		Post-MAI	48	260	142	192.71	20.38
		Design Grade	48	92.75	55,00	76.82	8.38
Experimental Group	**HMA**	Pre-MAI	21	239	192	205.63	12.39
		Post-MAI	21	260	156	202.94	25.08
		Design Grade	21	92.75	70.50	81.05	5.95
	LMA	Pre-MAI	27	187	134	170.22	14.66
		Post-MAI	27	222	165	185.51	12.37
		Design Grade	27	87.25	55	73.84	8.65
Control Group		Pre-MAI	32	231	113	183.13	26.42
		Post-MAI	32	230	103	183.33	28.33
		Design Grade	32	99.80	64,21	79.77	8.72
Control Group	**HMA**	Pre-MAI	19	231	179	198.63	15.68
		Post-MAI	19	230	178	198.42	15.65
		Design Grade	19	99.80	64.21	82.66	8.59
	LMA	Pre-MAI	13	175	113	156.36	18.35
		Post-MAI	13	195	103	157.27	26.60
		Design Grade	13	85	65	74.76	6.65

To examine the effectiveness of the metacognitive awareness level on metacognitive interventions, both the experimental and the control group were divided into two groups by non-hierarchical cluster analysis, based on the Pre-MAI results. Non-hierarchical cluster analysis is an analysis method that is performed by grouping similar data points in a data set. In this method, data points are grouped according to similarity criteria rather than according to a predetermined hierarchy (Davidson, 2002). As a result of the analysis, both the experimental group and the control group were divided into groups of high metacognitive awareness (HMA) and low metacognitive awareness (LMA).

Within-group and between-group comparisons were conducted to determine whether the low-awareness and high-awareness groups differ from each other significantly. When the experimental and control groups' values were examined within the group, it was found the HMA-LMA groups had a statistically significant difference in terms of metacognitive awareness level ($p < 0.05$) (Table 8). In contrast, when the experimental and control groups are examined between groups, the results indicate that both HMA and LMA groups from the experimental and control groups do not have a statistically significant difference in terms of metacognitive awareness level ($p > 0.05$) (Table 8).

4.1. *Metacognitive interventions and students' metacognitive awareness*

Independent-sample *t*-test analyses were conducted to investigate whether metacognitive interventions (CMAI and DMAI) applied systematically improve students' metacognitive awareness in the experimental group and whether the effectiveness of metacognitive interventions differs according to students' pre-test levels of metacognitive awareness. Post-MAI data obtained from the experimental group and control were used for independent-sample *t*-test analyses. The analyses were performed at a 95 % confidence interval and alpha was accepted as 0.05 (α=0.05).

According to the results, there was no statistically significant difference between the post-MAI scores of the experimental group and the post-MAI scores of the control group ($p = 0.09$, $p > 0.05$) (Table 9). In other words, the analysis did not show a significant effect of metacognitive interventions on the metacognitive awareness levels of the students in the experimental group, indicating that our first hypothesis was not confirmed.

Furthermore, no statistically significant difference was found between the post-MAI scores of the HMA groups in the experimental and control groups ($p = 0.50$, $p > 0.05$) (Table 9). However, a statistically significant difference was found between the post-MAI scores of the LMA groups in the experimental and control groups ($p = 0.006$, $p < 0.05$) (Table 9). When the effect size of this difference was

Table 8
According to Pre-MAI scores, *t*-test analysis results before the quasi-experimental study.

	t-test analysis with Pre-MAI scores		Mean Difference	t	Sig. (2-tailed)
Between Groups (Experimental and Control)	Experimental Group ($N = 48$)	Control Group ($N = 32$)	1.71	.305	.76
	HMA ($N = 21$) in experimental group	HMA ($N = 19$) in control group	7.00	1.526	.13
	LMA ($N = 27$) in experimental group	LMA ($N = 13$) in control group	13.85	2.456	.07
Within Groups (HMA and LMA)	HMA ($N = 21$) in experimental group	LMA ($N = 27$) in experimental group	35.40	8.581	**.00**
	HMA ($N = 19$) in control group	LMA ($N = 13$) in control group	42.26	6.686	**.00**

Table 9
t-test analysis results with post-MAI scores after the quasi-experimental study for metacognitive awareness.

t-test analysis with post-MAI scores		Mean Difference	t	Sig. (2-tailed)	Cohen's d Effect Size
Experimental Group ($N = 48$)	Control Group ($N = 32$)	9.38406	1.679	.09	–
Experimental Group	**Control Group**	**Mean Difference**	**t**	**Sig. (2-tailed)**	**Cohen's d Effect Size**
HMA ($N = 21$)	HMA ($N = 19$)	4.52632	.667	.50	–
LMA ($N = 27$)	LMA ($N = 13$)	28.24579	3.376	**.006**	**1.095 (Large effect)**

calculated, it was determined that there was a large effect ($d = 1.095$) (Table 9). In the experimental group, while the metacognitive interventions did not provide a difference in the metacognitive awareness of the HMA group at the end of the term, they provided a significant difference in the metacognitive awareness of the LMA group. As a result of the interventions, the mean of metacognitive awareness of the LMA group increased by 14,55 points in the experimental group (pre-MAI=170.22, post-MAI=184.77) (Table 7) and we conclude that Hypothesis 2 was confirmed.

According to these results, the interventions applied systematically in the architectural design studio improved only the metacognitive awareness of students with low metacognitive awareness from the experimental group. Consequently, we conclude that our first hypothesis was not confirmed, i.e., interventions did not result in a significant difference among experimental and control groups; however, our second hypothesis was confirmed. Students with lower metacognitive awareness levels benefited significantly from the interventions when compared to students with high levels of metacognitive awareness. We conclude that the administered minimal interventions were effective for only those students who had lower levels of metacognition suggesting that the content and format of interventions are significant factors in devising learning tools.

4.2. Metacognitive interventions and students' design course grades

Independent-sample *t*-test analyses were conducted to investigate whether metacognitive interventions (CMAI and DMAI) applied systematically in the architectural design studio improve students' design course grades in the experimental group and whether the effectiveness of metacognitive interventions differs according to the level of metacognitive awareness. Design course grades of students from the experimental group and control were used for independent-sample *t*-test analyses. The analyses were performed at a 95 % confidence interval and alpha was accepted as 0.05 (α=0.05).

According to the results, there was no statistically significant difference between the design course grades of the experimental and the control group ($p = 0.14$, $p > 0.05$) (Table 10). Furthermore, no statistically significant difference was found between design course grades of the HMA and LMA groups in the experimental and control groups either (for HMA $p = 0.50$, $p > 0.05$, for LMA $p = 0.75$, $p > 0.05$) (Table 10).

According to these results, our third hypothesis was not confirmed, and the minimal metacognitive interventions applied systematically in architectural design studios did not significantly impact the design course grades in the experimental group for both HMA and LMA in contrast to studies that show improvement (e.g., Clemente et al., 2017; Hargrove, 2013; Kurt & Kurt, 2017).

4.3. Power of metacognitive awareness levels in predicting the design course grade

Simple linear regression analysis was conducted to investigate whether the scores of Pre-MAI predict the design course grade. Pre-MAI and design course grade data of both the experimental group and the control group were used for analysis. The analyses were performed at a 95 % confidence interval and alpha was accepted as 0.05 (α=0.05).

According to the results, the correlation coefficient between Pre-MAI scores and design course grades was calculated as 0.45 ($R = 0.454$, $p < 0.05$) (Table 11). This result shows us that pre-MAI scores have a moderately positive significant relationship with design course grades and that the R square value was found to be 0.206 (R square=0.206, $p < 0.05$). According to this value, approximately 20 % of the variance in design course grades can be explained by pre-MAI scores. In addition, pre-MAI values according to the values in Table 12 have a significant effect on the design course grades because of the significance value ($p < 0.05$), and one standard deviation increase in the pre-MAI score causes a 0.45 standard deviation increase in the design course grade (Beta=0.454) (Table 12). According to these findings, students' metacognitive awareness levels starting the term are moderately and positively related to their design

Table 10
t-test analysis results after the quasi-experimental study for design course grades.

t-test analysis with design course grades		Mean Difference	t	Sig. (2-tailed)
Experimental Group ($N = 48$)	Control Group ($N = 32$)	−2,94	−1475	.14
Experimental Group	**Control Group**	**Mean Difference**	**t**	**Sig. (2-tailed)**
HMA ($N = 21$)	HMA ($N = 19$)	−1,61	−6,73	.50
LMA ($N = 27$)	LMA ($N = 11$)	−0.92	−0.318	.75

Table 11
Model summary for design course grades.

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.454[a]	.206	.195	.21099	1.579

[a] Predictors: (Constant), Pre-MAI.
[b] Dependent Variable: DCG (Design Course Grades).

Table 12
Coefficients for design course grades.

Coefficient[a]	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0 % Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	−0.251	.190		−1.322	.190	−0.629	.127
Pre-MAI	.004	.001	.454	4.381	**.000**	.002	.007

[a] Dependent Variable: DCG (Design Course Grades).

course scores. We conclude that our fourth hypothesis was confirmed suggesting that MAI scores could be helpful measures in predicting students' end of the semester academic performance and consequently have the potential to help instructors to tailor their teaching strategies.

5. Discussion

In this study, we investigated the effect of minimal metacognitive interventions applied within the scope of an architectural design studio course on the metacognitive awareness levels of architecture students and their design course grades. The study's results partially support the previous studies, which emphasise that effective design process management is related to metacognitive awareness. We will discuss the findings concerning the three research questions posed at the beginning of the study.

5.1. About the effects of interventions on students' metacognitive awareness

One of the main findings obtained from the study is that the minimal metacognitive interventions created a statistically significant difference in the metacognitive awareness levels of the LMA in the control group and the LMA in the experimental group. In contrast, no such impact was found for participants with the HMA. In addition, the effect size of metacognitive interventions on the metacognitive awareness of the LMA group in the experimental group was determined as a 'large effect'. These findings offer us an alternative perspective to studies (e.g., Blakey & Spence, 1990; Costa & McCrae, 1984) that show that questions or questionnaires increase metacognitive awareness and to the findings of studies arguing that metacognitive interventions increase individuals' metacognitive awareness (e.g., An & Cao, 2014; Hargrove, 2013; Maftoon & Fakhri Alamdari, 2020; Runco, 1994). The effectiveness of this type of intervention seems to be more related to students' metacognitive awareness levels. This argument coincides with Schraw and Dennison's (1994) argument that the effectiveness of metacognitive interventions depends on the level of metacognitive awareness and that interventions are more effective in the group with low metacognitive awareness (Hartman & Sternberg, 1992; Loyens et al., 2008).

There is, indeed, research indicating the effectiveness of metacognitive interventions may vary according to metacognitive awareness levels (e.g., Schraw & Dennison, 1994; Urban et al., 2021) as found in this study. Pennequin et al. (2010) reported in their study that metacognitive intervention was more effective in individuals with low metacognitive awareness, and they achieved better results in mathematical problem-solving. Similarly, White and Frederiksen (1998) and Zohar and David (2008) reported that metacognitive interventions have especially significant gains for low-achieving middle school students. White and Frederiksen (1998) found that low-achieving middle school students in terms of their Comprehensive Test of Basic Skills scores in a science education setting benefited more from metacognitive interventions helping students with monitoring and reflection on their learning processes. The authors concluded that such interventions are especially beneficial for disadvantaged students in catching up with higher-achievement students. Zohar and David (2008) suggest that explicit instructions of meta-strategic knowledge are especially important for low-achieving students.

In our study, we did not use explicit instructions, instead, used prompt-based interventions in parallel to an ongoing design task. This suggests that even implicitly administered minimal metacognitive scaffolding has a significant impact at least on the metacognitive awareness levels of LMA students and that together with explicit instructions the impact would be even more significant and probably would have an impact on HMA students as well. Individuals' learning styles and individual differences seem to have a significant impact on the effectiveness of explicit instructions and implicit interventions. Implicit interventions mostly involve encouraging individuals to think and explore on their own. Such interventions may be particularly effective for individuals with low metacognitive awareness but may have limited effects on individuals with high awareness (Hattie, 2008). On the other hand, explicit instruction interventions provide individuals with clear and structured guidance on how to use specific strategies. In particular, individuals with high metacognitive awareness may benefit more from indirect interventions because they may be more competent in discovering the implied strategies (Rosenshine, 2012), yet our study shows that when these interventions are minimal and implicit they have a significant impact on only students with lower levels of awareness. We think that students with higher levels must have already mastered the skills prompted by our interventions. In sum, the reason individuals with higher metacognitive awareness are not as likely to benefit from minimal interventions could be that these did not provide additional support for them since they might have already acquired related skills. In contrast, individuals with lower metacognitive awareness need more scaffolding and progress more easily with interventions as shown by previous research (De Jager et al., 2005).

Findings from other design learning studies do neither corroborate nor refute our findings since metacognitive awareness levels are not compared with pre and post-test measurements except for An and Cao (2014) study, which indicates that students made significant improvements in metacognitive planning skills, and Kurt and Kurt (2017), who reported enhancement of metacognition among students. There is, though, some supporting data from educational research (see Sandi-Urena et al., 2011), which shows that appropriate interventions help students improve their metacognitive skills, which in turn potentially will lead to better learning performances. Sandi-Urena et al. (2011) state that most research investigates the impact of interventions regarding improvements in the learning domain without questioning whether there is a difference in metacognitive awareness levels. Their study shows that students' metacognitive awareness levels as well as their performance in class improved after the interventions, including prompting and collaboration, highlighting the significant relation between the two. In their study, however, the metacognitive awareness scores of students decreased counterintuitively in the post-test measurements, which the authors see as a sign that students were stricter in assessing their metacognitive levels. In comparison, we found that those students with lower MAI levels had increased their awareness at the end of the study.

5.2. About the effects of interventions on students' design course grade

In Zohar and David (2008), the authors conclude that improvements in meta-strategic knowledge, i.e., understanding strategies that are suitable for a particular task, enhance students' task performance in science education. Based on their discussion, we hypothesized that a similar impact is foreseeable in design learning as well, which heavily relies on acquiring and improving conditional and procedural knowledge as in science learning. However, in our study, the improvement in metacognitive awareness levels did not translate into higher design grades. Our findings did not indicate any statistically significant differences between the design course grades of the experimental group and the control group. Based on the study results, we conclude that these interventions are not sufficient to increase course grades. This indicates that interventions need to be more structured and explicit in what is expected and what is to be learnt in addition to being solely composed of systematically applied prompts as intervention tools. In particular, more importance should be given to the planning and implementation of improvements in metacognitive awareness within the course. The current interventions were intentionally planned to be minimal to not interfere with the course flow and to initially explain the idea that metacognitive interventions might have a positive impact on design learning. One could conclude that if interventions were more structured and elaborate, they could have had a positive impact on students with higher metacognitive awareness as well.

In the design learning literature, studies investigating the effects of metacognitive interventions show that there is either an improvement in creativity performance or design grades contrary to our findings. Hargrove (2013), for one, measured students' creativity performance through their four years of education and found that the more students were exposed to creativity and metacognition-enhancing instructions the higher the improvement in their creativity was. More surprisingly, the study results show that there was no such improvement and at times decrease in students who were not exposed to such interventions suggesting that design learning with no accompanied reflective practice or cognitive activity puts students at a significant disadvantage as suggested by Mayer (2004) in discussing the shortcomings of pure discovery learning. Similarly, Clemente et al. (2017) also found significant improvements in the creativity of students after the intervention, which together corroborate the idea that metacognitive skills might improve not just students' cognitive processes of learning but also their creativity. The only study which looked at grades as in our study shows improvement in design grades (Kurt & Kurt, 2017), yet their results are mostly observational and not corroborated through control experiments.

There may be several explanations for this result. Designing and being creative involves a process that is not only related to metacognitive and cognitive abilities but also shaped by several factors such as technical knowledge, social, emotional, and cultural influences (Cross, 2001). We believe that although metacognitive abilities help in understanding, evaluating, and managing the knowledge of cognition and the regulation of cognition, they cannot contribute directly to declarative, procedural, and conditional knowledge necessary for efficient designing. However, it helps individuals to improve their awareness with regard to their deficiencies. Consequently, when metacognitive interventions are more varied and in-depth, as in the studies of Clemente et al. (2017) and Kavousi et al. (2020), the interventions have a positive effect on creativity, which in turn would lead to higher design grades since grades in design are primarily related to creativity. The results from a long-term observational study by Kavousi et al. (2020) indicate indeed that high-performing first-year design students are more concerned with metacognitive thinking, especially monitoring, and that low-performing students were more in control of the task in hand, suggesting a clear link between design grades and level of metacognitive levels.

An alternative or complementary explanation to why the improvement in metacognitive levels did not yield higher design grades might simply be related to the lack of appropriate explicit guidance in parallel to metacognitive interventions as suggested by Mayer (2004), who advocates that guided discovery is necessary for students to meaningfully learn and that otherwise in a pure discovery learning environment students may never be able to discern what is the relevant knowledge to focus on and learn. Instead, Mayer

(2004) advocates for a guided discovery strategy which emphasizes explicit instruction and guidance in promoting cognitive activities, such as "selecting, organizing, and integrating knowledge" along with behavioural ones, such as "hands-on activity, discussion, and free exploration" (p. 17). Our interventions did not go as far as Mayer's suggestions, but the results indicate that such interventions will further help students improve their design grades.

As covered by Zohar and David (2008), in the discussion related to whether the learning outcomes of direct instructions or discovery learning are better, having students think about their learning experiences results in long-lasting and transferable learning outcomes. The design learning environment that can go beyond just discovery learning by way of having students explicitly or in our case implicitly think about their learning experience will also lead to better learning experiences. In our study, the coupling of experience acquired through learning-by-doing in the design task and the possibility of thinking regularly on this experience lead to higher metacognitive awareness among LMA students. We claim that this is a clear indication that reflective practices in design as suggested by Schön are and should be an indispensable component of the learning environment. A student-led learning-by-doing approach, which is not supported by cognitive activities, is like what Mayer (2004) calls pure discovery, which is limited in the way it leaves students clueless about what needs to be learned. We, therefore, conclude that a significant improvement in metacognitive awareness levels of low-performance students is a key step in design learning.

5.3. About the predictive relationship between metacognitive awareness and design course grades

A significant result of the study from the simple linear regression analysis is that there is a positive, and moderately significant relationship between design course grades and pre-MAI scores. According to the findings, pre-MAI values can significantly predict end of the semester design course grades.

These findings are supported by studies in the literature suggesting that there is a positive relationship between academic achievement and metacognitive awareness (e.g., Hargrove, 2013; Kavousi et al., 2020; Lawanto et al., 2013; Pressley & McCormick, 1995; Wilson & Clarke, 2004). In this regard, the current study expands the literature (e.g., Hargrove, 2013; Lawanto et al., 2013; Pressley & McCormick, 1995; Wilson & Clarke, 2004) emphasizing linear associations between metacognitive awareness and design course grades.

The moderate correlation between the metacognitive awareness levels of architecture students and their design course grades supports the argument that the design course grades will increase as the students' metacognitive awareness increases as is in other learning domains such as university-level education (Li & Yuan, 2022), doctoral thesis writing (Yang & Bai, 2019), and reading comprehension (Dabarera et al., 2014). The finding coincides with Puryear's (2015) finding also regarding the positive, strong correlation between metacognition and creative products. Similarly, in the study conducted by Pretz and McCollum (2014) with fourth-year university students from different departments, the findings indicate a strong correlation between creative performance and self-assessment as metacognitive ability. Corroborating our findings, Kreitler and Casakin (2009) study found that architecture students' judgments about creative performance had a positive, moderate correlation with their creative performance. The results, therefore, draw attention to the importance and relationship of metacognition and metacognitive awareness in creative performance evaluation, as emphasized in the studies of Pesout and Nietfeld (2021), Akcaoğlu et al. (2023), and Urban et al. (2021).

More importantly, though, the predictive power of metacognitive awareness level highlights important potentials for studio instructors to tailor their teaching throughout the semester more in line with the guided discovery approach advanced by Mayer (2004). If starting the semester studio instructors understand the students' levels, they could accordingly use appropriate scaffolding to boost especially their monitoring skills, as found in Kavousi et al. (2020) study, and not just accomplishing the required tasks. Kavousi et al. found that high-performing students in a design course are the ones who are involved more in metacognitive activities monitoring their learning process compared to low-performing students who are more involved in controlling the tasks at hand and accomplishing individual design tasks such as sketching and model making, which is detrimental to their learning and their course grades.

GPA from previous education, general exam scores, and grades from some specific courses are known to be good indicators of overall academic achievement in college (Meier et al., 2015), yet we do not know whether the same is true for success in design learning. Anecdotally what is repeated in the field is that success in design is not linked to such academic measures and students with high GPAs from previous education or general exam score results do not necessarily predict the performance in the studio. Primarily this relates to the fact that pre-college education often does not prioritize design-related learning in comparison to humanities and sciences, which are the major domains that are measured in GPA and general exam scores. When compared to other fields, design instructors are at a double disadvantage because they can neither predict incoming students' potential in the design studio nor rely on their knowledge accumulated through years of education. Our results, therefore, give some idea that metacognition might help instructors predict how students will perform in the studio and tailor their studio teaching accordingly.

5.4. General discussion

The main theoretical contributions of this study stand out threefold. First, by drawing on pioneering scholars such as Schön (1983), it emphasizes the important role of metacognition in design learning and offers solutions to the challenges of discovery-based learning. Second, beyond the limited existing research, a quasi-experimental approach is adopted following the work of Zohar and colleagues on metacognition and design learning (Zohar & Barzilai, 2013; Zohar & Dori, 2011). Finally, by contributing to the educational literature that does not address design learning as a primary research topic, this study reveals how creative learning processes can be supported by metacognition, and these findings pave the way for the development of educational practices and policies, providing a broader perspective for design education.

Considering that the intervention applied in the study was minimal, it is not surprising that it could not sufficiently support students with already high metacognitive awareness. Therefore, the effect of metacognitive interventions may be stronger when applied in different combinations, in different varieties, at separate times, and in different environments for both high and low-metacognition groups. Science education studies are replete with other types of interventions (Zohar & Barzilai, 2013) that could also be of use in design learning environments. Additionally, teachers and studio instructors could have a more active role, and digital tools could be integrated with in-class activities to help students improve their metacognitive skills as studied in science education studies (Zohar & Barzilai, 2013). Furthermore, as stated by Aczel et al. (2018), one cannot overrule the fact that the analysis and the intervention used in the study may not have been sufficient to detect an impact. Consequently, more and repeated studies and other analyses are necessary to test the results of the current study to avoid an incorrect frequentist claim regarding unexpected findings.

Students' design learning processes as well as their cognitive and emotional development can be improved by integrating metacognition and metacognitive interventions into pedagogical approaches, practices, and interventions in design education. Integrating our findings with practical applications will allow educators to direct students' learning processes more effectively. For example, pedagogical approaches focusing on metacognitive interventions in design education help students determine their learning goals and direct their learning processes by encouraging their active participation. When integrated into the curriculum, these approaches can contribute to students' better understanding of their design processes and develop their problem-solving skills. The selection of educational environments and materials is also critical in this process. Physical and virtual environments in design education should be designed to support students' metacognitive abilities. For example, laboratory environments, workshops, and digital design tools can facilitate students' management of their learning processes by providing them with interactive experiences. Thus, students have the opportunity to develop their metacognitive skills while experiencing the design process through learning-by-doing.

Another important factor supporting metacognition is assessment and feedback. Assessment processes in design education should be structured in a way that helps educators analyse student performances and determine students' future learning goals. Along with providing constructive feedback, educators can render learning processes more effective by guiding students to identify their strengths and areas of development. Ultimately, we believe that considering these findings in design education practices will enable educators to more effectively support students and maximize their creative potential.

In sum, it is perhaps time to expand and move beyond Schön's paradigm of learning-by-doing in a design studio by way of relying more on what we know about cognition and learning as it is similarly suggested in education studies in highlighting the shortcomings of pure discovery learning (Kirschner et al., 2006; Mayer, 2004). Schön's emphasis on reflective practices was to the point, yet it had not led the way to install such practices beyond conventional desk crits and pin-up reviews. Mayer's (2004) proposal to emphasize the cognitive development of students together with behavioural activities, therefore, is right on target if we would like to truly follow student-led and student-empowered learning.

6. Conclusion

In this study, we designed a quasi-experimental study based on the view that metacognitive awareness has a positive effect on design learning and creativity. We aimed to draw attention to the complexity in design and creativity learning especially regarding knowing when, how, and why to use a particular strategy in design or a body of knowledge. We propose that metacognitive abilities and metacognitive awareness are important first because they facilitate self-directed learning as it is practised in design studios, and second because creativity entails knowing when, how, and why to use a certain body of knowledge.

In the study, we investigated whether minimal metacognitive interventions applied in the architectural design course created a statistically significant difference in students' metacognitive awareness and design learning processes. We also examined the type and degree of relationship between metacognitive awareness and design learning (design course grade). The results of the present study show that metacognitive interventions improve the metacognitive awareness of undergraduate architecture students with comparatively lower levels of metacognitive awareness. However, it indicates that the effectiveness of metacognitive interventions is especially related to metacognitive awareness. Consequently, we propose that dedicated courses or practices that will improve metacognition and metacognitive awareness in design course curricula will improve design learning and creativity.

The metacognitive interventions applied in this study were minimal interventions and studio instructors were not actively involved in supporting students' metacognition skills and knowledge. In future studies, it would be informative to study the impact of more substantial interventions together with an active teaching strategy in design learning environments. Future studies may investigate the effects of implementing different combinations of metacognitive interventions in the design learning environment, having instructors take a more active role in the intervention process, implementing metacognitive interventions beyond one academic term (preferably during design education), or opting for more structured interventions. Additionally, future studies may be designed to include creativity assessments in addition to metacognitive skills. This may help to better understand the effectiveness of interventions aimed at improving creativity in the design process. In addition, conducting focus group interviews or individual interviews, as well as experimental or quasi-experimental studies, may allow for a more in-depth interpretation of the results obtained. Such studies may provide valuable contributions in terms of developing educational practices and increasing the effectiveness of metacognitive strategies.

As for the limitations of the study, we had kept the scope of interventions as minimal as possible to establish a baseline for related future studies and did not include any metacognitive instructions as suggested by experts in the field (Veenman, 2016). This might also explain the unexpected findings of the study especially concerning the impact of the interventions on the metacognitive awareness levels of HML students. Veenman (2016) states that for effective instruction of metacognitive skills, the instructions need to be embedded within specific tasks, need to specify why learning such skills would help, and finally should expand over a sufficient length of period. We propose that the impact of the interventions in this study might have been more significant if the above principles were followed or if they were more explicit in informing students about metacognitive skills and knowledge since it is well established that explicit instructions help students improve in terms of both metacognitive skills and knowledge (Zohar & David, 2008). In future studies, we are planning to include these and others in design learning situations. A second limitation relates to the sample group, which included only fourth-year architecture students from one architecture school who are advanced learners and might have already acquired a substantial body of metacognitive skills and knowledge during their schooling, which followed a learning-by-doing paradigm. The results of the study are, therefore, limited to advanced learners from one school and might as well be different for beginning students or for students from different architecture schools with different priorities or from different cultures. Furthermore, the study participants had registered voluntarily in either the control or the experimental sections of the same class and we had not looked at how confounding variables might have influenced the results. In contrast to the results of random sampling studies, the results of our study, therefore, are limited given that the students in the experimental group consisted of only volunteers. Volunteering for an experimental study might have changed the motivational goals of the students in the experimental group and might have had some impact on the results (Shadish et al., 2002). Similarly, the instructors in the experimental group, even though they were closely following the same curriculum, might have been more motivated, which might have had an impact on the results. In future studies, one has to either increase the sample size, replicate the study, or use random sampling to further the results of this study. In addition, as suggested by Shadish et al. (2002), it is possible to lessen some of the problems related to sampling in quasi-experimental studies through different ways, which might be useful in future studies as well.

In conclusion, we advance that some of the shortcomings of self-regulated learning in design, which often puts most if not all students at a disadvantage, could be alleviated by employing instructional and learning practices that would ftheir level of metacognition and metacognitive skills. This, we argue, would help students reflect before they make a "leap in the dark" by way of deciding to leap or to hop, and by way of "foreseeing" what can come next in the dark.

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Author agreement statement

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

Abbreviations

MAI	Metacognitive Awareness Inventory
CMAI	Creative Metacognitive Awareness Intervention
DMAI	Design Metacognitive Awareness Intervention
HMA	High Metacognitive Awareness Group
LMA	Low Metacognitive Awareness Group

CRediT authorship contribution statement

Gizem Yazici: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Fehmi Dogan:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Supervision.

Data availability

The authors do not have permission to share data.

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Supplementary materials

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