The Transformation of Architectural Design Concepts During the Early Design Phase

https://doi.org/10.3991/ijep.v12i6.31717

Nahedh Taha Al-Qemaqchi(✉)
Department of Architectural Engineering, Cihan University – Sulaimaniya, Sulaimaniya, Kurdistan Region, Iraq
nahith.taha@sulicihan.edu.krd

Abstract—The most difficult objective for students in an architectural design studio is to produce a design concept satisfyingly. This is due not just to the difficulty of selecting an appropriate method of approaching concepts, but also because of the many transformations associated with the concept's evolution over time. This research examines the modifications that occur throughout the conceptual phase of a design session. We hypothesize that while students' conception methods have been more abstract in creating a concept, they are subject to more alterations during the early phase of design. The research conducts concept generation and transformations by monitoring a group of fourth-grade architecture students through their design process. It also tries to link those transformations to the various methods utilized by students to create their concepts. It appears that the transformations that occurred throughout the design sessions were either formal or functional-oriented. Observations clarify that those transformations are linked to the sort of concept generating, which is either abstract or concrete. By observing the design sessions, the research was able to confirm that the modifications implemented to the design concepts were tied to the nature of their selection of methods of production. When compared to concrete nature concepts, abstract nature concepts were more vulnerable to transformations throughout the conceptual phase on the scope of form and function.

Keywords—architecture design, concept generation, design methods, concept transformation

1 Introduction

The design studio teaching technique is commonly utilized in a current architectural design college education, in which lecturers use their experiences to aid students in their learning [1]. Following the preparation of a brief that typically highlights the major concerns related to the project, the traditional design session proceeds on to the conceptual phase, which typically lasts three to five weeks [2]. The student is trying to produce a concept during this phase through a range of learning approaches such as classroom design modifications, reference materials, self-exploration, and peer assessments. During this phase, students attempt to tackle the most critical challenges of the assignment with a highly creative design idea [3].

As Lawson noted [4], the conceptual phase appears to be a negotiation between the design problem and the design solution, and it lasts until the student is satisfied with the proposal. This means that until the timer runs out, the product will undergo several modifications. These changes typically reduce as the students near the deadline of the conceptual phase and are forced to reach a solution, with which the process of maturing those concepts begins [5].

2 Literature review

2.1 A concept in architecture

The architectural literature includes various definitions of the term "concept". They encompass a wide range of meanings, beginning with the idea and ending with the project proposal [6]. Taura and Nagai defined the concept as "perceptions that arise in the mind and which are expressed by cognitive units of communication that were a symbol, a term or a scheme" [7]. The mental representation that the brain employs to identify a class of symbols that are inferred from physical information is also denoted as a concept. Eilouti defined the concept as "the mental map that assigns meanings, links components, enhances creativity, and guides the design process to produce a design product" [5]. Sometimes, it is difficult to read the concepts through the design output in architecture, this is due to the difficulty of capturing the concept by the recipient and the difficulty of conveying the overall architectural message by the designer. Many students and novice architects experience the difficulty of translating mental content into epistemic units perceived by others, as a result of associating their design ideas with conceptual content that is not easily translatable in the architectural setting [8]. This impedes the achievement process and necessitates a lot of modifications during the design mission. The modifications that occur during the early stages of design are heavily influenced by the sort of design mission and the available information processed during the mission [9].

The concept modification occurs also throughout the ideation creative process and results in what is commonly referred to as "conceptual shifts." These shifts typically occur when components on the diagrams presented that were once regarded as one concept are viewed as another [8].

2.2 Concept and design

Unlike most other disciplines in the university system, the architectural curriculum is structured around a single, favored, "core" subject: design. Design is a decision-making process that yields approaches and methods for transforming resources into problem-solving solutions [10]. The architectural design process is regarded for its high specificity in the field of achieving an equal fit between the proposed capabilities and constraints [11].

The designer's desire to produce innovative forms, configurations, and relationships and he/she advances in his/her thinking successively between the initial state of the design data and the final design objective or what it will be. In this mental movement,

the designer tries to create a kind of dialogue that includes formation and reconfiguration based on his assessment of the target's state, then he moves freely to achieve the desired goal between what is abstract such as spaces, functional relations, internal and external circulation systems, and what is concrete as form, masses, and configurations [12]. The concept is often associated with the design process, which also has a wide spectrum of definitions. Most design researchers used frameworks based on a problem-solving process model to explain the rationale design process of that time. Indeed, design can be seen as an example of a process of construction whose aim is to solve ill-structured problems that lack clarity in terms of both the existing situation and the desired outcome [3].

Design concepts developed in the early design phase are critical because they influence the rest of the design realization process and impact design success. During the entire design session, this phase is commonly referred to as the conceptual phase [13]. It is a few weeks long and consists of two primary activities: the creation of a generic design concept and the graphic depiction of the design concept in the form of conceptual sketches and diagrams [14]. In recent years, as a result of the conditions that architecture schools have suffered due to the (COVID 19) pandemic, which showed the possibility of leading the design process remotely by instructors [32], the design idea preparation stage remained a difficult stage as a result of the loss of the atmosphere of enthusiasm associated with the architectural design studio and the absence of discussions with classmates, which can be a strong supporter of design in its initial stages [33].

Protocol analysis either retrospective or prospective has been widely used as a method to analyze the activities and find meaningful patterns from verbal protocol data. A design state relies on what has been produced by the series of episodes; whether incremental (continuous evolution of the prevalent paradigm), transformational (bringing new elements to the concept under development), or changeable (directing the design concept to the new one). As Goel previously stated, the transformation of ideas in the design process takes two types: vertical transformation develops the initial concept by adding more details to it; lateral transformation changes the existing concept to explore new ones, leading to a divergent style of thinking [15]. In an experiment on groups of students, Al-Qemaqchi observed that the nature of the cognitive activity associated with concept generation varied depending on the type of design task. The more symbolic the design tasks, the more abstract the activities become (e.g., creating assumptions and ideologies). Conversely, the more solid the design tasks were, the more sensory the activities become, (e.g., utilitarian and pragmatic processing) [8].

2.3 Concept and sketches

Architects (designers), according to Lawson, find it impossible to think without a pencil in their hand [16]. Designer ability is considered as designer fluency in sketching as a cognitive tool for the creation of the design [34]. These sketches are normally significant in achieving a good design. Although most designers are educated to sketch, what is drawn on the sketch may not exactly reflect what is in their heads. Sketches (visual or physical externalization, in a broader sense) provide key clues to

understanding the designer's ideas as well as the evolution of a design process [17]. As a result, it is evident that by integrating the trails of design activities and external presentations, we can have a more informative approach to showing and understanding the design process.

The sketching process is in the form of lateral and vertical concept transformation. Lateral transformation indicates the exploration of slightly different concepts and widening the possibilities while vertical transformation entails producing sketches in deepening and more detailed versions of the same concepts [13]. Many studies have looked into the role of sketching in design and how might aid to improve concept generation in design thinking [4, 18, 19, 20, 21, 31]. Sketching assists the designer in discovering unintended outcomes, the surprises that keep the design investigation moving in what Schön and Wiggins refer to as the reflective conversation with the problem' that is distinctive of design thinking [22]. The 'dialectics of sketching' is a conversation between 'seeing that' and 'seeing as,' where 'seeing that' is an introspective critique and 'seeing as' is analogical reasoning and reinterpretation of the drawing that prompts creativity [20]. Sketches enable the designer to perform not just vertical but also lateral transformations inside the solution space: the creative shift to new possibilities throughout the sequential development of a design concept. The uncertainty inherent in sketches is a positive aspect of the sketch as a creative tool [15]. In their protocol analysis, Suwa and Tversky discovered that there are four types of information incorporated in student sketches. Each of these categories included several subclasses, which together comprise the sketches produced by the student during the conceptual design phase [23]:

Emerging Properties: related to the generation of spaces, shapes, things, and angles.
Spatial Relations: deals with sizes, local relations of spaces, and global relations of the general composition.
Functional Relations: concern the practical roles (e.g., adjacency), abstract features reactions (e.g., forces) views, lights, and circulation of people/cars.
Background Knowledge: This accommodates the concept with the structure and site setting.

2.4 Generation methods and transformation

At the cognitive level, it is widely accepted that the design process consists of a sequence of design activities. They are described as imaging-presenting-testing [24], analysis-synthesis-evaluation [16], or seeing-moving-seeing [22]. Goals and objectives are generated through the analysis. Concepts are created through synthesized ideas and notions. Both concepts and goals are evaluated, and they go through more evaluation and synthesis. These actions are carried out iteratively rather than sequentially [35]. Thus, design is an iterative process where schemes are recognized, explored, revised, and enhanced until a solution is identified. During the conceptual design phase, this iterative or cyclic process is more visible. It is a time brimming with ideas, difficulties, and innovation [23].

Broadbent attempts to build a design approach for architects and outlines four techniques for developing design form, which he refers to as pragmatic, iconic, analogical, and canonic [25]. He identifies these approaches through a study of architectural

history, in which they can be proved to have been applied in various eras. Conjectures and refutations are two components that Broadbent uses to characterize the design process. According to Broadbent, the designer goes through a series of conjectures (ideas) and refutations (idea abandonment).

McGinty identified six components that form concepts in architectural design. Those components were ideas, super organized ideas, notions, (parti & esquisse), themes, and literal concern. He proposed that by using one or more of those components, the architect can approach the concept by one of the following approaches [26].

Analogy; in the area of architecture, is one of the most prevalent forms of concept-generating techniques. Ideas for this sort of concept come from a variety of sources. It refers to the process of simulating design concepts with external references.

Metaphors & Similes; emerge from the modelling of relationships between objects and differ from the first in that the link is unclear, allowing for interpretation and a variety of interpretations.

Essences; Rather than dealing with similarities, this technique conducts concepts via the ideologies used for generations.

Direct Responses & Problem Solving; Refers to the pragmatic concerns that predominate the architect when carrying out the concept.

Ideals; This sort of concept is focused on the designers' unique ideas and attempting to accomplish them on their own.

Eilouti identified eight methods of concept derivation during the design process. These methods are wider than what Broadbent suggested. A concept may be derived using one or more of the following eight methods [5].

Theme: launched by selecting a topic derived from the culture.
Analogy: depending on the similarity with an object.
Metaphor: focusing on meanings, and emotions, more than similarity.
Experience: emphasizing the experience that potential user expects or desires to live.
Symbolism: depending on a reference, it uses the language of memory.
Context: depending on the direct or indirect context.
Scheme: based on geometry, materials, or technology
Scenario: referred to as a "what-if" simulation method.

After developing a general design concept, the designer visually depicts it in the form of a conceptual diagram, sketch, physical model, or even a digital 3D model, to find precedents for the design concept and consider how certain features of the precedents might be applied to the present design challenge. The designer makes variants on the design concept to examine how a basic design concept may be realized in several but related spatial schemes. Manipulation of conceptual diagram(s) variants occurs to encourage conceptual shift and produce breakthroughs in the design process [14].

Concept development is characterized by a cyclical process involving loops of analysis and synthesis. In different phases of the design development process, the loops can elicit different levels of representations [27]. In the early phase, for example, the designers create hazy concepts that are not written down but evaluated to see if they will serve their intended purposes. Later in the development process, an existing design representation, (e.g., a 3D-CAD model), is revised, and the designer determines if the current model meets the desired criteria and whether the output has to be improved [28].

In his study on a sample of students, Al-Qemaqchi [29], finds that: according to the inadequacy of the experience, inefficient use of knowledge, and missed conception, those modifications last for a long period before getting a proper product that satisfied both the student and the teacher. The transformation of the design concept occurs as a result of the combined tutor assessment, peer assessment, discovery, and satisfaction appeal to the final product. The sequence of manipulating lasts for all design sessions. Due to the shortage of time, the student may be pushed to continue with his concept even if he/she is dissatisfied with the outcome, which is primarily related to the design fixation he had while executing the design task. The process of developing the concept that the student proposes is also related to making a variety of reformations to the design output to meet his/her goal to produce an innovative solution, so these modifications happen naturally as a result of the design concept improvement and development [30].

3 Method

3.1 Research objectives and methodology

This paper seeks to conduct the type and the way that concept transformation occurs during the conceptual design phase. The research aims to answer the following questions: Is there a link between students' ideation strategies and the concept transformation that occurs throughout the conceptual phase of the design task?

Through the monitoring of (44) fourth-year student samples that participated at the design studio the paper tried to address these transformations. This monitoring was applied in two Iraqi universities, Cihan University and Tishk International University during the academic years 2020, 2021, and 2022.

In the design studios in which the monitoring process took place, there were at least three instructors from an architectural background, holding a master's degree and a doctorate in architectural design, and with an experience of not less than (10) years in teaching architectural design, to lead the lesson. The research and its requirements were fully explained to them before starting the process.

During the observation period, (28) results were selected that fulfilled all requirements, and the rest were excluded due to incomplete information. To ensure that the research questions are answered, the students were given a design assignment consisting of a single type of project (a general hospital with 100 beds, an assignment last for a whole semester design session). The research methodology is composed of three phases following the sequence of the design task as follows:

Phase one: Instructors quickly addressed the task and guided students to the key aims of the design challenge, outlining the main spaces need and providing adequate time for them to examine the site and analyze the program requirements. Through site analysis, students became familiar with the social, physical, functional, and natural features of the site. Through program analysis, students were able to identify the important activities and functions within the building.

Phase two: In six design sessions, the students were required to produce a design concept. The initial concepts students formulated were discussed with studio teachers, both individually and in groups. Each session was allotted adequate time for classroom design changes, reference materials, self-exploration, and peer assessments.

During their performances, the students' work was monitored to document their concept generations and transformations by the instructors. The phase lasted until concepts were crystalized and it was time to start refining them.

Phase three: A protocol analysis was carried out, and the students' design concepts were categorized according to the methods employed to generate them using the previous Eilouti taxonomy. The transformations were addressed based on their emerging features, spatial relations, functional relations, and background knowledge. The paper used the judging of three architectural design instructors who led the design task to judge each of the categories of concepts presented by students during the preparation phase, as well as the nature of the transformations taking place on those concepts.

3.2 Concept generation

Students were urged to study as much as they could about the relevant disciplines, such as recognized building types, structures, and the human body, to abstract ideas for use in their design output. Protocol analysis was conducted through all sessions and depended on what the student reached in his/her sketch and present orally.

While reviewing students' design concepts, it became clear that the majority of students had frequently utilized analogies to create a sequence of concepts. Most students' domain analogies, were restricted to the architectural domain. Few students developed analogical linkages with faraway domains, (e.g., biology or organisms).

Few students attempted to alter the analogy method to metaphor, while the expanded meanings utilized ranged from health issues like caring and healing to more abstract concepts like sustainability and amenity systems. Thematic methods were more uncommon, and they were seen with only four students and connected to cultural and mythical storytelling. As for schematic concepts, they were a geometrical concern and depended on masses forming, circulation system, and functional issues. Few students were adopting digitalization into creating more advance and futuristic forms (e.g., using computer programs to generate alternatives).

The Symbolism approach was also reached by several students and the references that have been used mostly concerned the city landmarks and places. Some students were more intact with the socio-cultural symbols such as icons. Some of these symbolic representations were primarily concerned with enhancing and recalling specific events or memory traces. The most experienced approaches were conducted by applying spatial configuration and space arrangements of the design to produce a certain typology that helps to approach the problem-solving.

Three students' design concepts were connected to the spatial experiences of the occupants. One advocated for the building to encourage unexpected experiences for its users, while the other focused on natural lighting. The third student tried to enhance the affinity between the building and the users.

Most students tried to accommodate their concepts within a contextual approach (e.g., site surroundings), while some students approached more abstract contexts such as religions, customs, conventions, and traditions. The students tried to adopt a scenario by enhancing a related use between inside and outside, (e.g., the indoor components and the landscape features). This led to a conservation between the solid requirements and the inventive soft ones. It was noticed that the students were able to employ more

than one method to generate concepts during the design sessions (Figure 1). The breakdown of the above methods used by students in their concept generation and their combinations is shown in (Table 1).

According to the jury's classifying, students were subdivided into two categories during their concept generation-development process: those who were more concerned with solid thinking and those who were more concerned with abstract thinking. The first group is more concerned with concepts based on formal aspects (e.g., deriving a shape to produce a concept), whereas the second is more concerned with functional aspects (e.g., the relationship between spaces or the pragmatic look at the problem). Those two orientations could be alternated during the design, but they eventually dominated designer behaviour and during the design.

Table 1. The concept identification during all the design sessions (Researcher)

Student ID.	Concept Generation Method								Categories
	Theme	Analogy	Metaphor	Experience	Symbolism	Context	Scheme	Scenario	
1		●				●			Abstract
2	●		●				●	●	Abstract
3					●				Abstract
4		●			●				Abstract
5		●		●			●		Concrete
6		●			●				Abstract
7		●					●		Concrete
8	●	●					●		Concrete
9			●	●			●		Concrete
10			●						Concrete
11			●				●		Concrete
12			●					●	Abstract
13					●		●		Abstract
14					●		●		Abstract
15					●				Abstract
16		●			●				Abstract
17		●			●	●			Abstract
18					●				Abstract
19			●		●	●			Concrete
20		●		●			●		Concrete
21							●		Concrete
22	●		●				●		Concrete
23	●		●				●		Concrete
24		●					●		Concrete
25			●						Concrete
26			●						Concrete
27		●			●				Abstract
28		●							Abstract

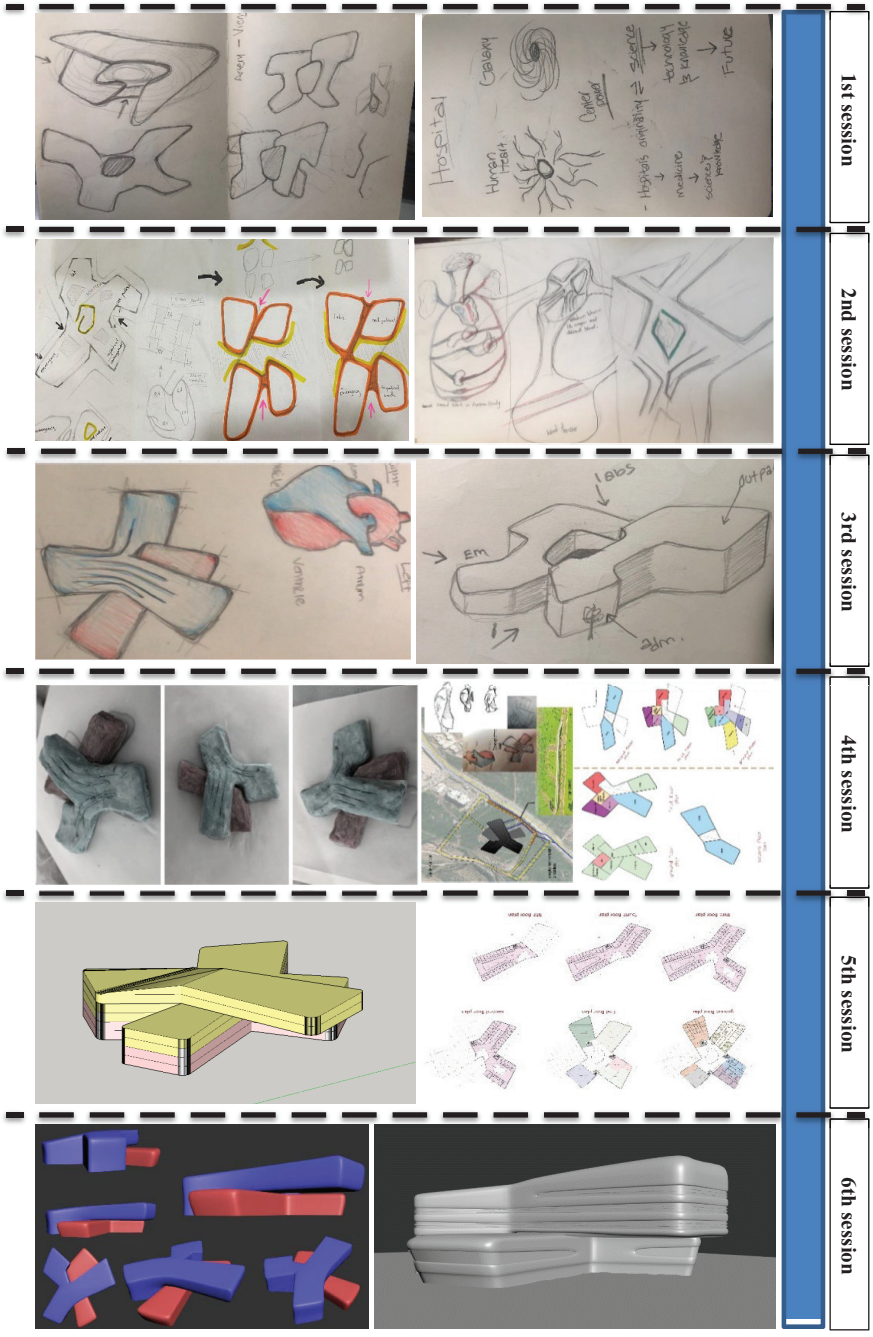

Fig. 1. A conceptual design phase breakdown of a student (ID: 16) and the concept transformations during the six design sessions (Researcher)

3.3 Concept transformations

The students are guided to propose their concepts based on their existing knowledge and then develop learning motivation by solving their cognitive conflicts between existing and new concepts. That led to continuous transformations into the conceptual phase, and those transformations were enhanced during studio work. The transformation was identified through the monitoring of the design sessions and checking out the student's verbal and diagrammatic outcomes which have been judged by the instructors (Table 2).

Table 2. Concept transformations during the design sessions

Student ID.	Concept Transformation												Category
	Session 1		Session 2		Session 3		Session 4		Session 5		Session 6		
	Form	Func.	Form	Func.	Form	Func.	Form	Func.	Form	Func.	Form	Func.	
1	2	0	3	1	3	1	2	1	1	4	0	3	Abstract
2	4	1	4	0	3	0	3	1	1	3	1	3	Abstract
3	0	3	0	3	2	3	1	3	2	2	3	1	Abstract
4	1	1	5	2	5	2	4	2	4	1	3	2	Abstract
5	2	0	2	0	3	1	3	1	4	2	4	3	Concrete
6	2	1	2	1	3	1	3	2	3	0	3	3	Abstract
7	3	1	3	1	3	1	3	2	1	3	1	3	Concrete
8	4	0	3	0	3	0	4	1	2	2	0	3	Concrete
9	4	0	4	0	4	1	2	1	2	1	3	2	Concrete
10	2	1	3	1	3	1	2	1	1	4	0	3	Concrete
11	2	0	2	0	3	1	3	1	4	2	4	3	Concrete
12	2	0	2	1	3	1	3	1	4	2	4	3	Abstract
13	1	3	0	3	2	3	1	3	2	4	3	2	Abstract
14	1	3	0	3	2	3	3	3	2	4	3	2	Abstract
15	0	3	0	3	1	3	3	3	2	4	2	2	Abstract
16	2	1	2	1	2	1	3	2	3	0	3	3	Abstract
17	2	1	2	1	3	2	3	2	3	1	3	3	Abstract
18	4	1	4	1	4	2	2	1	2	1	3	2	Abstract
19	5	1	2	1	4	1	3	2	2	1	3	4	Concrete
20	2	0	2	0	3	1	3	1	4	2	4	3	Concrete
21	3	1	3	1	3	1	3	2	1	3	1	3	Concrete
22	3	1	3	1	3	1	3	2	2	3	1	3	Concrete
23	4	1	4	0	3	0	3	1	1	3	1	3	Concrete
24	4	0	4	0	4	1	2	1	2	1	3	2	Concrete
25	5	1	2	1	4	1	3	2	2	1	3	4	Concrete
26	5	2	2	1	4	1	3	2	2	1	3	4	Concrete
27	1	3	0	3	2	3	1	3	2	4	3	2	Abstract
28	3	1	3	2	3	1	3	2	1	3	1	3	Abstract
Sum	73	31	66	31	85	38	75	49	62	62	66	77	
Average	2.61	1.11	2.36	1.14	2.71	1.36	2.68	1.75	2.21	2.21	2.36	2.75	

We have checked four types of transformations as Suwa, & Tversky, previously mentioned. It appears that the transformations that occurred throughout the design process were either formal or functional-oriented transformations (Figure 2).

We've also observed that these transformations that occur during design sessions are linked to a specific sort of concept-generating trend, which is either abstract or concrete (Figures 3 and 4).

Fig. 2. The average no. of formal and functional transformations during the design sessions (Researcher)

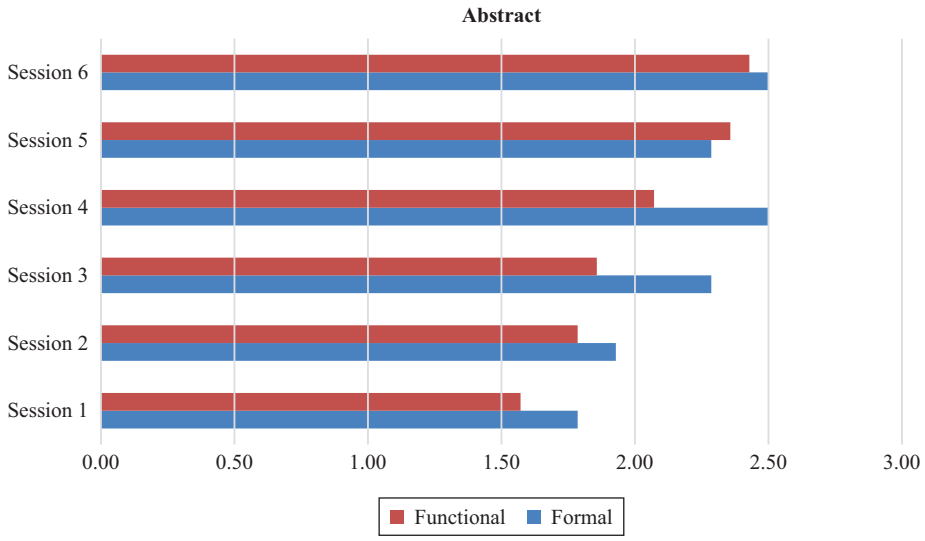

Fig. 3. Transformations occur according to abstract-oriented concepts created during design sessions (Researcher)

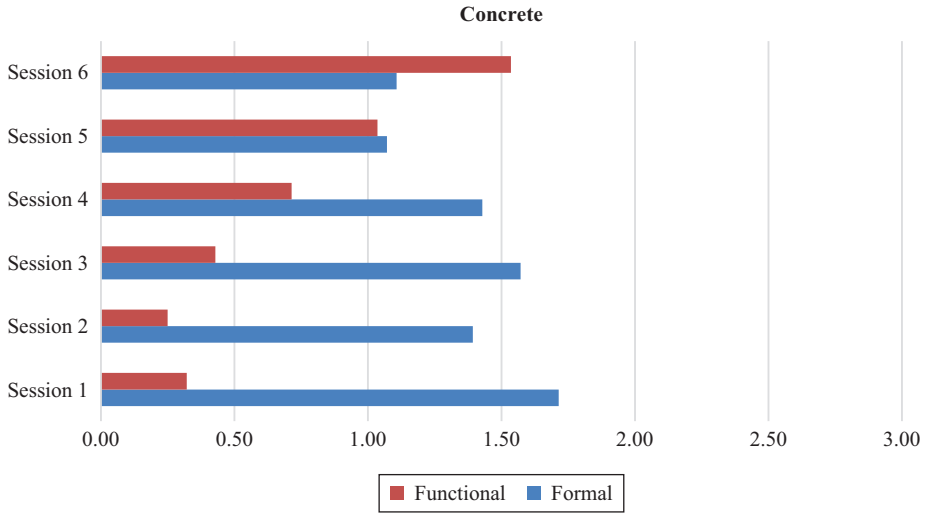

Fig. 4. Transformations occur according to concrete-oriented concepts created during design sessions (Researcher)

4 Discussion & conclusion

From the foregoing, it is clear that changes made during the conceptual stage of the architectural design process have nothing to do with the methodology adopted by the students to create those design concepts. The transformations are related to design and are carried out by the student in the design studio as part of design procedures.

It's important to note that these transformations follow two distinct patterns: one is concerned with the formal features of the design product, while the other is functional and pragmatic, and both sorts of transformations alternate over the design preparation stage. The functional transformations, on the other hand, are continuous and increase over time, but the formal transformations are typically continuous and unstable while the design phase is being completed. Perhaps this is due to the student's cognitive performance improving over time, allowing him/her to have a better understanding of the design validity and attempt to improve its performance value.

The research exposed the transformations that occur during the design sessions are more obvious and severe the more concepts were chosen by students' trend toward abstraction, (e.g., metaphor and symbolic). When the concepts are more solid, and concrete in nature (e.g., contextual), the transformations tend to be smaller. That supports the research hypothesis and provides a better understanding of the nature of the transformations that occur throughout the conceptual phase of the architectural design process.

It is useful to mention that the results of this research can support the process of pedagogical practices in architectural schools that follow the design studio model. Instructors can direct the students, implicitly or explicitly, during the assessment session, to the best procedure that can be adopted to accomplish the design task according to the

nature of the design problem and the building typology. Moreover, it can guide the instructor during the conceptual design phase to predict the amount and direction of the concept transformation that could be take place during that phase.

5 Limitations and future research

Like any other empirical study, this research has its limitations. First, the study primarily employed quantitative data. Future research can be carried out by conducting additional analysis with qualitative data gathering techniques. The study may be carried out with students from different universities and with a larger number of participants. Second, just one design experiment model was employed, which may have resulted in restricted findings throughout the design session; future studies may use a variety of design tasks to highlight the influence of changing building typology on concept creation and transformation.

6 Acknowledgement

The author would like to thanks the students and instructors who supervised the fourth stage design studies at both at the Department of Architectural Engineering, Cihan University-Sulaimaniya, and Department of Architectural Engineering, Tishk international University- Sulaimaniya for their efforts and cooperation during design lessons.

7 References

[1] Y. Wu, K.-H. Weng, & L.-M. Young, "A concept transformation learning model for architectural design learning process". *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 12, no. 5, pp. 1189–1197, 2016. https://doi.org/10.12973/eurasia.2016.1505a

[2] S. Kurt, "An analytic study on the traditional studio environments and the use of the constructivist studio in architectural design education". *Procedia – Social and Behavioral Sciences*, vol. 1, no. 1, pp. 401–408, 2009. https://doi.org/10.1016/j.sbspro.2009.01.072

[3] J. Koh, C. Chai, B. Wong, & H. Hong, *Design Thinking for Education, Conceptions, and Applications in Teaching and Learning (2015th ed.)*, Springer, 2015. https://doi.org/10.1007/978-981-287-444-3

[4] B. Lawson, "Cognitive strategies in architectural design". *Ergonomics*, vol. 22, no. 1, pp. 59–68, 1979. https://doi.org/10.1080/00140137908924589

[5] B. Eilouti, "Concept evolution in architectural design: An octonary framework". *Frontiers of Architectural Research*, vol. 7, no. 2, pp. 180–196, 2018. https://doi.org/10.1016/j.foar.2018.01.003

[6] N. Cross, "Design Cognition: Results from Protocol and Other Empirical Studies of Design Activity", in *Design Knowing and Learning: Cognition in Design Education*, C. Eastman, W. McCracken, & W. Newsletter, Eds. Hollande: Elsevier, 2001. https://doi.org/10.1016/B978-0-08-043868-9.X5000-1

[7] T. Taura & Y. Nagai, *Concept Generation for Design Creativity*, London: Springer-Verlag, 2013. https://doi.org/10.1007/978-1-4471-4081-8

[8] N. Al-Qemaqchi & E. Alsoofee, "The effect of design tasks on changing the conceptual structure for architectural engineering students". *Al-Rafidain Engineering Journal (AREJ)*, vol. 23, no. 3, pp. 95–111, 2015. https://doi.org/10.33899/rengj.2015.101563

[9] P. Leclercq & M. Locus, "Representation of Architectural Design Process; Between Formal and Functional", in *7th International Design Conference (Design 2002)*, Dubrovnik, May 14–17, pp. 189–196. https://www.designsociety.org/publication/29560/Representation+of+an+Architectural+Design+Process%3B+Between+Formal+and+Functional. [Accessed: May 24, 2021].

[10] J. Lee, M. Ostwald, & N. Gu, *Design Thinking: Creativity, Collaboration, and Culture*, Switzerland AG: Springer Nature, 2020. https://doi.org/10.1007/978-3-030-56558-9

[11] B. Tversky, "The cognitive design of tools of thought". *Review of Philosophy and Psychology*, vol. 6, no. 1, pp. 99–116, 2014. https://doi.org/10.1007/s13164-014-0214-3

[12] N. Al-Qemaqchi, "Thinking performance comparison of the designer in architectural education between the use of the digital and traditional method". *Al-Rafidain Engineering Journal (AREJ)*, vol. 20, no. 1, pp. 20–34, 2012. https://doi.org/10.33899/rengj.2012.47233

[13] D. Idi & K. Khaidzir, "Concept of creativity and innovation in the architectural design process". *International Journal of Innovation, Management, and Technology*, vol. 6, no. 1, pp. 16–20, 2015. https://doi.org/10.7763/IJIMT.2015.V6.566

[14] F. Dogan, "Architectural design students' explorations through conceptual diagrams". *The Design Journal*, vol. 16, no. 1, pp. 103–124, 2013. https://doi.org/10.2752/175630613X13328375149002

[15] V. Goel, *Sketches of Thought*. Cambridge, Mass., The MIT Press, 1995. (ISBN: 9780262519755). https://doi.org/10.7551/mitpress/6270.001.0001

[16] B. Lawson, *How Designers Think: The Design Process Demystified* (4th ed.). Architectural Press, 2005. (ISBN: 0750660775).

[17] S. Kim & Y. Kim, "Design Process Visualization and Review System with Architecture Concept Design Ontology", in *International Conference on Engineering Design*. ICED'07 28–31 August 2007, Paris, France. https://www.designsociety.org/download-publication/25612/Design+Process+Visualizing+and+Review+System+With+Architectural+Concept+Design+Ontology, [Accessed: Feb, 20, 2021].

[18] D. Schön, *The Reflective Practitioner*, London: Temple-Smith, 1983. https://qmplus.qmul.ac.uk/pluginfile.php/779502/mod_folder/content/0/Schon%2C%20%281999%29%20The%20reflective%20practitioner.pdf?forcedownload=1, [Accessed: Jan. 12, 2021].

[19] C. Chan, "Cognitive processes in architectural design problem solving". *Design Studies*, vol. 11, no. 2, pp. 60–80, 1990. https://doi.org/10.1016/0142-694X(90)90021-4

[20] G. Goldschmidt, "The dialectics of sketching". *Creativity Research*, vol. 4, no. 2, pp. 123–143, 1991. https://doi.org/10.1080/10400419109534381

[21] M. Suwa, T. Purcell, & J. Gero, "Macroscopic analysis of design processes based on a scheme for coding designers' cognitive actions". *Design Studies*, vol. 19, no. 4, pp. 455–483, 1998. https://doi.org/10.1016/S0142-694X(98)00016-7

[22] D. Schön & G. Wiggins, "Kinds of seeing and their functions in designing". *Design Studies*, vol. 13, no. 2, pp. 135–156, 1992. https://doi.org/10.1016/0142-694X(92)90268-F

[23] M. Suwa & B. Tversky, "What do architects and students perceive in their design sketches? A protocol analysis" *Design Studies*, vol. 18, no. 4, pp. 385–403, 1997. https://doi.org/10.1016/S0142-694X(97)00008-2

[24] J. Zeisel, *Inquiry by Design: Tools for Environment-Behavior Research*. Cambridge Cambridge shire; New York, NY, USA: Cambridge University Press, 1984. (ISBN: 0818503750).

[25] G. Broadbent, *Design in Architecture: Architecture and the Human Sciences*. London: David Fulton, 1988. (ISBN: 1853460591).
[26] T. McGinty, "Concepts in Architecture", in *Introduction to Architecture*, J. Snyder & A. Catanese, Eds. McGraw-Hill Book Company, NY, 1979. (ISBN: 007059547X).
[27] A. Ruckpaul, A. Kriltz, & S. Matthiesen, "Using Eye Tracking to Understand the Engineering Designers' Behavior in Synthesis-Driven Analyzing Processes – Experiences in Study Design", in *International Conference on Human Behavior in Design Proceeding*, Ascona, Switzerland: 2014 (ISBN: 978-3-906327-02-0).
[28] N. Cross, *Design Thinking: Understanding How Designers Think and Work*. Oxford: Berg, 2011. https://doi.org/10.5040/9781474293884
[29] N. Al-Qemaqchi, "The role of working memory in architectural design". *Sulaimania Journal for Engineering Sciences (SJES)*, vol. 5 no. 1, pp. 27–40, 2018. https://doi.org/10.17656/sjes.10071
[30] T. Dorta, E. Beaudry Marchand, & D. Pierini, "Externalizing Co-design Cognition Through Immersive Retrospection", in *Design Computing and Cognition'18*, pp. 97–113, 2019, https://doi.org/10.1007/978-3-030-05363-5_6
[31] D. Eissa, "Concept Generation in the Architectural Design Process: A Suggested Hybrid Model of Vertical and Lateral Thinking Approaches", in *Thinking Skills and Creativity*, p. 100589, Aug. 2019, https://doi.org/10.1016/j.tsc.2019.100589
[32] Z. Kanetaki, C. Stergiou, G. Bekas, C. Troussas, & C. Sgouropoulou, "Analysis of engineering student data in online higher education during the covid-19 pandemic". *International Journal of Engineering Pedagogy (iJEP)*, vol. 11, no. 6, pp. 27–49, 2021. https://doi.org/10.3991/ijep.v11i6.23259
[33] Z. Kanetaki, C. Stergiou, G. Bekas, S. Jacques, C. Troussas, C. Sgouropoulou, & A. Ouahabi, "Grade prediction modeling in hybrid learning environments for sustainable engineering education". *Sustainability*, vol. 14, p. 5205, 2022. https://doi.org/10.3390/su14095205
[34] I. M. Joao & J. M. Silva, "Concept mapping and mind mapping to lift the thinking skills of chemical engineering students". *International Journal of Engineering Pedagogy (iJEP)*, vol. 4, no. 5, pp. 42–48, 2014. https://doi.org/10.3991/ijep.v4i5.3538
[35] M. G. Ballatore, F. Barpi, D. Crocker, & A. Tabacco, "Pedestrian bridge application in a fundamentals of structural analysis course inside an architecture bachelor program". *International Journal of Engineering Pedagogy (iJEP)*, vol. 11, no. 5, pp. 4–18, 2021. https://doi.org/10.3991/ijep.v11i5.20151

8 Author

Nahedh Taha Al-Qemaqchi: earned a PhD. in Theory of Design. Worked since 1991 as an architectural studio instructor. In the meantime, he is an assistant professor, at the Department of Architectural Engineering, Cihan University-Sulaimaniya, Sulaimaniya 46001, Kurdistan Region, Iraq, His research interests include architectural design methods, architectural design pedagogy, protocol analysis, and architectural studio teaching analysis. ORCID: 0000-0003-2708-7807

Article submitted 2022-04-15. Resubmitted 2022-09-25. Final acceptance 2022-10-10. Final version published as submitted by the authors.