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Original Research Article

Revisiting Nature-inspired Thinking Process in Architectural Designs Using Zaltman's Metaphor Method (ZMET)

Saviz Tayyah[1], Fatemeh Mehdizadeh Saradj[2*], Mahnaz Mahmoodi Zarandi [3]

1. Ph.D Candidate in Architecture, Islamic Azad University, North Tehran Branch, Tehran, Iran.
2. Professor, School of Architecture and Environmental Design, Iran University of Science and Technology, Tehran, Iran.
3. Associate Professor, Faculty of Architecture and Urbanism, Islamic Azad University, North Tehran Branch, Tehran, Iran.

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Abstract

Statement of the problem: Understanding how mental maps are used by new learners of architecture can help us gain familiarity with their mental thinking and externalize their mental knowledge. This ultimately paves the way for structuring and organizing the ideas of new learners.

Research Objective: The purpose of this study is to raise awareness about the mental representations of new learners of architecture during nature-inspired design processes and to develop a consensus map of mental models and to improve the design thinking of new learners.

Research method: This field study is qualitative in nature, and with respect to its purpose, it is applied. In this study, first, the documents and opinions of experts were scrutinized then architecture learners' mental maps were elicited using the ZMET technique (Zaltman's proposed technique to get to the unconscious structure of individuals).

Conclusion: Analyzing the mental maps of new learners shows that nature has been able to influence their architectural design process. The results revealed that learners were inspired by nature in their architectural designs, 26% used it for semantic analysis. The results of interviews with the new learners showed that 21% of them mostly used nature in structural and geometric patterns. The patterns were used by 36% for finding and creating ideas, which account for a big share of the design process.These results highlight the necessity of promoting nature-inspired design in architectural studios and future studies.

Keywords: *Mind Map, New Learners of Architecture, Architectural Design, Nature, ZMET.*

Introduction

Man has long been in a friendly relationship with nature. To live in nature, humans have used architectural tools (Khakzand & Ahmadi, 2007). Nature[1] as the source of significant metaphors[2] can prevent learners from thinking in a superficial way (Antoniades, 2017). Metaphors, which play a key role in developing thinking and

* Corresponding author: +982173228249, mehdizadeh@iust.ac.ir

knowledge, shape human thoughts. Man uses an average of approximately six metaphors in each minute of talking, the more metaphors he uses, and more accurate information can be gained about his thoughts and feelings (Zaltman, 1996). Since mental images are the result of human evaluation of the environment (Nazif & Motalebi, 2019), understanding the designer's mental image[3] of a particular pattern of nature (in fact, the pattern refers to the perceptions of new learners about nature) can explain how nature influences the minds of designers (Zaltman, 1997). This highlights the necessity of searching for a method that is able to understand the mind of new designers, their mental images, and nature-inspired ideas sparkled in the minds.

The designer's mental image is obtained in the form of structures and their relationships in the mental map. Studying the mental map (drawing a set of concepts and relationships between them and eliciting the learner's mental knowledge) can be very useful in understanding the learners' minds. Figure 1 shows the research procedure of the study.

The current study attempts to gain an accurate understanding of the impact of nature-driven patterns on the minds of new designers through the ZMET[4] method. This method was used for eliciting the mental patterns of learners of architecture and understanding their thoughts in response to nature-inspired patterns.

1. What is the mental map of a new designer of architecture like in response to the patterns in nature?
2. At what stages of the design process can architecture learners reap much more benefits from the diverse aspects of nature's patterns?

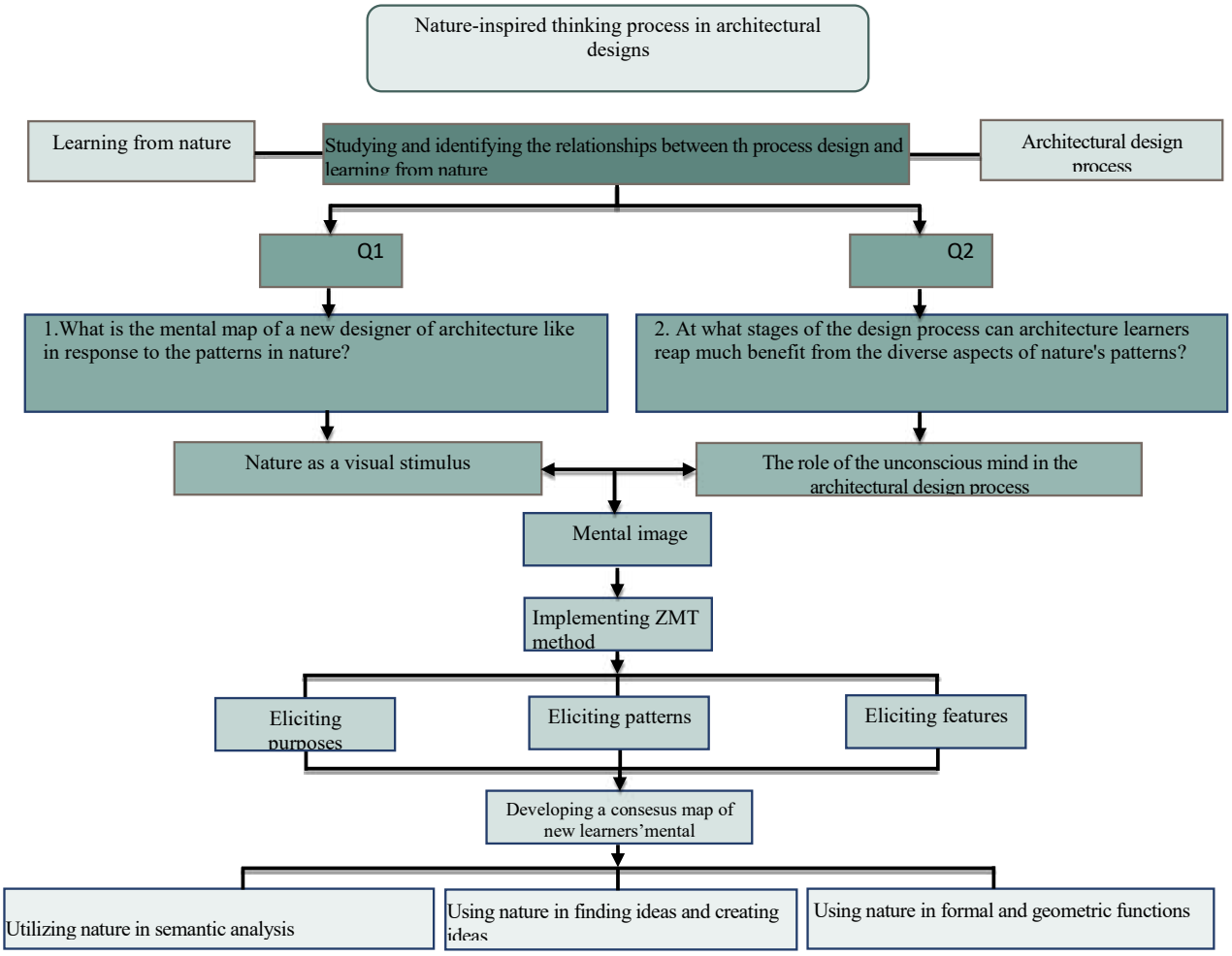


Fig. 1. Research procedure. Source: Authors.

Theoretical framework and literature review

• Nature as a visual stimulus

Given its many capabilities, nature is a great resource for learning and serves as a model for developing creative patterns, and discovering new ways for solving design problems. In addition, the various aspects of nature can serve as resourceful tools in the process of creating design solutions. Research has shown that nature is one of the sources of ideas in architectural design and some scholars have used the term bionic to learn more about nature and reap its benefits (Falahat & Shahidi, 2010; Faizi, Alipour & Mohammad Moradi, 2017; Chiu & Chiou, 2011; Araghizadeh, 2014; Fu, Moreno, Yang, & Wood, 2014; Sadri, Kavandi, Jozepiri, Teimouri & Abbasi, 2014; Gruber & Imhof, 2017; Sugár & Leczovics, 2017; Yeler & Yeler, 2017; Fayemi, Gilles, & Gazo, 2018). The results of Faizi and Alipour's (2014) research also show that architectural learners use nature more than any other source for inspiration. This research introduces nature as a visual stimulus that can serve as a model for leaners and facilitate the architectural design process.

• Nature as a pattern language

The components of the universe are received in the form of pattern language, and man consciously or unconsciously receives patterns from the environment and nature. Just as language allows a person to make a variety of sentences using words, a pattern enables a person to create unique structures, and like grammar, patterns share a similar general structure (Alexander, 2002) despite their small differences). The pattern is the basic method of understanding, thinking, and evaluating a subject that represented in the form of a real image in the mind (Sharif & Mohammad Ali Nejad, 2011). Patterns are acceptable examples of practical exercises in which there are laws, theories, applications, and tools (Barker, 2003). Patterns are an abstract interpretation of common concepts and perceptions of individuals that are represented with the help of symbols, needs, and norms (Habibi, 2003). Pattern language enables the user to create a coherent spatial combination and is a productive system that teaches the person the rules of combination and shows him how to create them (Sameh, 2015). Alexander believes that "mental patterns are nature-driven and are elicited through thinking" (Salingaros, 2004). He considers patterns as a very powerful tool for controlling complex processes, including the process of architectural design and achieving structural and functional coherence (Mohajeri & Ghomi, 2008). Wright also believes that nature is the best source for studying architecture and is the latest model for all designs (Antoniades, 2017). Due to the visual features of designs, nature as a visual stimulus can be inspiring to new learners and serve as a model for their mental imagery. During visual reasoning, mapping takes place in the unconscious mind.

The role of the unconscious mind in the design process

Nature transfers the appropriate instructions to the individual's unconscious mind where past experiences exist. The unconscious mind provides man with the power to manipulate the instructions and make choices. Koestler believes that unconscious thinking is reflected by images (Dandis, 2012), no designers deny the role of the unconscious mind and its effect on the design process (Amini, Flamaki & Keramati, 2019). Mental imagery also originates from the human's subconscious mind and his imaginary power.

• Mental image

New learners of architecture often begin to generate new ideas based on their mental images. After reviewing those images, they start manipulating, changing, and combining their components to create an image that is more compatible with the design problem. The human mind stores images in the deepest parts of the psyche; these images are structures and models that have been acquired during the developmental process (Jung as cited in Eftekharzadeh, 2013). Brief information that human beings create in their minds and use to understand and observe the phenomena of the real world is called mental image (Ghoraba & Tabibian, 2017).

Different methods of creativity teach us how different

interpretations can turn ordinary mental images into architectural ideas (Eftekharzadeh, 2013). Through this reflection and interpretation, creativity evoked by mental images allows one to manipulate the images (Kosslyn & Osherson, 1995) and process the initial idea of the design, which will ultimately shape the main schema of the designers. Since the architectural design is a recurring process, the designer is required to develop the initial idea at each stage and scrutinize the outcome of each stage based on his or her own evaluation and analysis (Schon & Wiggins, 1992), the depiction of mental imagery (mental map) learners at this stage leads to organization and structuring of ideas.

- **Mental map**

In 1943, Craik coined the term "mental map" for the first time. According to researchers, mental maps are images that affect the way humans perceive the world around them. Spicer (1998) refers to mental maps as images that influence human actions and shape his perceptions. Mental maps are basically based on past information and experiences, which are registered in the individual's unconscious mind, and allow him to use previous mental models when confronted with a new problem (Mortazavi & Sheikhi-Nejad, 2017). According to available studies, human mental knowledge is often unconscious, and 95% of his choices occur in the unconscious mind (Zaltman & Coulter, 1995), to which accessing is difficult. This highlights the necessity of using a method that can interpret mental knowledge and transform it into a schema (Christensen & Olson, 2002). Using mind maps, we can be familiar with the mental thoughts of individuals (learners of architecture). Such knowledge can be useful to both new learners and teachers because the mental knowledge of new students can be externalized and reveal it objectively. In so doing, teachers can help learners come up with new options in the design process.

Research methodology

This research is applied in terms of purpose, and terms of nature and data collection, it is exploratory, descriptive and it is field research. Given the data type, it is qualitative. With reference to the qualitative nature of data, predetermined hypotheses limit the discovery of research because unlike physical phenomena, human behaviors cannot be analyzed without discovering their hidden meanings. Therefore, in this research, no hypothesis was formulated. This study attempted to present a consensus map that architecture learners develop in the nature-inspired design process. To this purpose, in-depth personal interviews were carried out and accurate information of each person was collected.

Research Variables

The research variables and their relationships are also shown in Figure 2. The mediating variable of the mental image is an independent endogenous variable and serves as a dependent variable for nature as a visual stimulus (the independent variable) and in relationship with the mental map (the dependent variable) is an independent variable.

Zaltman's metaphor elicitation technique and its history

ZMET technique was first proposed by Zaltman in 1994. This technique assumes that 95% of thoughts occur in the unconscious mind and traditional research methods fail to reflect them (Zaltman, 1996). This technique is based on images and has been designed to elicit people's mental patterns. ZEMT is more reliable than other methods and it has shown good validity in eliciting and interpreting people's mental knowledge (Zaltman & Coulter, 1995; Chen, 2006). In this method, following the interviews, the mental map of each new student is drawn and then the maps are combined, a consensus map of their mental models is elicited (Coulter, Zaltman & Coulter, 2001). The visual nature of the ZMET method helps to understand the visual and spatial relationships in architecture (Luoma, 2003). For this reason, this method has received special attention in architecture. Lincourt selected nine architecture students and asked them to explain their preferences about gardens and landscapes. Data

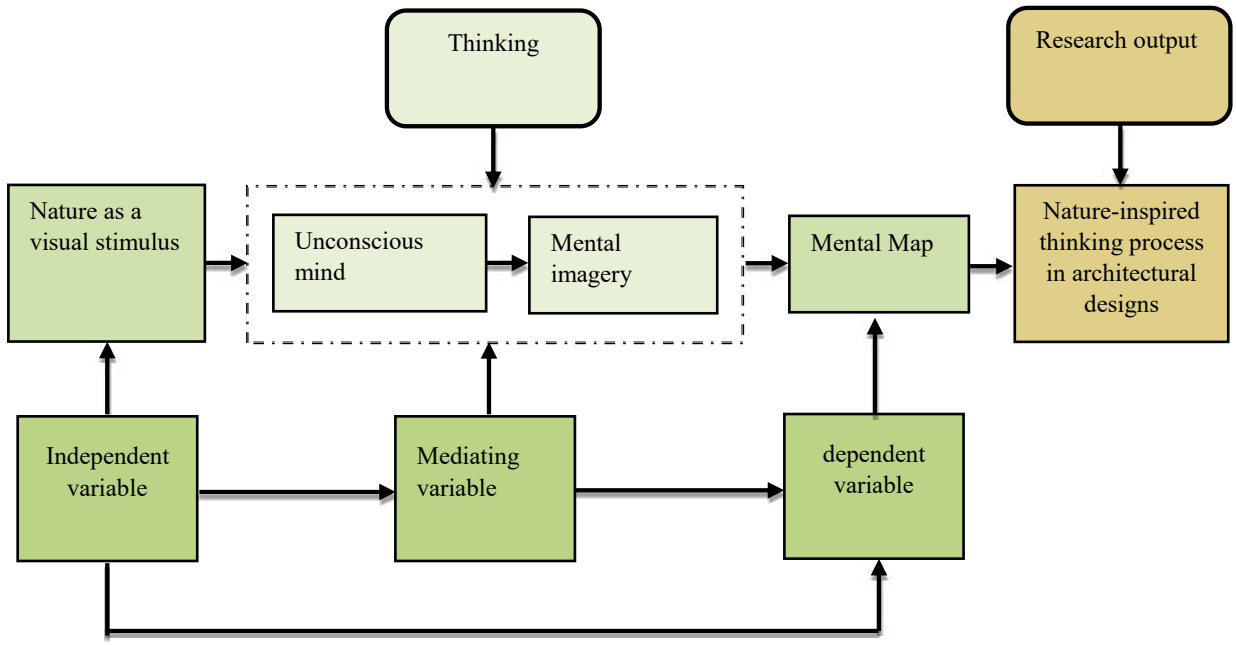


Fig. 2. Research variables and the relationship. Source: authors.

were collected through interviews and photo voices and elicited using ZMETmethod. The aim of this study was to improve the communication between landscape architects and community members and create better data for research and design projects through metaphors and their relationships. Lincourt (2011) concluded that ZMET has potential applications in landscape architecture research and education. Astorino Architecture Company also used the ZMET method in its designs for the Pittsburgh Children's Hospital, an apartment complex, a residential house, and an urban park. To determine and address the needs of patients, families, and staff, the company used the ZMET method. To this purpose, participants were asked to search for images that reflect their deepest thoughts and feelings about children's health care. In so doing, the key metaphors were identified and this led to a revolution in the design of a distinct health center (Conley, 2005). In another study carried out nine graduate students of architecture by Chiu & Chiou (2011), the impact of nature on learners' creativity was investigated with the help of the ZMET method. To this purpose images and a video clip containing seven types of crabs were used as a source of design inspiration. The results of this study showed a strong and stable relationship between architectural design and nature. This reinforced the designers' belief that nature can help designers to develop design ideas. In general, the ZMET method consists of three main steps: before the interview, during the interview, and after the interview. These steps are as follows (fig. 3).

Sample and sample size

In this study, the new students of the 3rd Architecture Project (Continuous undergraduate course) at Islamic Azad University, Rasht Branch, were recruited as the sample of this study in two consecutive semesters in February 1997 and October 1998, and 15 of them were selected as the sample. (The sample size in the ZMET method is small. Validation studies show that in this method four to five in-depth interviews transmit more than 90% of the information9. In slightly larger samples, the interviews can vary from 8 to 16). The sampling method was non-probabilistic and purposive. The sample size was determined theoretically based on the researchers 'judgment and the experience of the students' visits to the museum. Because

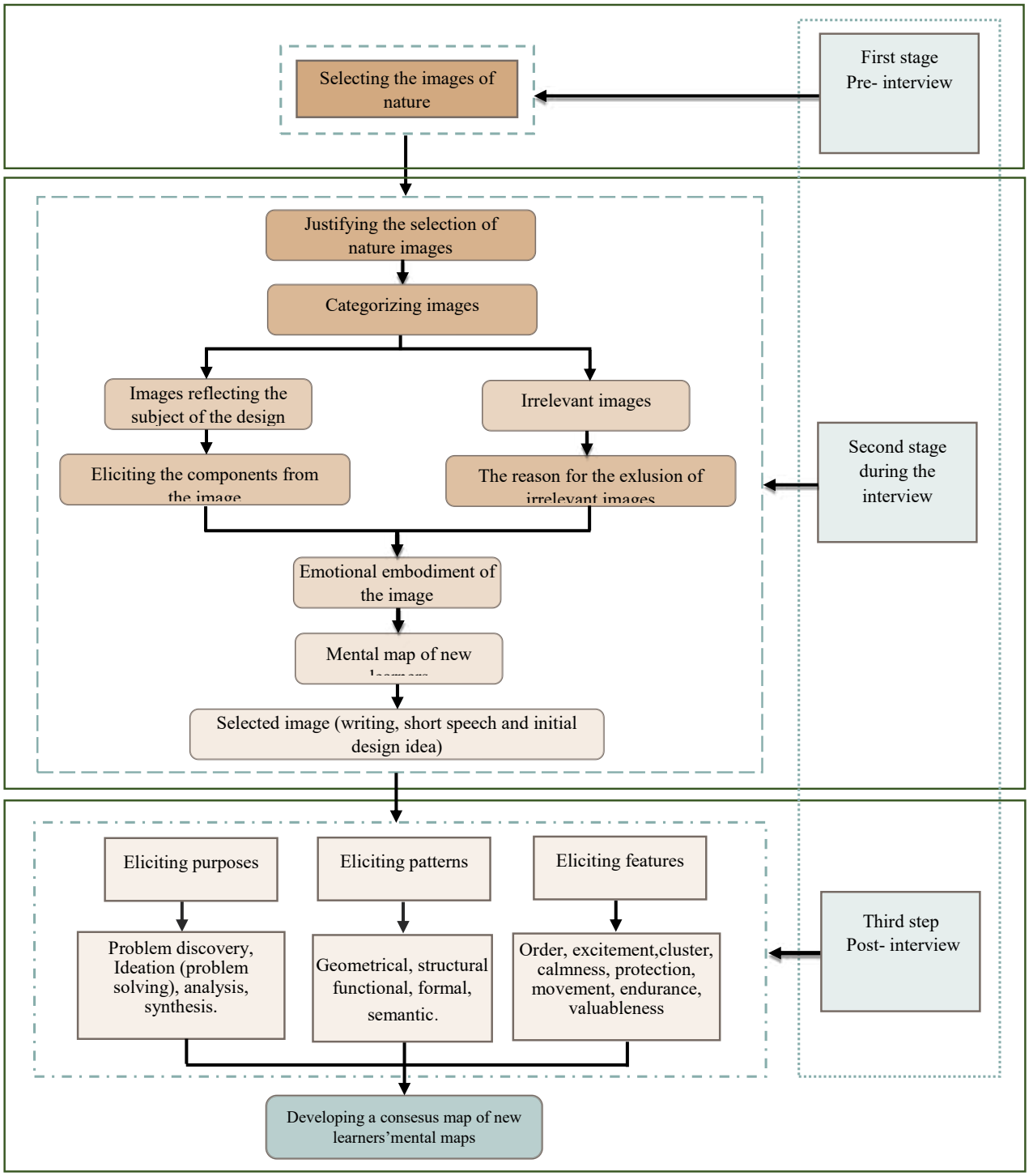


Fig. 3. Stages of evaluating new learners during the architectural design process. Source: authors.
(*Raw mental images originated in nature and the new learners')

in qualitative methods and research, theoretical saturation determines the sample size, the sampling process continued until new codes emerge and the collected data are saturated. Table 1 shows the analytical choices made by new learners along with the nature-inspired examples evoked in the minds (Column 2 of Table 1) based on their experience of attending museums (Column 4 of Table 1).

The research procedure was as follows:

1. Announcing the "Rasht Museum of Visual Arts" as the subject of the project.
2. Using nature as an approach to the design process.

3.Using the ZMET technique to infer and elicit the nature-driven process of design thinking.

At the beginning, the new learners were asked to analyze the characteristics of the visited museums based on their experience (column 4 of Table 1) and to select their desired metaphors of nature (inanimate, vegetal, animal, human) from what they searched, collect, and present the images of nature that reflect their attitude toward the subject of the design (museum) (pre-interview stage) (columns 2 and 5 of Table 4). For example, the P[1] learner searched and presented 12 images of nature. The images indicated his mental pattern of the subject of the design (Column 3 of Tables 2 and 3), and then the interview was carried out with each participant. Tables 2 and 3 present new learners' examples of metaphors that were elicited through the interviews with the learners using the content analysis .

Research implementation steps

1. Justifying the selection of the images of nature: At this stage, during the interview, new learners reported the major changes in their thinking and explained the reason why they selected some images of nature and how the selected image was related to the subject of the design. What features in the museum encouraged them to choose the current images from the ones they searched for.

2. Categorizing images: In this stage, the new learners were asked to describe his / her mentality and categorize the images to come up with new codes and components.

3. Identifying irrelevant images: Students were asked to identify the images that were in sharp contrast to or rarely associated with the subject of the design and then set out their reasons.

Table 1. Features of nature-driven patterns and the authors' analysis of new learners' architecture. Source: authors.

New learners' code	Selection of examples from nature	Gender	**Museum visited by the new learners**
P1	Shell	M	Museum of Sacred Defense (Tehran), Museum of Anthropology (Ardabil), Mirza Kuchak Museum (Rasht), Armitage Museum (St. Petersburg)
P2	Sansevieria	M	Museum of Contemporary Art (Tehran), Museum of Glassware (Tehran)
P3	Dinosaur	M	Louvre Museum (Paris), Hagia Sophia Museum (Istanbul), Miniature Museum Garden (Tehran)
P4	Cactus	F	Museum of Contemporary Art (Tehran), Museum of Nature and Wildlife (Tehran)
P5	Eye	F	National History Museum (Baku), Haidar Aliaf Museum (Baku), Mirza Kuchak Museum (Rasht), Hegmataneh Museum (Hamedan)
P6	Swallow	M	Falak Al-Aflak Museum (Khorramabad), Qajar Museum (Tabriz), Sultan Ahmad Museum (Istanbul), Niavaran Museum (Tehran)
P7	Hive	M	Glassware Museum (Tehran), Haidar Aliaf Museum (Baku)
P8	Frog	F	Mirza Kuchak Museum (Rasht), Qaz Qala Museum (Baku), Bu Ali Sina Museum Hamadan)
P9	Spinal cord	F	Money Museum (Tehran), Peace Museum (Tehran), Museum of Nature and Wildlife (Tehran)
P10	Shell	F	Anthropology Museum (Isfahan), Vanak Church Museum (Isfahan), Mirza Kuchak Museum (Rasht)
P11	Peacock	M	Rasht Museum (Rasht), Rural Heritage Museum (Rasht), Golestan Palace (Tehran)
P12	Sea wave	F	Mirza Kuchak Museum (Rasht), Rasht Museum (Rasht)
P13	Walnut shell	M	Museum of Contemporary Art (Tehran), Vanak Church Museum Isfahan),Museum of Nature and Wildlife (Tehran)
P14	Spider's web	M	Mirza Kuchak Museum (Rasht), Haidar Aliaf Museum (Baku)
P15	Snail	M	

Table 2. The desired patterns and metaphors selected by P1 from nature. Source: authors.
(Note: ✓shows the final selection of P1)

Description / Nature	Features	Pattern of nature	Metaphor
Inanimate	Stability	Stone	Fossils show years of preservance and immortality.
	Attraction	Soil	
	Memory	Fossil	
vegetal	Protection	Cactus	Sansevieria represents endurance, perseverance and long-term hard work.
	Endurance	✓ Sansevieria	
	Stability and sturdiness	Palm	
Animal	Protection	Spider's web	The spider's web is a symbol of protection.
	Power	Tiger	
	Constant effort	Badger	
Human	Heart	Emotion	Human memories are recorded in his mind.
	Human skeleton	Durability	
	Brain	Recording memory	

Table 3. The desired patterns and metaphors selected by P2 from nature. Source: authors.
(Note: ✓shows the final selection of P2)

Description / Nature	Features	Pattern of nature	Metaphor
Inanimate	Valuableness	Diamonds	Structure and materials used in diamond convey a sense of value to humans.
	Protection	Cave	
	Memory	Fossil	
vegetal	Preservation	Stem	Flowers creates a sense of attraction because of the colors and patterns
	Attraction	Flower	
	Stability and sturdiness	Palm	
Animal	Calmness	Fish	The role of oysters in the preservation of valuable substances (pearls) is inspiring.
	Valuableness	Shell✓	
	social interaction	Bee	
Human	Sentiment	Heart	Human heart is full of emotions.
	Stability	Tooth	
	Unity	Foot movement	

4. Justifying the exclusion of some images: During the interview, the new learners explained the reasons for excluding other selected images, their views or mentality they had from the selected image, that they

have now seen them as irrelevant or unrelated to the subject matter.

5.Selecting images reflecting the subject: Among the images presented by the new learners, each student chose one of the most efficient images that in his or her opinion was strongly associated with the subject of the design. In the design process, he observed its features and analyzed its information and then used it

6.Eliciting the components from the images: Analyzing the mental structures of the new learners in response to the selected images led to identifying the components they were looking for in the selected images. The components were specific to those images and were the main reasons why the learners had chosen the image. These components led to the understanding of patterns reflecting the new learners' conscious selections of the images. Eventually, these patterns helped in fulfilling the main objectives based on which the learners had chosen their patterns.

7. Practicing embodiment of emotion: At this stage, learners were asked to use their five senses to describe their chosen images and explain their experience about nature-driven ideas through these senses in comparison to the subject of the design.

8. Drawing a mental map: In this step, each of the new learners was asked to draw their own sketch using the components extracted from the previous steps.

9. Conveying the thought process based on the selected image: New learners were asked to summarize their thinking process separately in three ways: writing, short speech, and initial idea design.

10 . Developing a consensus map of mental models: After compiling the maps, a consensus map of mental models was developed based on the common ideas to show nature-driven design.

A total of 180 images of nature were searched and selected by new learners (columns 2 and 5 of Table 4) which were mainly used for eliciting their mental information about the museum (columns 3 and 6 of Table 4) and in the first seven stages of research. Table 4 shows some of the images received from new learners.

Discussion

After data collection, we combined the mental maps of the new students to develop a consensus map. At this stage, we replaced the stated associations and features with close and similar meanings reflecting a common concept. This helped us to develop a more readable centralized consensus map to elicit the mental knowledge of new learners. For example, the concepts of memory, history, and movement (A journey from the past to the present), expressed by three different learners were all coded as a movement. In the ZMET method, the components need to be mentioned at least by one-third of the sample size, and one-fourth need to indicate the communication codes (inter-component relationships) (Zaltman, 1997) to be included in the consensus map. Therefore, to enhance the accuracy of data analysis, in general, we selected the components and relationships with the frequency of 4 and incorporated them into the consensus map, and we discarded the items whose frequency was less than 4. In the following section, three general categories of components (features, function, and purpose) are described in detail.

Features of the subject of designs

Features include concepts and mental associations of the new learners about the museum (the subject of the design). Each participant explained the characteristics of the museums based on his or her views, definitions, previous experience, and attitudes towards the places he had visited. The most important features of the museums from the new learners' point of view are presented in Table 5 (first column of Table 5). Protection and movement with 8 frequencies emerged as the most important features of the museum. This means that, according to the new learners, the museum is a place where valuable artifacts are preserved and displayed and is a journey from the past to present, and for them, these concepts, more than any other features were inspiring in designing museums. Other features and frequencies of their use by the participants can be seen in the table

Table 4. Images received from new learners. Source:authors.

No.	Image	Metaphor used by new learners	No.	Image	Metaphor used by new learners
1		Stability and sturdiness	12		Endurance
2		Movement and motion in a fixed place	13		Stability and antiquity
3		Stability and movement	14		Security and social interaction
4		Sentiment	15		Light and sight
5		Thinking and recording events	16		Stability and resistance
6		Protection and strength	17		Security
7		Protection	18		Strength
8		Protection	19		Antiquity
9		Historical value	20		Valuableness and protection
10		Resistance and durability	21		Beauty
11		Protection and endurance	22		Calmness

- **Patterns in nature**

Each of the features described by the new learners about the museum (Table 5) contributes to the objectivity of mental concepts. It also reflects mental dimensions and shows how the geometry of a building, the activity contributing to a readable function, the created structure, the attractive shape, the composition of a building, and color can make the designs vivid. It is noteworthy that the features refer to the feelings and mind-set of the designers about the subject of the design (museum) which they encountered or not encountered, and it is not clear how these features or characteristics enter the design process.

Each learner consciously chose patterns from nature in the design process based on the characteristics of the museum described and their selected image. The patterns refer to the perceptions that learners had about their selected images (examples in nature) based on the characteristics of the museum and used in the design process (see Table 6 for classification). As mentioned earlier, components with a frequency of fewer than 4 times were excluded from this category. Meanwhile, semantic, structural, and geometric patterns with 12 and 10 times were the most prominent, and a large number of learners benefited from them. For example, relying on the valuableness, movement, calmness, and excitement of the museum and being inspired by nature, P 5 used formal, functional, and geometric patterns in the design of the museum and the results of the interview highlight these features. These patterns are shown in Table 6.

- **Purposes**

Finally, the emerging patterns from the features of the selected images were used in the design processes by new learners. Thus, after conducting interviews with them and reviewing their design processes, we determined at what stages of each design process each new learner used these patterns. Table 7 shows at which stage, these patterns helped each new learner, and at what stage they

Table 5. Features of the museums chosen by the new learners. Source: authors.

Features	Definitions and examples derived from the quotes of new learners in the interview	Frequency
Protection	. The purpose of museums is to preserve objects of high value	8
Movement	A museum is a place where people experience going through history and displaying the history	8
Valuableness	A museum is a place where valuable historical and artistic artifacts are displayed	7
Calmness	A museum is a resting place for relieving human stress.	7
Collection	A museum is a place where beautiful, precious, rare objects are collected and people of the same tastes gather together	6
Endurance	A museum is a lifelong and enduring place in the preservation of human remains.	6
Excitement	A museum is an attractive space where a sense of excitement and fun is created for the audience.	5
Order	Arrangement and classification can be seen in the works in the museums.	4
Peace	One of the missions of museums is to promote a culture of peace by reflecting the dire consequences of war and violence.	3
Evolution	In the museum, one can see the process of human evolution.	2
Thinking	A museum is a place for thinking and arguing	2

Explanation: features including protection (8 times), movement (8 times), valuableness (7 times), calmness (7 times), cluster (6 times), endurance (6 times), excitement (5 times) and order (4 times) were selected by the new learners and to enhance the accuracy of data analysis, the feature with the frequency less than 4 were removed from the analysis process.

Table 6. Nature-inspired patterns selected by the new learners. Source: authors.

Pattern	Definition	Examples of students'quotation	Frequency
Semantic	A sense of security and, tranquility excitement, endurance, movement	Value of works, a sense of security and tranquility, excitement, endurance, movement	12
Structural	It represents the mental dimension and is the tool that an architect uses to create what he or she wants.	Valuableness. I feel like I'm moving into a history museum. A museum is a place where old objects are protected A museum is a calming place. I feel excited and happy in the museum	10
Geometric	The basis of architectural work is a construction which requires a precise geometry and order.	Order, endurance, valuableness, movement, protection, calmness, excitement.	10
Functional	It includes activities or sets of responses that lead to effective outcomes in the environment.	The value of the works in the museum, the sense of endurance in the museum, the protective role, the feeling of peace and comfort, the collection of important works, exploration of history and the past, feeling of excitement in the museum, and the order of things.	9
Formal	It is a man-made structure that includes components with complex relationships.	Protection, endurance, cluster	5
Motific	It presents a new attractive shape and composition in the building.	Calmness, excitement, order	1
Colorful	Color can change moods, spaces, and improve a person's mood.	Calmness, excitement	2
Textural	It makes the structures in architecture look more vivid	Excitement	1

Explanation: Patterns, semantic (12 times), formal (10 times), geometric (10 times), functional (9 times) and structural (5 times) were selected by the new learners and to enhance the accuracy of data analysis, the feature with the frequency less than 4 were removed from the analysis process.

unconsciously used the design process. According to experts, what is similar in most architectural design processes is the existence of five stages of problem discovery, problem-solving (ideation),

analysis, synthesis, and evaluation (Mahmoodi, 2001; Dubberly, 2004; Lawson, 2005; Mozaffar & Khakzand, 2008; Bagheri & Mardomi, 2011; Lillian, Abedi, Baghaei & Bahrami, 2017; Jabal Ameli, Mozaffar, Karimi & Ghasemi, 2018). Therefore, the same steps were selected as the target components and were used to elicit the designs, in which step the selected models of the learners were involved and affected. According to Table 7, learners used patterns in the stages of ideation, problem discovery, and synthesis, respectively, by selecting 12, 9, and 8 times more than other steps in the design process, respectively.

Finally, by aggregating the three tables, we elicited major components from the mental maps of the new learners.

- **Relationship of the components**

Features, patterns, and purposes are the metaphorical or conceptual components of research that are related to each other. A consensus map was developed by eliciting these connections through interviews with new learners. What helps to clarify the process of pattern-based design thinking from nature is the creation of a consensus map as the final step in the ZMET method, which was the result of the mental maps of each student and was drawn according to Figure 4. The numbers in this chart are extracted from Table 8, which shows the relationship between the components. For example, in Table 8 and Figure 4, the relationship between the calmness and the formal pattern and the relationship between the formal pattern and the discovery of the problem are highlighted for a better understanding of the subject. In the consensus image, arrows show the relationship between components while numbers depict the frequency of the set of connections between components. Figure 4 shows components at three levels of features, patterns, and purposes.

Table 7. The purposes of using patterns by new learners. Source: authors.

Purposes	Definition	Examples derived from the quotes of new learners in the interview	Frequency
Problem-solving (ideation)	Outlining the main concerns that require to be addressed by reference to basic concepts. This will facilitate the process of the problem-solving	Design problem: transparency and readability in the direction have been the main idea. -The grandeur of the museum building as the main idea can lead to the concept.	12
Problem Discovery	Finding the right questions that are worth answering.	The main idea in the design of the museum is displaying values over time. -The issues of stability and sustainability in the museum are important. -Moving from old to new can be valuable issues in museum design	9
Synthesis	Establishing the connection between the elements and understanding their role in general and putting all the elements together to form a new format.	- Linking and combine the analyzed components of the selected image to solve the problem. -Connecting the elements of the selected pattern of nature and creainga new concept.	8
Analysis	Separating and selecting of components and elements.	Identifying and analyzing the elements of the selected image for synthesis Analyzing the components of the selected nature to arrange them in a new format	4
Evaluation of Initial Ideas	Determining the applicability of the initial idea.	Paying attention to the function, stability and form of the initial idea in relation to the design idea. Investigating the readability of the relationships of the combined spaces in the new format in response to the needs of the design.	3

Explanation: Ideation (12 times), problem discovery (9 times), synthesis (8 times) and analysis (4 times) were selected by the new learners and to enhance the accuracy of data analysis, the feature with the frequency less than 4 were removed from the analysis process.

Table 8. Components elicited from the mental maps of the new learners. Source: authors.

Objective examples	New learners' code	Features								Patterns					Purposes			
		Valuableness	Endurance	Movement	Protection	Calmness	Cluster	Excitemenr	Order	Semantic	Formal	Functional	Structural	Geometric	İdentification of problem	Problem solving (ideation)	Analysis	Synthesis
Shell	P1	✓		✓	✓		✓			✓		✓		✓	✓	✓		✓
Sansevieria	P2	✓	✓			✓				✓		✓	✓			✓		✓
Dinosaur	P3	✓	✓	✓				✓		✓	✓	✓	✓	✓	✓	✓		
Cactus	P4		✓		✓	✓				✓	✓	✓			✓			
Eye	P5	✓		✓		✓		✓			✓	✓		✓	✓	✓	✓	
Swallow	P6			✓		✓	✓		✓	✓					✓	✓		
Hive	P7	✓			✓		✓	✓		✓	✓	✓	✓	✓			✓	✓
Frog	P8				✓	✓						✓				✓		✓
Spinal Cord	P9		✓		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓		✓
Turtle	P10			✓	✓					✓		✓			✓	✓		
Peacock	P11	✓		✓		✓	✓		✓	✓	✓	✓		✓	✓	✓		
Sea Wave	P12			✓				✓		✓	✓			✓	✓			✓
Walnut Shell	P13	✓	✓		✓					✓	✓		✓	✓		✓	✓	✓
Spider's Web	P14		✓		✓		✓		✓	✓	✓			✓		✓		✓
Snail	P15			✓		✓					✓			✓		✓	✓	
Total		7	6	8	8	7	6	5	4	12	10	9	5	10	9	12	4	8
Ratio		13/0	11/0	15/0	15/0	13/0	11/0	09/0	07/0	26/0	21/0	19/0	10/0	21/0	27/0	36/0	12/0	24/0

Explanation: For example, the ratio of the semantic patterns used by the new learners for the subject of the design is 26%. This percentage was obtained by dividing 12 (the number of the semantic patterns selected by the new learners) by the total number of components chosen at the pattern level (12 + 10 + 9 + 5 + 10).

As can be seen, some components have more connections. From 17 elicited subcategories, 13 subcategories including valuableness, endurance, movement, protection, calmness, excitement, form, meaning, geometry, performance, problem discovery, problem-solving, and synthesis shape a strong network called the nature-inspired central network of architectural design. For example, the "protection" feature with 5 outputs, the "semantic" pattern with 8 inputs and 3 outputs, the "geometric" pattern with 7 inputs and 4 outputs, and the "formal" pattern with 6 inputs and 4 outputs have the most relationships with the other components. The purpose of "problem-solving (ideation)" with 5 inputs, "problem discovery" and "synthesis" with 4 more inputs have been mostly used by the new learners, and others such as "cluster" and "order" at the level of features, "structure" at the level of

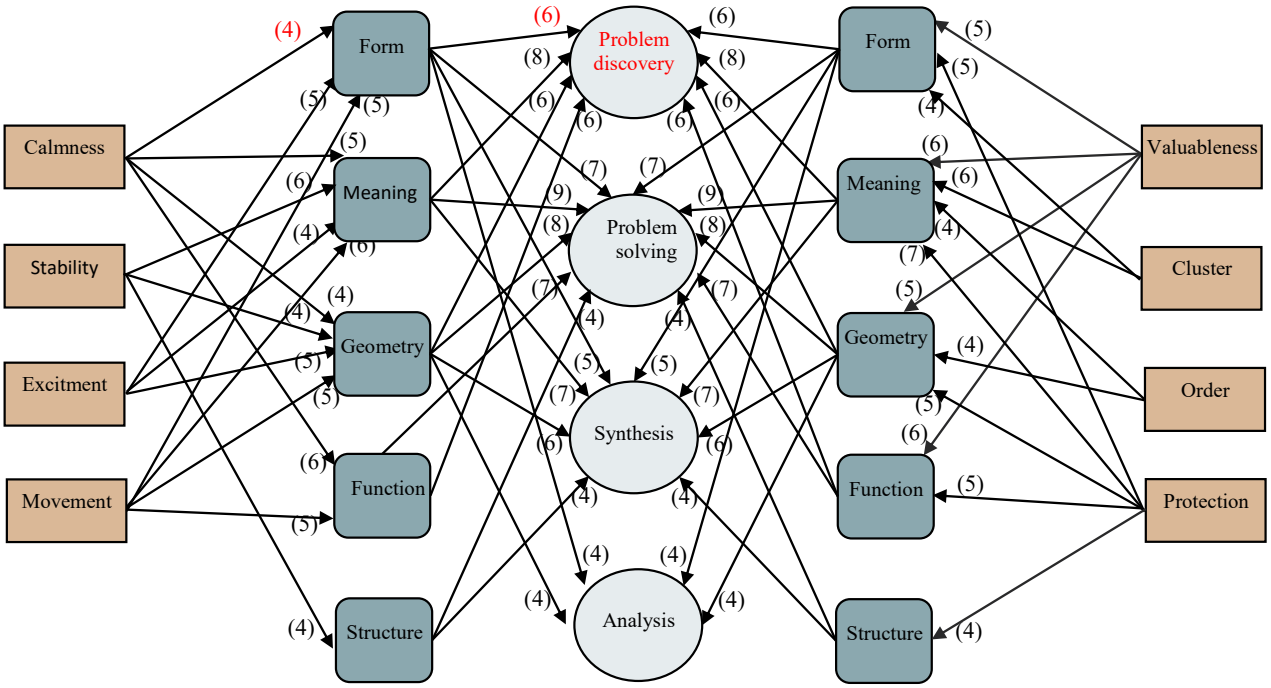


Fig. 4. A Consensus map of the new learners in designing museum inspired by the patterns in nature. Source: Authors. (Rectangle: Feature-Square: Pattern-Circle: Purpose)

patterns and "analysis" at the level of purpose have been rarely used in the network. Probably future studies can examine their relationship with the main network. Figure 5 presents the samples of the designs prepared by the new students, and Figure 6 shows the application of the ZMET methodology in the architectural studio and different stages of its implementation in the design studios

Result & Conclusion

The impetus behind this study was to access the mental representation of learners to understand how learners used nature in the architectural design process. This study was an attempt to determine the mental map during nature-inspired design and to understand at which stages of the architectural design process, it can be more helpful. Using the results, learners can be effectively guided and helped in the design thinking process.

New learners and designers have less access to the right mental imagery than their experienced counterparts since they are not experienced enough in architectural design. Therefore, introducing appropriate visual images as visual stimuli can be effectively used in the design process. Nature can be used for visual stimulation of design learners, and given its capabilities, it can be a case to discover similarities, associate meanings, and interpret them from the perspective of design, experience, and learning. The results of the present study echo the results of previous research (Lincourt, 2011; Conley, 2005) and indicate that employing metaphors in nature and the discovering relationships between them indicates the depth of thoughts and feelings of the viewers and, Chiu & Chiou (2011) indicated a stable relationship between architectural design and nature. But what has been overlooked in previous research is the role of nature and its contribution to learning in the stages of the architectural design process, as well as its impact on the mental map of new learners. According to the results of research and analysis, the process of architectural design, new learners have mostly benefited from nature at the stage of ideation.

The obtained consensus map also suggests that nature has inspired learners in their architectural designs, 26% used it for semantic analysis of the characteristics of the design project. 21% of them

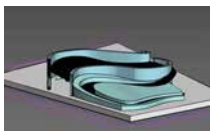
New learners' code		Pattern	Final Project	No		Pattern	
P1	Shell	Semantic Functional Geometric	 	P5	Eye	Formal Functinal Geometric	 
P2	Sansevieria	Semantic Functional Structural	 	P10	Turtle	Semantic Functional	
P3	Dinosaur	Semantic Formal Functional Structural Geometric		P14	Spider's Web	Semantic Formal Geometric	 
P4	Cactus	Semantic Formal Functional					

Fig. 5. Sample of designs prepared by the new learners. Source: authors.

mostly used nature in the formal and geometric patterns and 36% used it for finding and creating ideas, which account for a big share of the design process. The results highlight the necessity of promoting nature-inspired design in architectural studios and future studies.

The main of this study is to raise awareness of the mental associations of learners in response to the patterns in nature to improve the architectural design thinking of learners. As a result of the authors' theoretical findings from other previous research, it became clear that a mind map is a creative approach that subconsciously leads learners to deep imagination and visualization on the subject of design and shapes and creates diverse ideas in their minds. The design of initial ideas and interviews with learners are used as resources to understand the impact of patterns in nature on the design process

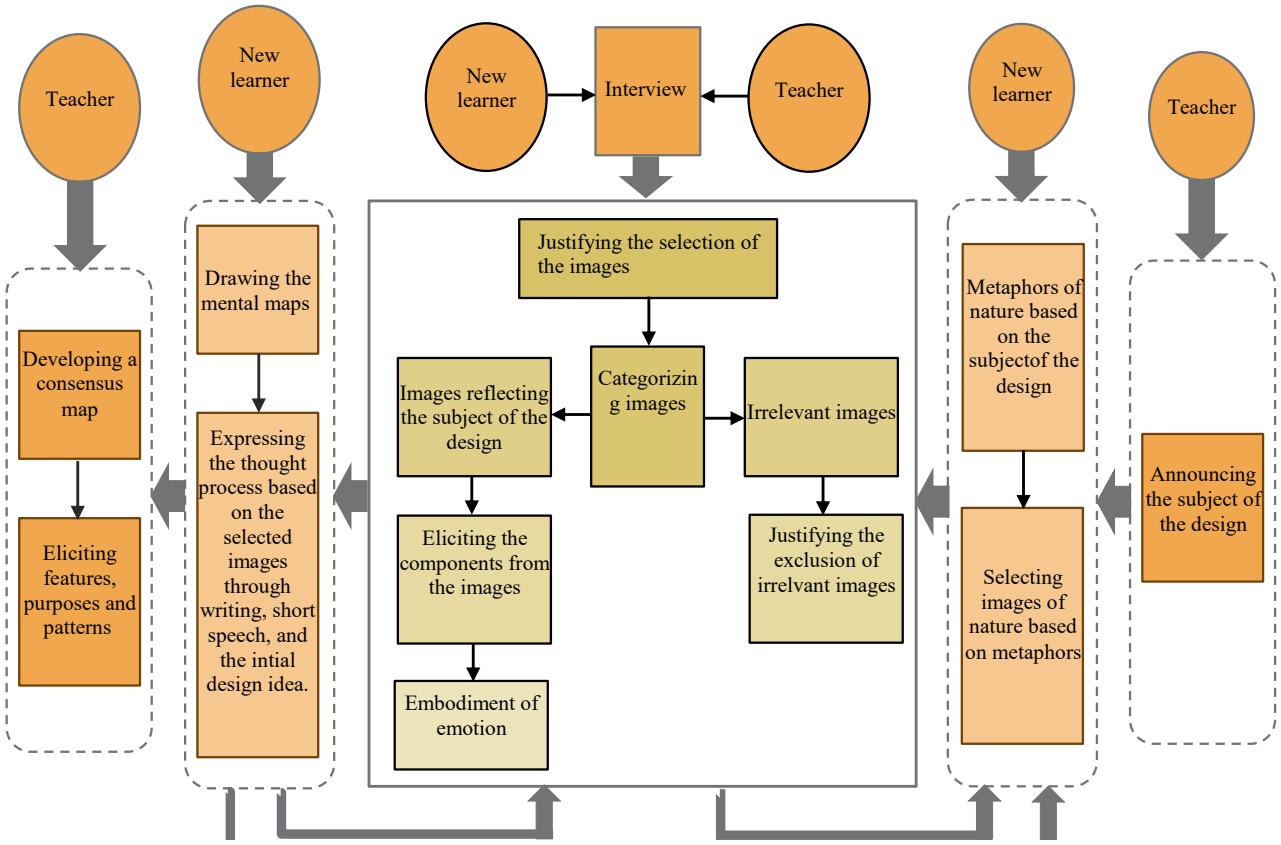


Fig. 6. Implementation of the ZMET methodology in the architectural studio. Source: authors.

As a result, given the process mentioned in the preparation of the mind map, learners can think about the subject of design in different centralized ways (writing, short speech, and initial idea design). This process will enhance their creativity. Future studies can examine the method and results of this research by focusing on the other functions (except museums and formal uses). It is hoped that the proposed concepts of this research and the mental maps of new learners in the nature-inspired thinking process in architectural designs serve as a springboard for future studies and training in studios. It is suggested that quantitative research should be carried out to focus on the creativity indicators of the designs obtained from this method in architectural studios for new learners. Design thinking as an introspective behavior is influenced by factors such as place, time, gender, and individual factors. Therefore, results and analysis may vary if different factors are included. All of the factors can be explored in future studies

Endnote

1.Nature refers to its examples driven from inanimate, human, animal, and vegetal patterns. The different meanings of nature can be described under three general categories of the perceptible world, essence, and origin of the world and have two tangible and intangible aspects. This study has focused on its tangible aspect.

2.The term metaphor means borrowing or using a word to refer to something which is not literally relevant but there is a similarity between their meanings or they share a commonality in a single adjective.

3. Mental image is the active part of our mind that makes us act and shape ourselves. These mental images affect our view of the world and, accordingly, affect our choice (Shepard, 1978).

4. Zaltman Metaphor Elicitation Technique (ZMET) is a technique for eliciting people's unconscious mental structures.

5. Bionic is derived from the Greek words "bios" (nature and life) and English "technics" (technique). Bionic architecture, which can be considered as a nature-inspired architecture in general, can play an important role in the ideation and creativity. Nowadays, this field is very popular with designers, especially architects. The goal of bionic design is to apply knowledge of nature innovatively and is never considered an independent profession. Bionics is the extraction of natural biological knowledge that can be used as the basis, model, and source of inspiration and creativity for architectural designs.

6. Reasoning involves the two processes of "image perception" and "interpretation of image content" that interact with each other (Goldschmidt, 2013).

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