Improving Architecture Students' Design Skills: A Studio Experience

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Abstract

Design is a complicated task that requires the simultaneous operation of different cognitive processes. Many researchers claim that the design process is something that can be supported with various implementations. Design education helps students improve their design skills by utilising different types of exercises. This article presents a case study wherein third-year undergraduate students at an architecture school's design studio were the subjects. The normal workflow of the studio was reinforced with checkpoints where the students were asked to complete exercises based on sketching, writing and visual analogy. The aim of the case study was to stimulate different cognitive processes in the students' brains through structured exercises to support their design process. This study questions the interrelation between each cognitive process and their relationship with the overall design process, plus whether verbal and written tasks as well as sketching, as cognitive exercises, contribute to the design process. The case study's findings indicate that students derived significant support from the exercises, and that there is correlation between the students' participation level in the exercises and their success in the design task. The case study also shows the interrelation between the writing and sketching exercises and their effects on the students' success in the design process. This article suggests that design educators would benefit from structuring methods efficiently in order to achieve better results when training neophyte designers.

Keywords

design skills, novice designers, design education, architectural design, student designers, architectural education

Introduction

Architectural education has become a major field of research during the last few decades on account of its complex and abstract structure. After being institutionalised in the seventeenth century through the architecture school Ecolé des

Beaux-Arts, architectural education witnessed numerous attempts to develop strategies for creating effective methods to transfer the knowledge and skills necessary to create architectural products. In the latter half of the twentieth century, theoretical aspects of architectural education came into prominence, bringing design and creativity-based issues into focus. Nowadays, scientific methods to establish the complicated cognitive processes of design have superseded soft strategies of the past, which treated the design as a mysterious process involving creativity.

Creativity is a source of design skill and one of the most significant features of the human mind. However, there is not a single definition of creativity accepted universally. The definition varies depending on the discipline and the context of the study. Nevertheless, there are some key attributes for any outcome to be considered a creative work. According to Simonton (1999), any creative output should have at least three characteristics: novelty (it is original), usefulness (it is functional and adaptive), and surprising (it is unobvious, therefore eliciting an aesthetical or affective response). Creativity breaks former rules and then generates unexpected and valuable things and ideas (Gero 1996). Because of its indistinct and ambiguous definition, creativity has been considered a challenging subject to study empirically. However, psychology-based literature nowadays provides a wealth of evidence depicting the psychological factors that facilitate creativity: elements of personality, cognition and motivation can either facilitate or impair creativity (Amabile 1996; Csikszentmihalyi 2009; Sawyer 2012).

Design is a cognitive process that consists of creative-thinking cycles. According to Forsyth and Crewe (2006), it refers to the artistic process of creating new forms and the artistic quality of those forms. Design is an artistic process, but it includes more exigences beyond artistic and aesthetic quality. Technical, social or other context-based aspects must be taken into consideration in the course of design. Barbara Tversky *et al*. (2003) claimed that what distinguishes design from art is function; design is for a purpose, usually a humane one. Therefore, it is necessary to examine strategies and methods that facilitate the design process and the product to precisely fulfil their purpose by supporting and enhancing the capability of the designer and their skills.

This article claims that forming a strategy based on a combination of different specific exercises can be a useful method to develop architecture students' design skills. Design schools, particularly schools of architecture within the scope of this article, are the where design students start and continue to develop their expertise through acquiring knowledge, experience and skills. Consequently, architecture schools and educators in those schools are responsible for composing and generating strategies to transfer the required features of design and to develop the students' design skills to transform them into well-equipped designers in their professional careers. Accordingly, this article discusses a case study whereby studies focusing on how to enhance design skills were examined, and a structured programme was designed and implemented at an architectural design studio course for third-year undergraduate students to examine the development (if any) of their design skills.

Aim of the study

The aim of the study was to devise methods and strategies that can improve design skills and implement those strategies in teaching in order to develop architecture students' design skills. Since one of the most important goals of architectural education is to provide students with instruments that assist them in becoming well-equipped architects, this research claims that specific strategies are beneficial to the design studio in supporting students hone their skills.

This study questions whether the use of multiple cognitive processes with different systems supports the design process in developing design solutions. Sloman (1996) claimed that there were two independent cognitive systems, one associative and similarity-based, and the other symbolic and rule-based. Gentner and Medina (1998) assumed that the similarity-based and rule-based cognitive systems operated simultaneously as well as interactively in problem-solving. Therefore, an important portion of the study is devoted to the examination of the design processes and their outcomes relative to the activities of different cognitive processes throughout the course of design.

Research Questions

The objectives of the study were to examine the use of different cognitive exercises, such as sketching, writing or visual analogy, in design education and to implement those methods in the architectural design studio process. To test the outcomes of the case study, the following research questions were asked:

- RQ 1: Does stimulating cognitive processes in design support students with their design tasks?
- RQ 2: Do verbal and written tasks as cognitive exercises in design contribute to the design process?
- RQ 3: What is the interrelationship between each cognitive process and their relationship with the overall design process?
- RQ 4: Does repetition of certain types of exercises have a positive effect on student success based on experience?
- RQ 5: Do sketching tasks as cognitive exercises in design contribute to the design process?

Cognitive Processes in the Human Brain

The human brain functions through a complex web of networks consisting of neural activities. The complexity of the human brain makes it difficult to perceive how the brain works and functions as the mind (Jerath & Crawford 2015). Various studies in the field of cognitive informatics have been conducted to explain and analyse the brain's activities. Cognitive informatics, the transdisciplinary study of cognitive and information sciences, investigates the internal information processing mechanisms and processes of natural intelligence (Zhong 2006). It provides a coherent framework of contemporary theories to explain human cognitive processes, such as problem-solving, learning, decision-making and consciousness (Wang & Chiew 2010). In this context, Wang *et al.* (2006) developed a model depicting the cognitive processes in the human brain called the layered reference model of the brain (LRMB). According to this model, the brain and human intelligence behaviours can be explained by 39 cognitive processes across six layers known as the sensation, memory, perception, action, metacognition and higher cognition layers (Wang *et al.* 2006). Layers five and six, the metacognition and higher cognition layers, comprise the conscious processes of the brain, and processes, like abstraction, knowledge representation, imagery, analogy and creation transpire, in these layers (see Figure 1). Design as a conscious process of the mind requires these cognitive processes to be active.

In design education, these processes need to be conscious to establish an effective learning progression. At this point, cognitive structures appear functional as they play an important role in learners' information-processing ability, where they serve as frames of reference, and allow learners to grasp and work with one or several aspects of a concept (Navaneedhan & Kamalanabhan 2017). By forming cognitive structures for the design education courses, one can stimulate cognitive processes that are beneficial for the design continuum.

The Nature of Design Problems

Design is an ill-structured process where different cognitive approaches are employed interconnected to each other. It has different phases, such as analysis, interpretation and synthesis, with an expected result of a creative design solution. Therefore, it benefits the designer to have different types of stimuli throughout

Subconscious Processes		Conscious Processes	
Layer 1	Layers 2-4	Layer 5	Layer 6
Sensational cognitive processes	Subconscious cognitive processes	Meta cognitive processes	Higher cognitive processes
1.1 Vision	2. Memory	5.1 Attention	6.1 Recognition
1.2 Audition	3. Perception	5.2 Concept establishment	6.2 Imagery
1.3 Smell	3.1 Self-consciousness	5.3 Abstraction	6.3 Comprehension
1.4 Tactility	3.2 Motivation	5.4 Search	6.4 Learning
- Heat	3.3 Willingness	5.5 Categorization	6.5 Reasoning
- Pressure	3.4 Goal setting	5.6 Memorization	6.6 Deduction
- Weight	3.5 Emotions	5.7 Knowledge representation	6.7 Induction
- Pain	3.6 Sense of spatiality		6.8 Decision making
- Texture	3.7 Sense of motion		6.9 Problem solving
1.5 Taste			6.10 Explanation
- Salt	4. Actions		6.11 Analysis
- Sweet			6.12 Synthesis
- Bitter			6.13 Creation
- Sour			6.14 Analogy
- Pungency			6.15 Planning
			6.16 Quantification

Figure 1
Classification of cognitive processes in the LRMB reference model (Source: Wang *et al*. 2006)

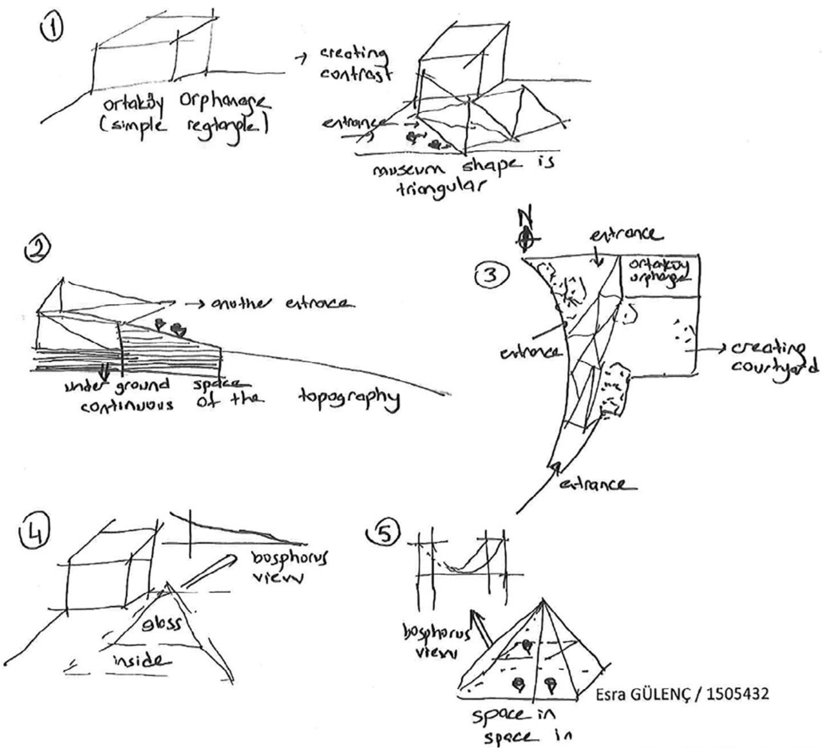

Figure 2
Sample student work from checkpoint two (Source: the authors)

the process. There are various opinions on the design process. According to Asanowicz (2004), intuition, unpredictability and a lack of logic are the key ingredients of creativity. The ill-structured nature of design problems obliged designers and educators in the past to handle the design process as an intimate, unpredictable and mysterious course that cannot be explained with concrete evidence. Araujo (1976) claimed that in architecture, knowledge is derived simultaneously from our intellect and from our emotions as well as logic. This kind of approach generally employs empirical methods, which result in learning by doing. Nevertheless, during the last decades, scientific and systematic work has been conducted to reveal the concealed activities in the human mind during the design process, so that researchers and academics can base their studies regarding design on more empirical information. Sloman (1996) suggested that we are endowed with two independent cognitive systems, each dedicated to one mode of reasoning: one associative and similarity-based, the other symbolic and rule-based. Goldschmidt (2001) proceeded on that perspective with the assumption that two parallel interactive cognitive systems operate during problem-solving: one rule-based using underlying reasoning and the other based on similarity. This scientific approach permitted design educators to form educational strategies and methods according to the data from this scientific research. Thus, several different strategies may be used to develop students' design skills. These strategies support the formation of different cognitive processes. Among them are four groups of exercises that have been employed throughout the design studio course in the scope of this article with various combinations in different phases of design:

The role of sketching in design

Sketching has a vital role in the design process, both in the initial and latter stages. Sketching, commonly defined as 'drawing' is an activity that all human beings are involved in on some level. Although for some communication and reasoning tasks, ordinary drawing skills are insufficient (Goldschmidt 2008), even a two-year-old child tends to draw things to explain their thoughts to other people, far earlier than they learn to read and write. Therefore, drawing (or sketching) can be called an instinctive activity.

Sketching is a method of representation designers use to communicate their abstract ideas and knowledge into concrete graphic forms for viewers and/or themselves. The initial reason for the existence of sketches is to help the brain visualise the ideas and store them as concrete images. In this context, sketches can be defined as supportive tools for the human brain's visualisation process of mental images. Fish (1999) claimed that early design sketches are like catalysts in that they can combine with and swiftly transform superimposed mental information in the working memory.

Sketches are likely to support the design process in its different phases. In the first stages of design, sketching may be like brainstorming where different ideas are recorded randomly. The design process is a productive cycle or a two-directional path where the sketches function as the most important elements of dialogue. Accordingly, sketching stands out as an important cognitive phase in the design process.

The role of visual analogy in design

Visual analogy is another cognitive process that can be used in different stages of the design process. An important feature of human cognition is the ability to use analogical reasoning (Holyoak & Thagard 1997). Simply defined, analogy is the likeness or relation between two different phenomena or situations in certain circumstances (Clement & Gentner 1991).

Visual analogy is one of the most commonly used types of analogy. It can be employed as an effective method to solve ill-structured problems, such as those encountered in the design process. Several empirical studies (Casakin 2002; Casakin & Goldschmidt 1999; Verstijnen *et al*. 1999) have proven that the use of visual analogy improves the quality of design solutions (Casakin 2004). The use of analogy, especially by novice designers, contributes to learning new abstract concepts as well as extending and applying previously acquired knowledge (Goldschmidt 2001).

The role of writing in design

As design problems are defined as visual-based thinking processes, the main triggers are visual stimuli. However, verbal and written sources can also be employed as stimuli in design. While writing, students perform whole-to-part processing as they divide the gestalt of a complex visual image into segments that can be expressed serially in writing (Pollock *et al*. 2002). The architectural education accrediting body considers good writing an essential competency (Oda 2015).

There is empirical evidence of a correlation between the design and writing processes. In their study Soygeniş *et al*. (2010), discovered that students who were able to concentrate on what they were going to do and explain it in text, performed well in sketching. Mozes (2006) studied reading and writing skills in a landscape design studio and found this approach worth examining. According to the given data mentioned above, using verbal-thinking systems based on reading and writing skills is beneficial in the design process, providing a unique cognitive layer in the designer's brain.

Information-based knowledge

Although design issues are mostly defined as ill-structured problems, they have a well-structured side as well. A design product has to meet certain criteria, such as functional integrity, structural composition, legal regulations and environmental requirements, which can be summed up as a design product's technical requirements, and they have considerable influence on the design process. The well-structured side of the design problem can be used to define limitations and provide a framework for the design process. Particularly in the early stages of the design process, the information given to the students may help them tackle the design problem. The given information may be encoded in the declarative memory and consist of facts, declarative encodings of procedures that must be followed or concepts that specify objects' general properties (Van Merrienboer 1997).

Study methodology

The study's methodology consisted of a theoretical part with a literature review about various cognitive processes related to design skills and exercises fostering these cognitive processes, followed by a case study to validate the research questions derived from the literature review. According to Yin (2009), case studies are used as research strategies in many situations to learn more about various phenomena: 'case studies are the preferred strategy when "how" or "why" questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context' (Yin 2009, 1). As the topic investigated in this article meets these criteria, conducting an exploratory case study is a suitable research method. In exploratory methods, the researcher first explores qualitative data and then uses the findings in a second quantitative phase (Creswell 2014). This article's case study was designed as a group of exercises within the framework of a structured design studio course where students' work – consisting of sketches, analogies and writing – was evaluated by experts. The results of their evaluations were generated as quantitative data and elaborated upon for the interpretations of the findings.

One of the biggest challenges in research in the field of architecture and design is transforming products' abstract values into quantitative and measurable data. In this article, the authors tried to overcome this through the design of the exercises used in the case study and the assessment criteria used to evaluate the students' work. First, the exercises, as the subjects of assessment, were created to respond to the brain's cognitive processes to investigate the potential effects of sketching, writing, visual analogy and information-based knowledge on the success of the design process. The planned exercises reflected to what extent the stimulation of various cognitive layers contributes to the design students' academic performance. Second, regarding the need for a scientific study to be verifiable and measurable, the assessment of the students' work was based on certain criteria, such as graphic, semantic and contextual quality. Thus, the researchers ensured that each student's score for every single exercise was valid, based on a combination of relevant criteria derived from the literature and previous studies (Blanchette & Dunbar 2000; Goldschmidt 1992; McDonagh-Philp & Lebbon 2000; Mozes 2006). Additionally, to overcome the any potential bias on the part of the evaluators, four different experts were assigned to evaluate the students' work: three of the evaluators were studio instructors, while one was an external examiner. The results of the evaluators' reliability check are presented in the data analysis section. The students' exercise scores are presented and cross-related in the findings section.

Case study: The structured studio experience

To test the effects of employing various cognitive processes on design skills, a case study was designed in an architectural design studio because studios are at the core of architectural education. The design studio selected for the case study caters for third-year undergraduate students, who in the architectural education system in this case, were starting the second half of their education. It was expected that during the first half of their education, they were equipped with the skills and theoretical knowledge to execute a design process properly, starting from the first concept phase through the details to final production. Study participants were all students at the same faculty, with various social backgrounds and random levels of academic success.

The total number of students attending the design studio course was 39 in three different groups, and one instructor was assigned to each group. The general framework of the course was to design a museum in an urban and historical context. The contents of the museum, and thus, the details of the building programme were left to the students' initiative. The students were responsible for researching the design problem and the given site (they had three site options in different districts of the city).

The design of the structured studio

Within the framework of this exploratory case study, the studio was designed in such a way that it was possible to augment the course with additional exercises and lectures to test the aforementioned cognitive processes. After the course's introduction, site visits and preliminary student research, group discussions and desk critiques were held in which the students began to form their initial design ideas and concepts. The process was supported by lectures organised in correlation with the design phase. There were four lectures: the principles of museum architecture, structural issues, sustainability in architecture, and acoustics and system details. The lectures represented the information-based portion of the design process, and they were claimed to stimulate certain cognitive processes based on the students' previous knowledge. The additional structured exercises, which took place at different phases of the design process, included various assignments about sketching, writing and visual analogy. The assignments were intended to activate certain cognitive processes in the students' brains and thus were expected to support their design process through different types of verbal and visual stimuli.

The checkpoints

The studio's weekly schedule is shown in Table 1. The exercises designated at certain phases of the design process were called checkpoints, and they were

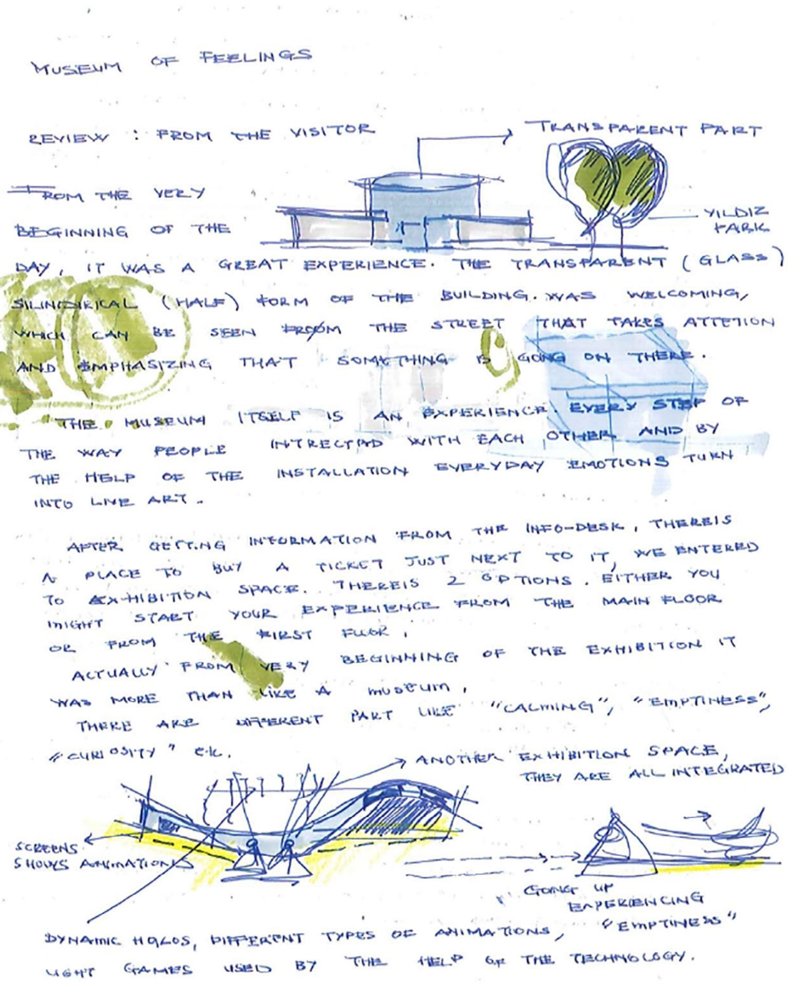

Figure 3
Sample student work from checkpoint three (Source: the authors)

integrated into the natural flow of the course. The checkpoints aimed to support the students by activating different cognitive processes via various exercises that were claimed to be benefit the development of the design process. The instructors gave pre-exercise explanations about the objectives of the exercises and the kind of benefit students could derive from each one to increase the students' willingness to participate and to assure them that the exercises would contribute to the design process. Nevertheless, the exercises were optional so that only interested students executed the given tasks.

The first checkpoint was scheduled after the fourth week. The students were asked to sketch their design ideas (exercise A1), and they were encouraged to use domain and visual analogies in their design ideas (exercise C1). Additionally, they were asked to write about their design concepts in order to organise their ideas and intentions more systematically and rationally (exercise B1). The threefold exercise was assumed to activate various cognitive processes in the students' minds, focusing on the general concept of design and the students' intentions for their

TABLE 1 The weekly schedule of the design studio (Source: the authors)

Time	Assignment	Exercises
Week 1	Introduction to the studio and site visit	Information-based knowledge
Week 2	Student presentations and group discussions	
Week 3	Student presentations and group discussions	
Week 4	Lecture 1 (principles of museum architecture) and desk critiques	Information-based knowledge
Checkpoint 1	Students explain the *general concept* of their design • using sketches (exercise A1) • using writing (exercise B1) • using visual analogy if appropriate (exercise C1)	Writing as a design tool Thinking sketchesVisual analogy
Week 5	Desk critiques	
Week 6	Lecture 2 (structural issues in design) and desk critiques	Information-based knowledge
Week 7	Desk critiques	
Week 8	Interim jury 1	
Checkpoint 2	Students explain the *spatial organisation and structure* of their design • using sketches (exercise A2) • using writing (exercise B2)	Writing as a design tool Thinking sketches
Week 9	Desk critiques	
Week 10	Lecture 3 (sustainability in architecture) and desk critiques	Information-based knowledge
Week 11	Desk critiques	
Week 12	Interim jury 2	
Checkpoint 3	Students write an observatory text about their museum design from the perspective of a visitor • by writing (exercise B3) • sketching (optional) (exercise A3)	Writing as a design tool Thinking sketches
Week 13	Lecture 4 (acoustics and system details) and desk critiques	Information-based knowledge
Week 14	Desk critiques	
Week 15	Final jury	
Checkpoint 4	Students write a project report about their design (exercise B4)	Writing as a design tool

design idea proposals they were due to present in the upcoming weeks. Metacognitive processes, such as concept establishment, abstraction and knowledge representation, as classified in the LRMB, were targeted for activation through these exercises.

The second checkpoint took place after the eighth week, and the students were asked to write and sketch their design's layout and structural system (exercises A2 and B2). At this stage of the design process, the students were expected to concentrate on space planning, the characteristics of spaces, their interrelationships and organisation. How the students integrated their information-based knowledge attained from lectures throughout the process was also considered. The methods used for the exercises were writing and sketching as these skills can help develop systematic approaches to the design problem. These exercises targeted the higher cognitive processes of comprehension, reasoning and decision-making, according to the LRMB. (see Figure 2)

The third checkpoint was in the twelfth week and was based on a fictional scenario where the students wrote an observatory text from the point of view of a person who visited the museum the students designed (exercises A3 and B3). Thus, the students had the chance to assess and interpret their work from different perspectives and imagine how other people perceived the features and facilities they designed. The main method in this checkpoint was writing a text; sketching was left to the students' initiative. By doing this, the students' eagerness to sketch their design ideas, even when they were not obliged to do so, could be assessed. The higher cognitive processes of the LRMB, such as recognition, imagery and deduction, were expected to be triggered through this assignment. (see Figure 3)

The fourth checkpoint was an exercise completed on the final day of the studio course wherein the students were required to write a report about their designs (exercise B4). The intention was to make the students critically appraise their work so that they could learn from their idea's strengths and weaknesses. This exercise aimed to stimulate the higher cognitive processes of explanation, synthesis and planning.

Data analysis

The exercises conducted by the students at each checkpoint were assessed and graded. The data were analysed using the Statistical Package for the Social Sciences (SPSS) system through Analysis of Variance (ANOVA). The students' competencies in sketching and writing about a given condition or concept were examined and evaluated according to the relevant criteria for each exercise. The criteria for sketching included graphic quality, semantic quality and the contextual quality of the sketch's content according to the given problem. The criteria for the writing exercises also included semantic quality and the relationship between the content of the written material and the question. To inspect the sensibility of both types of exercises, the correlation between the content of the sketch and the written material was also examined. Regarding the visual analogy exercise at the first checkpoint, the criteria included conceptual quality, quality of visual expression and its relationship with the given context.

The assessment scale ranged from zero (the lowest score) to ten (the highest score).

The students' work was evaluated by four professionals – three of whom were instructors at the design studio, while one was an external examiner – to test the reliability of the assessment. A correlation coefficient of r = 0.84 for the four sets of scores was found to be satisfactory in indicating the inter-scorer reliability for the evaluations.

Regarding the sample, 39 students registered for the design studio course in total, 21 of whom participated in all four checkpoint exercises. The remaining 18 students participated in three or fewer exercises, so they were excluded from the assessment. The work of the 21 students who participated in all of the checkpoints was assessed according to the criteria defined for the sketching, writing and visual analogy exercises so that each student received a score for their performance in those exercises. By calculating the average score of all the participating students, the mean values for each exercise were defined. Regarding the sketching exercises, the mean value in checkpoint one was 5.07; in checkpoint two it was 5.57 and in checkpoint three, 6.17 (see Table 2). In the writing exercises, the mean value for the first checkpoint was 5.63, for the second checkpoint 6.12, the third checkpoint 6.83 and the final checkpoint 7.21 (see Table 3). For the visual analogy exercise at the first checkpoint, the mean value was 5.95 (see Table 4).

The findings

The additional exercises executed in different phases of the design studio's course answered the research questions practically, indicating that the exercises could potentially benefit students in terms of augmenting the students' design skills.

Regarding the outcomes of the assessment for all the exercises, correlation was established between participation in the exercises and the students' final grades. The 21 students who participated in all the exercises at the four checkpoints secured an average final grade of 7.41/10. Regarding the rest of the students, 18 out of the total number of students (39) obtained an average grade of 6.15/10. Standard deviations smaller than the half of the average grades indicate that the difference between the average grades of the two groups are meaningful (Hossain *et al.* 2014).

TABLE 2 Mean values for the sketching exercises (Source: the authors)

SKETCHING EXERCISES MEAN VALUES								
		Crt. 1	**Crt. 2**	**Crt. 3**	**Crt. 4**	**Crt. 5**	**Crt. 6**	**Mean val.**
Checkpoint 1 Exercise A1	Minimum	1	1	0	0	0		0
	Maximum	9	9	9	9	10		10
	Mean	4.33	5.10	5.29	5.43	5.23		5.07
	Std. dev.	1.717	1.647	1.746	1.806	1.871		1.856
Checkpoint 2 Exercise A2	Minimum	0	0	0	0	0	0	0
	Maximum	9	9	8	9	9	9	9
	Mean	5.19	5.21	5.40	5.86	5.90	5.86	5.57
	Std. dev.	1.929	1.982	1.921	2.037	2.016	1.851	2.219
Checkpoint 3 Exercise A3	Minimum	2	2	2	3	4	4	2
	Maximum	8	8	8	8	10	9	10
	Mean	6.00	5.80	5.93	6.25	6.34	6.70	6.17
	Std. dev.	2.116	2.033	2.026	2.188	2.201	2.342	2.246

TABLE 3 Mean values for the writing exercises (Source: the authors)

WRITING EXERCISES MEAN VALUES		Crt. 1	Crt. 2	Crt. 3	Crt. 4	Mean val.
Checkpoint 1 Exercise B1	Minimum	2	2	2		2
	Maximum	9	9	8		9
	Mean	5.64	5.65	5.60		5.63
	Std. dev.	1.502	1.579	1.522		1.566
Checkpoint 2 Exercise B2	Minimum	3	1	2		1
	Maximum	9	9	9		9
	Mean	6.00	5.98	6.37		6.12
	Std. dev.	1.406	1.568	1.421		1.582
Checkpoint 3 Exercise B3	Minimum	2	0	3	4	0
	Maximum	10	10	10	9	10
	Mean	6.83	6.88	6.87	6.74	6.83
	Std. dev.	1.512	2.002	1.429	1.223	1.852
Checkpoint 4 Exercise B4	Minimum	3	4	3	4	3
	Maximum	9	9	10	10	10
	Mean	6.76	7.06	7.21	7.79	7.21
	Std. dev.	1.385	1.293	1.473	1.327	1.513

The average results of the students for both the sketching and writing exercises increased over time, meaning the results of the exercises performed at the later checkpoints were higher than the earlier ones. The first average mark for the sketching exercises was 5.07, and this increased sequentially to 5.57 and then 6.17. Similarly, the average mark for the writing exercises was 5.63 at the first checkpoint, and this increased at each subsequent checkpoint to 6.12, 6.83 and then 7.21 at the last checkpoint. This may indicate that the students improved due to the experience and practice they acquired (RQ 4).

The students proved themselves to be more successful in the writing exercises than the sketching exercises. The average grade for all the writing exercises was

TABLE 4 Mean values for the visual analogy exercises (Source: the authors)

VISUAL ANALOGY EXERCISE MEAN VALUES		Crt. 1	Crt. 2	Crt. 3	Mean val.
Checkpoint 1 Exercise C1	Minimum	0	0	0	0
	Maximum	9	9	9	9
	Mean	6.32	6.18	5.26	5.95
	Std. dev.	2.873	2.877	2.903	2.954

TABLE 5 Average results for Student 14 (Source: the authors)

Average sketch 1	Average sketch 2	Average sketch 3	Average writing 1	Average writing 2	Average writing 3	Average writing 4	Average writing	Average visual analogy	Total average	Grade
3.15	3.67	3.41	3.08	5.50	.31	6.81	5.18	4.50	4.36	9.32

6.45, whereas the average grade for all the sketching exercises was 4.92. Only one student was better at sketching than writing: their average result for sketching was 7.32, whereas for writing it was 4.95 (RQ 3).

The students' average grades in the exercises were proportional to their success in the design process (RQ 3). There was one anomalous student (Student 14) who had a final grade of 9.32(/10) though their average result in the exercises was only 4.36 (see Table 5).

The interrelation between the sketching and writing exercises was proportional, thus providing evidence to support the statement in RQ 3. The six students who had the best results for sketching (avg. score 6.52) also attained above-average scores in the writing tasks (6.72 > 6.42). Similarly, the six students with best writing exercise results (avg. 7.29) also attained above-average scores in the sketching exercises (6.10 > 5.60).

The correlation between the results of the sketching exercises and the final grades were not very clear. Although success in sketching corresponded to success overall, several exceptions were noted when certain students' results were examined. For instance, the best sketcher, who had an average result of 7.32 in sketching, did not attain the highest final grade. That honour went to the sketcher with an average result of 3.41 and a final grade of 9.32/10 (see Figure 4) (RQ 5).

The students' performance in the writing tasks and their final grades were mostly related to each other with no drastic differences in results. Typically,

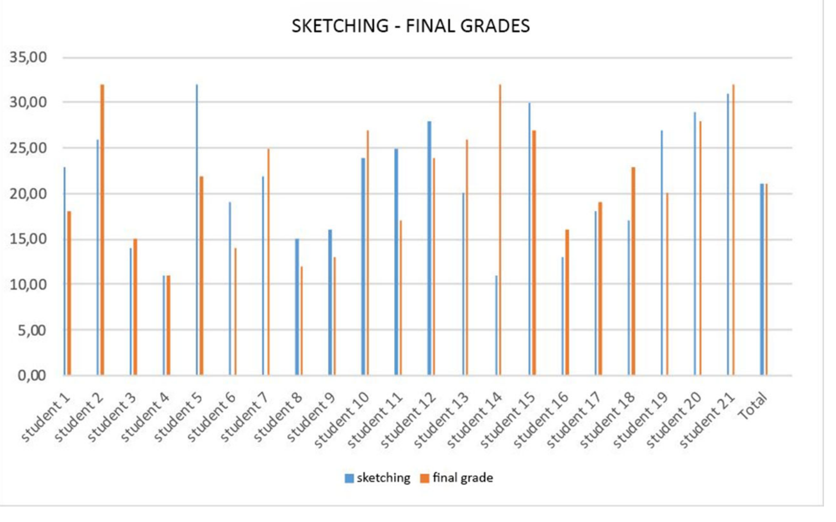

Figure 4
The correlation between the sketching exercises and final grades (Source: the authors)

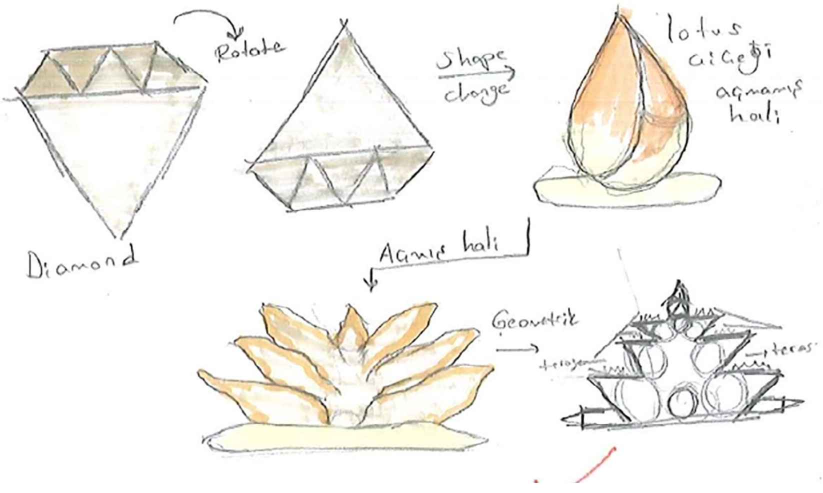

Figure 5
Sample student work for visual analogy (Source: the authors)

students who did well in the writing exercises received higher final grades (RQ 2), though there were three exceptions: Student 4, Student 6 and Student 14. Students 4 and 6 had relatively high scores for their writing exercises (6.05 and 7.22, respectively) but received lower final grades (4.73 and 5.63, respectively). In contrast, Student 14 attained a low score for the writing tasks (5.18) but had a high final grade (9.32).

Various researchers have asserted that writing is an important contributor to the design process (Mozes 2006; Oda 2015). Accordingly, writing was included as an exercise in all four of the case study's checkpoints. The steady increase in the writing exercises' average results (see Table 6) and their reflections on student

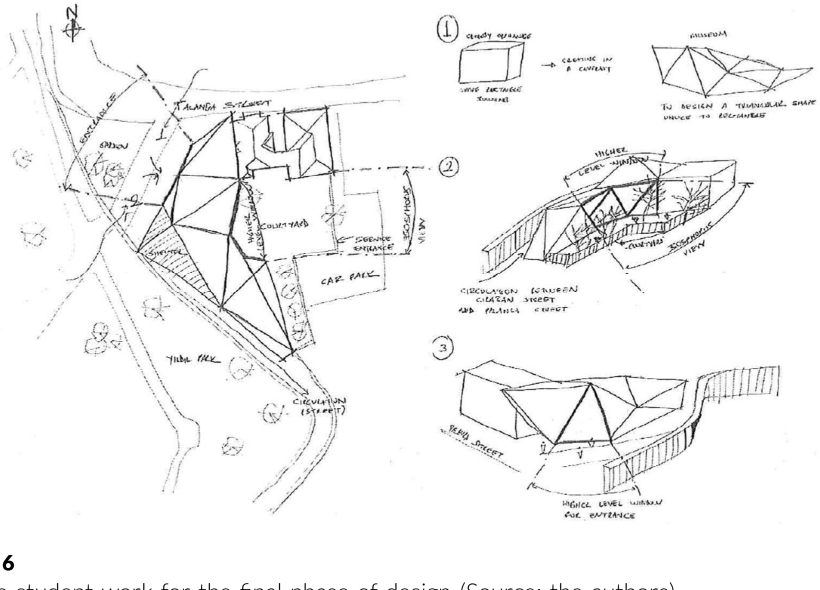

Figure 6
Sample student work for the final phase of design (Source: the authors)

TABLE 6 Average results for writing tasks at different checkpoints (Source: the authors)

Checkpoint	Checkpoint 1	Checkpoint 2	Checkpoint 3	Checkpoint 4
Writing exercise average results	5.63	6.12	6.83	7.21

performance support the statement that writing exercises might be used to improve students' success in design assignments (RQ 2).

At the third checkpoint, the students were asked to write a story about a trip to their designed building and facilities from a visitor's perspective. This particular exercise received the highest participation rate (34 out of 39 students), and the average score of the exercise was relatively high (6.83/10), higher than the other writing exercises undertaken thus far. This may be proof that students are more interested in exercises that are not frequently encountered.

There was no significant finding regarding the correlation between the use of visual analogy and final design success. The average final grade of the students who used visual analogies was not significantly different from the average result of students who did not use visual analogies. However, there was some correlation between visual analogy and writing skills. The students who used visual analogies were more successful in the writing exercises, with an average score of 6.57 compared to an average score of 6.02 for those who did not use visual analogies. The relationship between writing and creating visual analogies may warrant further investigation. (see Figure 5)

Regarding the outcomes of the case study, the students were more successful when they were given a framework or instructions based on the design phase with clear definitions and a statement of aims. The average final grade (7.41/10) of the 21 study participants is considered quite high for this level of education. Even though it is not possible to claim that the exercises at the checkpoints explain the difference between the average results of the two groups, the parallelism between student success and participation in the exercises is remarkable. Furthermore, it was observed that the students grew more attached and dedicated to the given tasks over time, which probably helped them concentrate better on the final design. The scores for both the sketching and writing exercises increased from the first checkpoint to the final one, suggesting that conducting these exercises throughout the different education levels would better develop students' design skills; however, this merits further discussion. (see Figure 6)

Another important point noted from the case study was the students' good results in creating stories and scenarios about their projects. The writing exercise at the third checkpoint had a high level of participation (34/39), and the participants received relatively high grades (6.83/10), which may indicate that exercises based on unconventional or non-traditional tasks have a positive effect on students; they were enthusiastic to consider their work from a different perspective. Increasing the number of these types of exercises would probably have various benefits for design education, which may merit further discussion and investigation.

Conclusion

Designers, particularly novice designers, experience challenges during the design process due to its complex structure. Segmenting the design process into cognitive layers to ensure that the designer deals with the problem in fragments may help simplify the process. The various cognitive processes in design may include sketching, visual analogy, writing about the design and information-based knowledge. Models have been developed addressing the various cognitive processes, such as Van Merrienboer *et al.'s* (2002) 4C/ID Model for meaningful multimedia learning, which claims there are four components to the learning process: learning tasks, supportive information, procedural information and part-task practice.

The transdisciplinary approach in design education – bringing art, science and technology together – can be observed in architecture's history, as one of the main objectives of the Bauhaus architecture school. This kind of approach requires a combination of different cognitive activities throughout the educational period. Today, there is consensus regarding the necessity to include art, science and technology in a design curriculum (Findelli 2001). Further studies concerning the integration of teaching methods from other disciplines into design education are needed to strengthen the relationship between design education and other disciplines based on technology or social sciences. Applied social and behavioural sciences require understanding of human cognition and emotions so that designers can perform valid, legitimate tests of their ideas before their deployment (Norman 2010).

This article's research was motived by a desire to understand the cognitive processes involved in design and how best to incorporate them into design education by creating methodologies or scientific strategies. One can assert that creating a framework for a design studio course is useful for students because it helps activate various cognitive processes in their brains. In recent years, there has been a growing interest in the study of the cognitive aspects of design as a basis for design education (Oxman 2004) with many researchers studying the cognitive processes of design (Akin 2002; Akin & Lin 1995; Baron & Steinberg 1987; Delage & Marda 1995; Goldschmidt 1992; Oxman 2001; Schön 1985). These studies are predominantly concerned with creating a structure for design education that can be qualitatively and quantitatively assessed, to find methodologies that support the development of design skills and to form a roadmap for design students to follow throughout their design education journey.

This article's case study utilised the metacognitive processes outlined in the LRMB, such as concept establishment and abstraction, and higher cognitive processes, like imagery, deduction and decision-making. The model has promising features that can provide a scientific foundation for design teaching. Further studies relating the model with design education would benefit the design and teaching community.

Interrogating the case study's methods and strategies is a concern of metacognition as well. Mayer (2009) claimed that good metacognitive strategies can help learners expand their learning capacities. Furthermore, metacognition helps design students attain a greater degree of success within a design process and in upcoming design problems by calling upon their knowledge of previous experiences. Further studies on the relationship between metacognition and design education involving the LRMB is a theme that needs addressing in the field of design teaching studies.

This case study only reveals findings and outcomes for a certain group of students, under certain conditions; yet, it is potentially generalisable to theoretical propositions, as Yin (2009) asserted that case studies can be generalisable to theoretical propositions but not to populations or universes. The experience gained from the case study reveals that activating different cognitive processes in the human brain can benefit design students, as they need to satisfy different concerns simultaneously throughout the design process. Each cognitive process benefits a different task, whereas combining these processes forms a more comprehensive and productive solution for design. This article's case study shows that there is potential correlation between using scientific methods in the design process and the students' academic performance, although there might be other reasons to explain the relative success of the students who fully participated in the structured exercises, such as their academic background or high interest in the given design problem. The other students, who partially participated in the exercises, might have lost interest in the exercises or simply found them unnecessary.

This study's contribution to understanding cognitive processes in the human brain is not limited to design studios and design-based activities. Applicability of this approach to other disciplines needs addressing. It contributes to all types of learning and teaching activities so that it is possible to structure courses to stimulate certain cognitive processes through different tasks and exercises. Further research into an architectural curriculum based on the LRMB, integrating cognitive processes into teaching with a holistic understanding, would be beneficial for students regarding the development of their skills.

In recent years, design thinking has become an important term in many disciplines. The transdisciplinary approach is reflected in education so that new methods are sought to bring multiple disciplines together. Utilising the human brain's cognitive processes through a structured curriculum in various disciplines is an interesting subject for further research.

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