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A Concept Transformation Learning Model for Architectural Design Learning Process

Yun-Wu Wu, Kuo-Hua Weng & Li-Ming Young
China University of Technology, TAIWAN

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Generally, in the foundation course of architectural design, much emphasis is placed on teaching of the basic design skills without focusing on teaching students to apply the basic design concepts in their architectural designs or promoting students' own creativity. Therefore, this study aims to propose a concept transformation learning model to achieve the learning objective via the input-process-output learning process, which focuses on: (1) the information transmission of the concept (or conceptual frame); (2) the students' simulation, analogy, analysis, and innovation; and (3) the works output (or learning output).In this study, three design assignments of 2D composition, 3D composition, and architecture form composition are given to the students to promote their motivation of active learning via the concept transformation learning model. The effectiveness of the concept transformation learning model is verified by comparing the results of the pre-test questionnaires and the post-test questionnaires. The questionnaire results also indicate that, with the concept transformation learning model, students' creativity can be effectively promoted so that they can become more interest and more active in their learning. The research results can be referred by further teaching and studies of architectural design.

Keywords: concept transformation learning model; creativity; learning process

INTRODUCTION

For developing countries, it is equally important to seek industrial technology development breakthrough and develop knowledge economy (Dedre Gentner & Smith, 2012). Therefore, it is of great urgency for them to cultivate creativity of next generations (Cheung & Leung, 2014) (Gustina & Sweet, 2014). In the current college education of architectural design, the method of design studio is mostly used in which the teachers use their own knowledge and experiences to guide the students in their learning of architectural design. However, in this method, the students can only learn the professional know-how without acquiring the capability of systematic

Correspondence: Li-Ming Young,
Department of Architecture, China University of Technology, No. 56 Sec. 3, Singlong Rd., Taipei 116, Taiwan.
E-mail: steven@cute.edu.tw

knowledge construction or development on their own. In this method, it is difficult to inspire the students' own creativity and motivate them to have active learning.

According to previous research, analogical learning (Wu & Weng, 2012) and social interaction learning (Wu, Huang, & Weng, 2014) can help students to accumulate experiences in building their own cognitive structures and effectively improve their creativity. However, in the above-mentioned research, the teaching experiment only lasted for five weeks and covered just one unite of the curricula; therefore, they only verified the short-term benefits of analogical learning and social learning for the students without exploring their long-term benefits for the students.

Therefore, in this study, a longer experiment period (18 weeks) covering three units (2D composition, 3D composition and architecture form composition) of the curricula is used to provide a learning process of concept transformation and analogical thinking for the students to learn new knowledge, merge it with their existing knowledge through assimilation and accommodation so that their newly acquired knowledge can be changed and internalized as part of their cognitive structures and form new schema. The students can then use their new schema to come up with more creative designs in their future design works. To sum up, this study focuses on how to incorporate concept transformation into architectural design education in order to effectively encourage students' creativity and guide them to have active learning of architectural design. The results of this study can provide references for curricular design and research of architectural design in the future.

State of the literature

- Traditional learning of architectural design is mainly based on the mechanism of design studios, in which students learn face-to-face from teachers. However, in such learning, there is a lack of teaching model and strategy that can guide students in their knowledge construction and inspire their imagination.
- Learning based on analogical thinking can help students to connect their existing knowledge about architectural design with the new knowledge through the process of assimilation and accommodation to build their own schema and improve their creativity.
- In this study, the teaching strategy of analogical thinking is used to provide a learning process of concept transformation to help students construct their knowledge structures about architectural design and then complete their design works.

Contribution of this paper to the literature

- This study is intended to apply the concept transformation model in the teaching of architectural design.
- Through a three-unit architectural design practice (from 2D composition to 3D composition and then to architecture form composition), the students in this study undergo a concept transformation learning process composed of cognitive conflicts, analogical thinking and then analogical learning. Through their concept transformation, they can internalize their newly learned knowledge into their existing knowledge structures to from new schema and consequently improve their creativity.
- According to the analysis results of this study, the introduction of the concept transformation model in the teaching can help to improve the insufficiencies in the traditional design-studio teaching method, cultivate students' capability of knowledge construction, and significantly enhance students' learning motivation and efficacy.

LITERATURE REVIEW

Architectural design learning process

The traditional teaching method of architectural design is based on the practice of design studio (Kurt, 2009), in which the curricular design is unit-based and the teachers teach knowledge to students through lecturing and providing guidance for the students in their group discussions and peer critiques (Uluoğlu, 2000). In group discussions, the students have to communicate face to face with the teachers and their peers and constantly have self-reflection in order to find the best solutions to their problems. In the process of traditional architectural design teaching, there are learning activities such as design revisions in class, learning from reference materials, self-exploration, peer assessments, and design work evaluation at the end of the semester.

In the design-studio type teaching of architectural design, more focus is placed on teaching students the design drawing skills or techniques and requiring them to complete their designs before the deadline than inspiring them to develop their independent thinking and creativity. As a result, it is difficult to motivate the students in their learning for the students only receive passively what is taught to them and do not have their own independent thinking/understanding about the goals of the assignments or the course as a whole.

Analogical thinking

Analogy is an important process in learning and discovery (D. Gentner & Toupin, 1986)(Dedre Gentner & Smith, 2012). Analogy is to find similarity or relevance between acquired knowledge and new problems and then solve the problems with the relevant knowledge. In analogical learning, students are guided to observe an object or activity which is similar or relevant to the object or activity they intend to learn. Then the students can find common concepts between the two in order to have better learning results.

An analogy is a comparative relationship between the structural elements of two domains. It can also be seen as a comparative narrative of the similarity between two domains (Reinders Duit, 1991). The ability to solve a problem of a new or unknown domain through metaphors of a known domain or similar problems solved earlier is called the ability of analogical reasoning (Helman, 1988)(Cubukcu & Cetintahra, 2010)(Dedre Gentner, 2003). The similarity (or relevance) between existing knowledge and knowledge to acquire is very important. Analogy is a very helpful tool for learners to organize their available knowledge.

Generally, in traditional teaching of architectural design, much is focused on low-level cognitive teaching while the teaching methods are so simplistic that it is impossible to transfer concept learning to complicated real-life contexts. As a result, students do not know how/what to learn to fulfill the design goals. In addition, due to the lack of thinking stimulants, it is difficult for students to feel inspired in their learning. Moreover, in the traditional design-studio teaching method, students are like apprentices and their design works are revised by the teachers several times. Such repetitive revisions may frustrate students and consequently make them less motivated in their learning of architectural design. Nersessian (1992) confirmed that analogical reasoning is the key step of inspiration in many explorative learning processes and, through analogical thinking, students can be inspired to find design problems on their own. Analogical thinking can help students to discover problems on their own and stimulate them to have abstract thinking, develop their design concepts, complete the categorization of different components for their designs, and ultimate build their knowledge structures about architectural design by expanding their relevant schema with a series of related cognitive contents.

In this study, the analogical thinking model for architectural design learning developed by Wu & Weng (2012) is used together with the learning process of analogical learning (observation and discovery) and analogical reasoning (schema construction and application) to guide the students in solving the cognitive conflicts between their existing knowledge and newly acquired knowledge through the process of assimilation and accommodation to merge their new and old knowledge about architectural design and consequently enhance their design creativity.

Concept transformation

According to Bigge & Shermis (1999), the acquisition of knowledge does not mean the ability to apply the acquired knowledge. The information processing process from knowledge input to knowledge output is the key to knowledge comprehension (Bigge & Shermis, 2003; R. Duit & Treagust, 1995). According to

research on knowledge or concept learning process based on the perspectives of constructionism, learning of knowledge or a concept is a process of the learner's active construction of knowledge. It is a process of cognitive operation or a process in which external information (knowledge) is processed and converted into long-term memories (Glynn & Duit, 1995). According to the theory of constructionism, humans' mental development and learning is a process of humans' active interactions with the environment. Furthermore, according to the cognitive conflict theory, social knowledge is social experiences obtained from social interactions and transmissions. It is one of the factors Piaget included in his exploration of cognitive development process. Social knowledge is not derived directly from concrete objects or obtained directly through sensual perceptions but acquired through interactive actions among learners.

According to Piaget (1983), cognitive development requires the possession of a certain level of schemas, which are seen as the basic building blocks of human cognition. In the process of cognitive development, learners will take actions according to their existing schema when encountering new external environments. Different learners have different existing cognitive structures and they construct their new schemas or modify their existing schema in accordance with their own cognitive structures. Piaget (1983) explained the learning process of concept transformation with "assimilation" and "accommodation":

1. Assimilation: learners apply their existing knowledge in the external environments and the experiences derived from this process are integrated into learners' existing cognitive structures. In other words, learners use their existing cognitive structures to assimilate similar experiences they have from the external environments.
2. Accommodation: leaners change or adapt their existing cognitive structures to accommodate external experiences/environments that are different from learners' existing cognitive structures. In other words, learners develop new cognitive structures to adapt to the new experiences and environments.

The learning process of concept transformation is a process of continuous interactions between assimilation and accommodation, in which learners adjust and replace their existing knowledge (existing concepts) and new knowledge (learned concepts) as well as construct new knowledge from their social learning. Therefore, learners have to proactively acquire new knowledge and integrate it with their existing knowledge and then convert it into their own knowledge.

According to constructionism, concept transformation learning can effectively help students to understand the concepts they have to learn. It has been applied in different disciplines and proven effective (Lord, 1994). However, it has been rarely used in the practice or research of architectural design education. Posner et al. (1982) proposed the "conceptual change model" to explain the learning process in which existing concepts are changed into concepts to learn (Posner, Strike, Hewson, & Gertzog, 1982). In this process, learners must first have dissatisfaction with their existing concepts, and then accept an alternative concept as intelligible, plausible and fruitful in order to have the conceptual change (Demirel, 2005) (Bilgin, Karakuyu, & Ay, 2015). This is also a process of cognitive structure construction, through which learners can clearly understand and learn useful knowledge (because they are not satisfied with their existing knowledge and find alternative knowledge intelligible) and then come up with more and better solutions to their problems (because the new knowledge is plausible and fruitful).

In the architectural design learning process of this study, the students are guided to propose their own concepts based on their existing knowledge and then to develop learning motivation by solving their own cognitive conflicts between existing and new concepts. In addition, the application of analogical learning in this study can help the students to develop their schema of architectural design concepts

from relevant cases to construct their design knowledge systems and complete their designs.

Creativity

The realization of creativity requires flexible thinking and problem-solving capability (Bruton, 2011) to facilitate the formation of creative concepts and implementation of the concepts into completed works.

Creativity is composed of diverse elements (Mumford & Gustafson, 1988). It is a kind of extremely complicated phenomenon. Rhodes (1961) proposed the four defining elements, "4Ps", of creativity: personality, product, process and place. Amabile (1996) also proposed the componential theory of creativity, suggesting creativity is composed of elements such as task motivation, domain-relevant skills, creativity-relevant skills, and social environments (which have an influence on one's internal and external motivation). Woodman and Schoenfeldt (1989) believed that the expression of creativity varies from person to person and is subject to the influences of interactions among factors such as personal characteristics, cognitive styles, cognitive capability, and social environments. Gardner (2011) also believed creativity in a professional field is subject to the influence of interactions among the creator's intelligence, personal characteristics, social support and opportunities in the field.

Based on the concept of evolution, Csikszentmihalyi (1997) proposed two systematic theories about creativity with the focus on the interactions among persons, domains and fields, suggesting that creativity is a result of the interactions of persons, products and environments.

As indicated by Sternberg and Lubart (1999), research on creativity has adopted the confluence approaches, not only investigating personal factors of the creators but also exploring external factors of the creators, such as environmental and cultural factors.

Based on the above-mentioned discussion, the development of creativity requires not only the foundation of knowledge but also the capabilities of sensual perception, cognition, association, integration, symbolization and conceptualization. Through knowledge-based activities such as design, creativity is connected with knowledge (Finke, Ward, & Smith, 1992; Gabora, 2002). The cultivation of creativity is not based on instant inspiration but a learning strategy of analogical thinking to integrate new and existing knowledge. Through the learning process starting from cognitive conflict to analogical thinking and finally to analogical learning, one can construct new concepts or knowledge in order to improve his or her creativity.

RESEARCH METHOD

Research subject

The subjects in this study are 170 freshmen from the Day School and Night School of the department of architecture of a private university in northern Taiwan. There are totally 12 teachers teaching the three units to these subjects.

Concept transformation learning model of architectural design

In this study, a concept transformation learning model is developed based on the concepts of cognitive conflict, analogical thinking and analogical learning. The model is then used in actual teaching of three curricular units (2D composition, 3D composition, and architecture form composition) over 18 weeks in a course that is intended to equip the students with basic concepts about architectural design. In the 18 weeks, there are three assignments. The first assignment is about 2D composition, in which the teachers guide the students to draw references from

relevant paintings and incorporate the references together with their existing knowledge in this assignment. In the classroom, the teachers also prepare suitable teaching materials to teach the students basic design concepts about composition, materials, colors and other basic design knowledge and techniques, promoting the students' development of cognitive conflicts between their existing knowledge and new knowledge by causing the students' dissatisfaction with their existing knowledge and attempts to combine their existing knowledge with the new knowledge. Through this assignment, the students can be guided and motivated to develop their schema as the foundation for further learning of architectural design.

The second assignment is about 3D composition. Each of the students is required to select and draw references from a painting (a 2D work) and then use the references to create a 3D composition. Since the students cannot directly convert or duplicate their paintings into their 3D designs, they will suffer from obstacles in their designs. Therefore, the teaching method of analogical thinking is introduced in this stage. The teachers provide relevant cases (works by students from earlier years or works by architectural design masters) to promote analogical thinking among the students based on their schema developed in the previous stage, guiding them to think about how to use the concepts they have learned into their designs. Since this assignment is about 3D composition and the students only have previous experiences with 2D composition, this also creates a cognitive conflict for them, inspiring them to integrate their existing and new knowledge to develop a complete cognitive structure and the problem-solving capability needed to complete their works. In this stage, the students have to first find out what difficulties are with the assignment (i.e. alternative concepts) and then propose their own design concepts (composition elements, themes, materials and colors) based on what they have learned from the cases provided by the teachers, design drafts of their peers and discussions with their peers (i.e. mapping and inference phases). Finally, in the transfer and identification phases, the teachers guide the students to incorporate the architectural design concepts they have learned into their own schema (i.e. intelligible knowledge) to develop their own design creativity and problem-solving capability so that they will be able to produce more and better designs (i.e. plausible and fruitful knowledge).

The third assignment is about architecture form composition, in which each of the students is required to use the design concepts they have learned to design an architectural structure that can accommodate eight people. From the previous two assignments, the students have developed their complete cognitive structures about design (such as concepts about basic composition and materials). In this stage, the teachers introduce to the students new knowledge about architectural design such as structure, dimension and field, guiding the students to learn architectural design based on their existing concepts of design. Since the students are required to produce 1:1 models of their designs, they cannot simply duplicate what they have learned from the relevant cases. The students have to use their established schema to come up with the suitable themes, design elements and materials for this assignment. From this "learning through doing" activity, the students can learn more about the concept of architectural structure and combine the newly acquired knowledge with their existing knowledge. In this stage, the students can learn how to take the initiative in their architectural design knowledge schema construction through analogical learning and thinking. Through the three assignments, the students can learn how to apply the concepts they have learned from the course into their architectural design works. This is in line with the goal of scaffold learning in education. In this study, it is found that the concept transformation learning process from cognitive conflict to analogical thinking and to analogical learning is helpful for the students in their long-term learning and development of cognitive structures, turning them from complete novices into more experienced architecture designers.

In addition, in this learning process, the students' cognitive structure construction has also changed from case-based learning in the earlier stage to concept-based learning in the later stage, which is helpful for the students to develop their own creativity and capability of design problem solving.

EMPIRICAL ANALYSIS

Quantitative analysis

In addition to the teaching experiment, in-depth interviews and questionnaire surveys on the students are also conducted before and after the teaching experiment. The questionnaire in the survey uses a five-point Likert scale and is composed of questions covering five dimensions: 2D composition, 3D composition, creative composition, concept transformation, and creativity improvement. The answer "very agree" to a question is equal to five points while the answer "very disagree" to a question is equal to one point. The questionnaire results are collected and analyzed. The analysis results are shown in the Table 1.

Analysis results

The questionnaire survey results are analyzed to find out the influence of the concept transformation learning model on the students' learning performance and creativity development. According to the *t* test results of the students' learning performance before and after their analogical learning, the students' post-test scores (M=105.02) are higher than their pre-test scores (M=89.52) and the *t* value of the pre-test and post-test average scores is -18.487 (p=.000) with a degree of freedom at 170, which reaches the level of significance ($<$.001). This indicates a significant improvement of the students' scores in all the five dimensions after their concept transformation and analogical learning.

DISCUSSION AND CONCLUSION

Freshmen studying in departments of architecture are novices of architectural design. Because of their lack of basic concepts and experiences, they cannot flexibly use what they have learned in class into their design works, let alone developing their own creativity of architectural design. In this study, a concept transformation learning model is developed with the learning process starting from cognitive conflict to analogical thinking and finally to analogical learning. During the teaching experiment over a semester in this study, three assignments are given to the students to (1) receive information/knowledge about architectural design transmitted from their teachers in class; (2) develop simulation, analogy, analysis and innovation through their interactions with the teachers and peers; and (3) demonstrate the results of their learning. Through the concept transformation learning process, the goal of helping the students to improve their architectural

Table 1. Paired t-tests assessed the significance of the effects of dimension

	Pre-test		Post-test		
Dimension	**Average**	**SD**	**Average**	**SD**	**t**
2D Composition	13.09	2.23	15.87	1.82	-15.226***
3D Composition	16.67	2.76	19.50	2.66	-13.761***
Creative Composition	23.76	3.86	27.49	3.76	-13.162***
Concept Transformation	10.18	1.84	12.16	1.70	-13.811***
Creativity Improvement	25.80	4.72	29.97	4.80	-15.294***
Score	89.52	12.13	105.02	11.66	18.487***

*Note：N=170, ***p<.001*

design capability and creativity is fulfilled.

According to the analysis results of this study, the students are found more motivated to learn, better at understanding the core concepts of architectural design, and more capable of flexibly using design concepts to produce creative design works.

Also according to the responses from the students in the questionnaire survey, the concept transformation learning model can help to improve the insufficiencies of traditional teaching methods, enabling the students to have significant improvement in their learning performance and consequently come up with creative design works. As indicated by the *t* test results of the questionnaire responses, the students' post-test scores (M=105.02) are higher than their pre-test scores (M=89.52), suggesting a significant improvement in the students' overall learning performance and their learning in each of the five dimensions after their analogical learning. From the 18-month teaching experiment and the three assignments in this study, the students can establish their own schema and problem-solving capability. This finding indicates that the concept transformation learning model has not only short-term benefits but also long-term benefits for the students' analogical learning and cognitive structure construction.

The findings of this study about the benefits of concept transformation learning model for cognitive development can provide references for teaching in the other disciplines than architectural design. In addition, it is suggested that future research should be conducted to explore how to assess the improvement of students' creativity in architectural design through more specific or concrete methods. Last but not least, it is suggested that follow-up research should be conducted on the students during the coming three years before their graduation to further explore the long-term benefits of the concept transformation learning model for their learning performance.

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