COGNITION MODEL IN CONCEPTUAL DESIGNING

Case studies of architecture students' designs

WAEL ABDELHAMEED
University of Bahrain, PO Box 32038, Isa Town, Bahrain
South Valley University, Faculty of Fine Arts at Luxor, Egypt
wael.abdelhameed@gmail.com

Abstract. Both design researchers and cognitive scientists have developed various process models to study human creative behaviour in design. The models developed are often based on observations of design processes and analysis of design protocols. This research paper reports the-state-of-the-art in the area of cognition models that present design activities in conceptual designing. The research paper investigates the approaches of these cognition models. A new approach of a cognition activity model in conceptual designing is proposed. The new approach used in the introduced model takes into the account factors and activities that are related to the external environment of design (design medium). The external environment has an important role in the cognition activities and the evaluation process in a way that can hardly be ignored or neglected. The presented model of cognition activities in conceptual designing highlights two main factors employed in all the iteration loops of the model, namely: media use and representation. Case studies of architecture students' designs have been analyzed. The analysis of these case studies helped in forming the proposed model. Various results have been concluded and reported.

Keywords. Cognition model; conceptual designing; design process; design theory.

1. Cognition Models in Previous Research

In the field of cognitive science, most cognitive models and design models that describe cognitive processes in design (Finke et al., 1992; Maher et al., 2001; Benami and Jin, 2002) indicate the iterative nature of design cognition. Both

design researchers and cognitive scientists have developed various process models to study human creative behaviour in design. The models developed are often based on observations of design processes and analysis of design protocols.

Finke et al. (1992) propose the Geneplore model, a general model of creative cognition that can be applied. To the conceptual design of products, the majority of the cognitive processes in the Geneplore model have been empirically identified in an engineering design experiment (Shah, 1998).

French (1985) develops activities of analysis of the problem and conceptual design. Maher et al. (1996) introduce 'Co-evolution' between problem-space and design space. Shah et al. (2001) propose a model of Design Thought Process to describe generation and interpretation of ideas. A cognitive model of creative conceptual design to capture interactions between cognitive processes, design entities, and design operations, is developed (Benami, 2002).

Jansson and Smith (1991) proposed a theoretical model of the conceptual design process, which describes the movement between configuration space and concept space. In addition to, relationships between design ideas emergence and design solution directions have been proposed (Abdelhameed, 2006).

In these models which are taken into consideration as examples, the focus is on clarifying work or thinking steps involved in design rather than capturing what information is generated by these steps and how the information is processed through various iterations.

2. Approaches of the Previous Models and the Presented Model

The approaches of models described in the foregoing part share a main characteristic, which treats the design process as a single iteration loop that provides little distinction in conceptual design in terms of different types of iteration including their roles and mechanisms.

2.1. PREVIOUS MODELS APPROACHES

The cognitive models of conceptual design in previous research have some shared characteristics and influences (French, 1985; Dzbor, 1999; Cross, 2000; Dorst and Cross, 2001; Kruger and Cross, 2001; Benami and Jin, 2002; Abdelhameed 2006; Jin and Chusilp, 2006). Some features can be distinguished in the models, e. g., iteration of problem and solution, which is described as co-evolution between problem-space and solution space (Dorst and Cross, 2001), iteration of problem definition (Dzbor, 1999), feedback from the evaluation stage back to the generation stage (French, 1985; Cross, 2000; Abdelhameed 2006).

On the other hand, there are some major distinctions between these models. Jin and Chusilp (2006) described a model of the conceptual design process in terms of cognitive activities and mental iteration loops. They explored how design mental iterations can have an impact on the design process and design performance to be indented.

In another realm, engineering design, Adams and Atman (1999; 2000), Adams (2001), Adams et al. (2003) studied iterative behaviour in engineering student design processes and revealed both behavioural and performance differences between freshman and senior students in their engineering design coursework. Their results suggest that iteration is a significant component of design activity that occurs frequently.

Abdelhameed (2006) maintained the role of media, the external representational environment of conceptual designing, inside the processes of design idea emergence and design solution directions.

2.2. PRESENTED MODEL APPROACH

In order to study mental iterations in conceptual design, a model is needed which can identify cognitive design activities, and in the same time, addresses information generated from, and used by, these cognitive activities. The model should also be able to capture various types of iteration loops as a part of the design process.

The underlying assumption of the approach is that: there are evaluation activities and tools that shape the evaluation processes and their outputs. The concern of the paper covers only the evaluation activities that are more related to conceptual designing, rather than to psychology and mental processes.

The approach of the presented model does not explicitly take into the account visual design thinking and creativity in the introduced model. However, visual design thinking and creativity associated with media use are embedded in all cognition and representation activities, and their iteration loops whereas each of those iteration loops has reciprocal impact with visual design thinking and creativity, Figure 1.

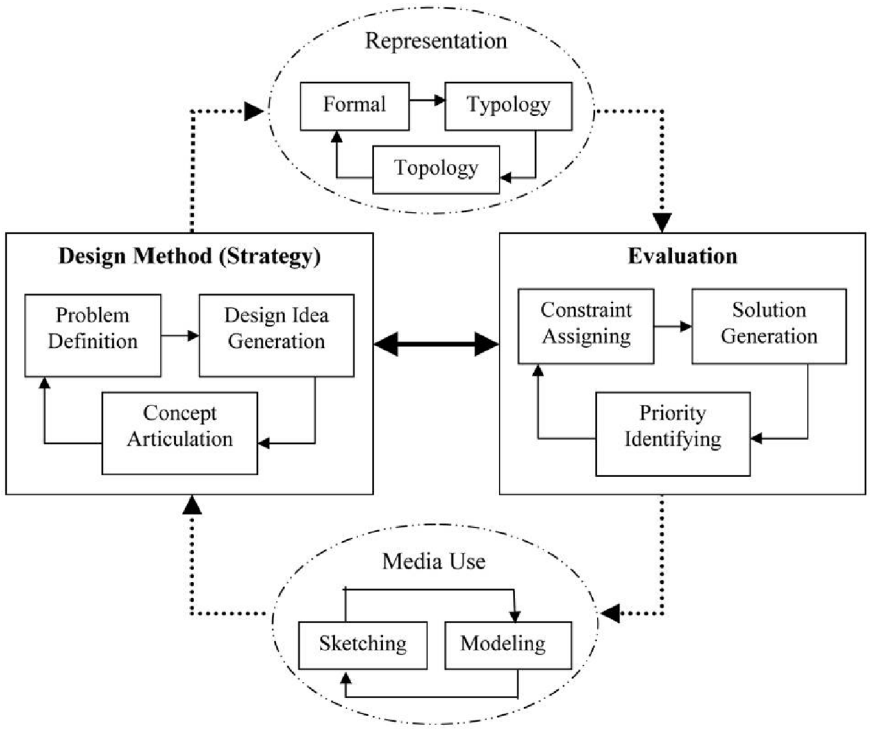

Figure 1. The cognition model of conceptual designing, showing its iteration loops and the two proposed external factors of media use and representation.

3. Cognition Model

Most studies have regarded the generation of a solution–design in our case– as the outcome of the creative process (Runco and Pritzker, 1999). However, there is no solid theory in the literature review regarding the creative processes used in designing (Rowe, 1987). Without venturing too much into the cognition processes and their related realms such as creativity, there are main activities inextricably linked to conceptual designing. The paper focuses on two of those activities–some may maintain them as tools– namely: media use and representation activities.

These two activities acting as factors of evaluation processes are employed in all the iteration loops of the cognition model presented in Figure 1. The two factors and the iteration loops in the presented model will be illustrated, in order to describe the model.

3.1. EXTERNAL FACTORS

The external factors previously mentioned, also, act as loops in their impact on the cognition activities. There is no certain order for using or employing either the loops of these factors or the iteration loops of the cognition model. It may vary from one design case/situation to another and from one personal style of design thinking to another.

The first factor is media use where media are the external environments of thinking that our minds employ and benefit from. In addition to, the individual use of media interactively impacted by the personal visual design thinking play a crucial role in this episode. The paper maintains that this personal use of a medium has significant roles in the cognition activities in such an important way that they should be appeared into the cognition model.

Media act as tools that allow architects to generate, record, interpret, and manipulate tentative forms they have in mind during designing. These potentials are dispensable for ethos that governs the design process. The paper, therefore, proposes that media use should be included and esteemed inside cognition activities of conceptual designing.

The representation activity is the second factor, which can be illustrated through its classifications and constraints. The paper defines three levels and constraints of the representation process related to and based on the form creation process. The first level is formal that refers to the spaces and components of the design itself, while the second is topology which is linked to the surrounded area of the design and its environmental properties. The third level, typology, is the representational drawings that express macro environmental factors and their impact on the design and its surrounded area.

Shapes and forms of design are constructed as outputs through the repeated representation activities. Through these three types of representation and drawings, design is explored and evaluated.

3.2. ITERATION LOOPS

The model in Figure 1 classifies the cognition processes of conceptual designing into two main iteration loops, namely: design method (strategy) and evaluation. These two main loops are simultaneously performed through visual design thinking. Meanwhile, media use and representation accompanied with their impact inside the cognition activities have their own modifications on the outputs.

Each of these main loops has its own internal activities and territories that reciprocally impact each other. This reciprocal impact is evident where concepts, in the first loop of design method, have a leading role in design-ideas generation

and problem definition, and in the same time, concepts may be constructed according to design-ideas generation and problem definition.

The evaluation, in the second loop, is preformed cyclically through its internal activities, till the design is fully evaluated. The internal activities of evaluation are constraint assigning, solution generation and priority identifying. These activities and their related processes are simultaneously conducted impacting the first loop of design method.

The cognition model loops and the external factors are cycled, however, the linear nature is evident through evaluation outputs, whereas each evaluation episode may result in forth or back movement in the design development scale, Figure 2.

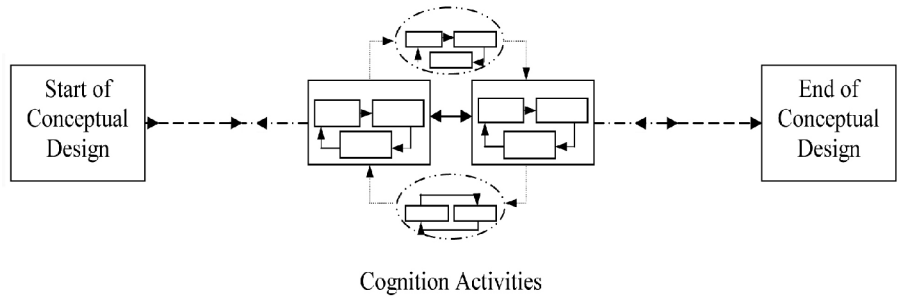

Figure 2. The Linear Nature of Conceptual Designing through the Forth and Back Movement of Cognition Activities.

4. Case Studies

The analysis of case studies of architecture students' designs helped not only in forming the presented model but also in providing evidences for both the proposed loops and factors, and their relations. Student were asked to provide self-records of each explicit stage, action and reasoning of their design processes. The explicit sequences records with the supplementation of students' textual explanations were used to analyze the cognition processes students employed.

Two design projects, elementary school and health centre, were introduced for the students to freely choose one. The program requirements were defined including the architectural components and their needed areas. The layout of the two projects did not have any limitation except the defined area of each project. Students chose freely their own sites. Also, students had the freedom to define the design components and their areas according to their own conceptualization processes.

The required projects were purposely kept only two in order for the researcher to easily track and group transformational steps of the cognition rationale and the reasoning, for analysis and more future research work.

5. Analysis of Architecture Students' Designs

Students started designing through various kinds of sketches that fit their capabilities and potentials. The proposed components of the presented model were tracked in terms of analyzing the designs. The results of analysis each component of the cognition model in Figure 1 is reported as follows:

5.1. MEDIA USE AND DESIGN METHOD

During performing the initial tasks of problem definition, concept articulation, and design-idea generation through sketching, different uses of media were reported.

Some students preferred to use physical modelling while others wanted to use digital media. The type of media use was crucial to each student whereas the fluency s/he has in using the medium facilitates the cognition processes. This fact was explicit in their self records. However, the students were directed to use physical modelling in the initial phases of their conceptual design. After having initial forms, students had the flexibility to choose their preferred medium/media to explore and develop their forms. This direction of the design method aimed at two objectives: first objective was to reduce the range of media use to an extent that enables the results' comparison; second objective was related to another research conducted by the researcher/instructor in order to measure physical modelling impact on conceptual designing–which is not our concern in this research paper.

Inside the same episode, design method was varied from one student to another. Some started with a certain concept that highly impacted the problem definition while others used the objectivity in problem definition to generate a design idea and to articulate a concept.

In other design methods, the subjectivity during defining the design problem was evident and tracked in some case studies. This subjectivity led to articulate concepts of these designs.

In other words, there is not a particular pattern or order in conducting the design method or in using the design medium. Each student preferred a certain design medium and a specific design technique to perform his/her conceptual design.

5.2. REPESENTATION AND EVALUATION

Conducting the first cognition loop of design method, students had tentative forms. They were encouraged to explore and evaluate their tentative forms based on the three levels of representation in Figure 1. Different kinds of

drawings and modeling associated in the same time with different evaluation methods on the formal level led to the composition and proposition of forms and shapes structuring the components of design. While in both representational levels of topology and typology, the drawings and modeling express the influential factors of macro and micro environments on the design itself.

Students used the second loop of evaluation with its internal activities to finalize their initial forms with more details. They simultaneously conducted these internal activities without certain order.

Some students started with assigning constraints from the formal representation level, and ended with identifying priorities in terms of representation levels of topology and typology. Other ways of thinking and designing were also identified and tracked where students started from the two groups of factors, namely: the macro environment and the surrounded area of design. However, solution generation process, in both reported directions, was based on the outputs of evaluation episodes.

In some case studies, the output of this evolution loop resulted in modifying what has been adapted at earlier point in the first loop. Solution generation and other evaluation activities were re-conducted and in the same time re-influenced by the new modified criteria. In other words to simply describe these particular case studies, some students after evaluation processes of representation on the typology level found that the layout chosen in an earlier point of design does not conform to their concepts. They therefore chose to modify their concepts, and kept the layout and its typology drawings. But, two students from these particular case studies chose to change the layout and chose completely new sites which conform their concepts.

Consequently, it can be concluded that: the reciprocal impact between the two main loops and the two proposed factors not only exists but also provides a concrete evident for the validity of the presented cognition model and its iteration loops.

8. Summary, Conclusion, and Future Research Work

This research reported and presented the-state-of-the-art in the area of cognition models in conceptual designing. The research investigated the approaches of these cognition models. The research proposed a new approach of a cognition activity model in conceptual designing.

The new approach used in the introduced model takes into the account factors and activities that are related to the external environment of designing (design medium), and to the different types and levels of representation.

The research analyzed case studies of architecture students' designs. This analysis helped in forming the proposed model, and in providing evidences for

its loops and their relations. At the same time, the research provides a more understanding in the research subject matter and the related areas.

The study and presented model described above are not intended as a completed work, rather than serving as a part of a research work that attempts at developing teaching methods inside the design studio. Most importantly, this paper may act as a vehicle for testing the cognition activities, their possibilities, and the accompanied influential external factors.

The methodology of conducting the whole study in the design studio is a workshop of design where students can explore their own design methods and personal cognition activities in conceptual designing. The explicitness of their design strategies, tactics, and techniques stimulate their own intuition and reasoning abilities.

The results of this study and the future research can help in both realms of conceptual design, and architectural education inside the design studio, through establishing the strategies, components, and impacts. More analysis to the recorded design methods of students' projects will be conducted further, based on more relations and reciprocal impacts of the conceptual designing activities.

References

Abdelhameed, W.: 2006, the Relations between Design-Idea Emergence and Design-Solution Direction: A digital-media use in mass exploration of architectural design ideas, *Proceedings of the 2nd ASCAAD conference*, American University of Sharjah, UAE.

Adams, R. S.: 2001, Cognitive processes in iterative design behaviour, Ph.D. thesis, University of Washington, Seattle, WA.

Adams, R. S. and Atman, C. J.: 1999, Cognitive processes in iterative design behavior, *Proceedings of the 29th ASEE/IEEE Frontiers in Education Conference*, San Juan de Puerto Rico.

Adams, R. S. and Atman, C. J.: 2000, Characterizing engineering student design process - an illustration of iteration, *Proceedings of the ASEE Annual Conference*, St. Louis, MO.

Adams, R. S., Turns, J. and Atman, C. J.: 2003, Educating effective engineering designers: the role of reflective practice, *Design Studies*, **34**, 275-294.

Benami, O.: 2002, *Cognitive approach to creative conceptual design*, Ph.D. thesis, University of Southern California, Los Angeles, CA.

Benami, O. and Jin, Y.: 2002, Cognitive stimulation in creative conceptual design, *Proceedings of ASME DETC'02*, Montreal, Canada.

Cross, N.: 2000, *Engineering design method: strategies for products*, John Wiley & Sons, New York, NY.

Dorst, K. and Cross, N.: 2001, Creativity in the design process: co-evolution of problem-solution, *Design Studies*, **22**, 425-437.

Dzbor, M.: 1999, Support for problem formalization in engineering design: an enquiry into the role of knowledge level models, *The 10th International Symposium*, Vienna, Austria.

Finke, R. A., Ward, T. B. and Smith, S. M.: 1992, *Creative cognition-theory, research, and application*, MIT Press, Cambridge, MA.

French, M. J.: 1985, *Conceptual design for engineers Design Council*, London, UK.

Jansson, D. G. and Smith, S. M.: 1991, Design fixation, *Design Studies*, **12**, 3-11.

Jin, Y. and Chusilp, P.: 2006, Study of mental iteration in different design situations, *Design Studies*, **27**, 25-55.

Kruger, C. and Cross, N.: 2001, Modelling cognitive strategies in creative design, in J. S. Gero and M. L. Maher (eds), *Computational and cognitive models of creative design V*, University of Sydney, Australia.

Maher, M. L., Poon, J. and Boulanger, S.: 1996, Formalising design exploration as co-evolution: a combined gene approach, in J. S. Gero and F. Sudweeks (eds), Advances in formal design methods for CAD, Chapman and Hall, London, UK.

McKoy, F. L., Vargas-Hernandez, N. and Shah, J.: 2001, Influence of design representation on effectiveness of idea generation, *Proceedings of ASME DETC'01*, Pittsburgh, PA.

Rowe, P.: 1987, Design Thinking, The MIT Press, Cambridge, Massachusetts; London, England.

Runco, M and Pritzker, S (eds): 1999, Encyclopedia of Creativity, Academic Press, San Diego.

Shah, J.: 1998, Experimental investigations of collaborative techniques for progressive idea generation methods, *Proceedings of ASME DETC'98*, Atlanta, GA

Shah, J., Vargas-Hernandez, N., Summers, J. and Kulkarni, S.: 2001, Collaborative sketching as an idea generation technique for engineering design, *Journal of Creative Behaviour*, **35**, 169-198.