



Establishment of a Digital Knowledge Conversion Architecture Design Learning with High User Acceptance

Yun-Wu Wu

China University of Technology, TAIWAN

Apollo Weng

China University of Technology, TAIWAN

Kuo-hua Weng

China University of Technology, TAIWAN

Received 27 May 2016 • Revised 2 October 2016 • Accepted 11 October 2016

ABSTRACT

The purpose of this study is to design a knowledge conversion and management digital learning system for architecture design learning, helping students to share, extract, use and create their design knowledge through web-based interactive activities based on socialization, internalization, combination and externalization process in addition to learning in the "design studio" at school. In addition, the technology acceptance model3 is used in this study to measure how students accept the system developed in this study by analyzing the user behavioral and environmental factors that can affect their use of the system. The results of questionnaire surveys based on TAM3 indicate that this digital learning environment based on knowledge management can effectively reduce the challenge of "ill-defined design problems" for students and help to promote better learning results. Therefore, it can be concluded that the knowledge transfer learning system developed in this study is very helpful for learning of architecture design.

Keywords: knowledge conversion learning systems, architecture design learning, technology acceptance model 3

INTRODUCTION

Because of easier access to information and more convenience in data transmission in recent years, e-learning has been widely used in higher education (Lee, Hsieh, & Chen, 2013; Wang, 2011). However, easy access to a vast amount of data online also causes the problems of cognitive overload for students, who have difficulties in processing the data and extracting from them useful information to establish and apply their own knowledge structures in solving problems they frequently encounter in architecture design (Tergan, 2005).

Architecture design is a kind of knowledge-intensive activity that depends heavily on the use of digital tools (such CAD) and hand drawings to produce the design. In their learning

© **Authors.** Terms and conditions of Creative Commons Attribution 4.0 International (CC BY 4.0) apply.

Correspondence: Kuo-hua Weng, *China University of Technology, Taiwan.*

✉ ghwong@cute.edu.tw

State of the literature

- According to literature, knowledge is socialized, externalized, integrated and then internalized into one's implicit knowledge; it becomes his or her own valuable knowledge asset.
- Exploring how to help students learn architecture design and establish their own cognitive structures of architecture design effectively through a digital learning environment of knowledge conversion and knowledge management.
- TAM3 is used in this study to evaluate the use of the architecture design knowledge conversion and management digital learning system and explore the influence of external factors on the users' attitudes toward and use of the system.

Contribution of this paper to the literature

- According to literature, knowledge is socialized, externalized, integrated and then internalized into one's implicit knowledge; it becomes his or her own valuable knowledge asset.
- Exploring how to help students learn architecture design and establish their own cognitive structures of architecture design effectively through a digital learning environment of knowledge conversion and knowledge management.
- TAM3 is used in this study to evaluate the use of the architecture design knowledge conversion and management digital learning system and explore the influence of external factors on the users' attitudes toward and use of the system.

of architecture design, students rely on regular suggestions from their teachers and revisions of their design drafts by their teachers in the classroom. In addition, they also have to collect a lot of information outside the classroom to solve their design problems. However, because most design problems are ill-defined, students often have no clue of how to collect the right information or acquire the right knowledge to express and solve their problems (Rittel & Webber, 1973). Still, pressed by the assignment deadline, they are forced to continue looking for the right knowledge to solve the ill-defined design problems (Angeli & Valanides, 2009). Therefore, to prepare students with the ability of knowledge application for better development in the future, it is a very good method to incorporate knowledge management into actual teaching activities to improve learners' capability of knowledge management and problem solving (Sharma & Chandel, 2013).

In the teaching/learning process of architecture design, it is very important to guide students in incorporating their creativity into the concept of architecture design and encourage them to learn in a more proactively fashion in order to help them learn more effectively (Wu, Huang, & Weng, 2014). In the existing literature of knowledge management, most of the focus is on its applications in the construction industry or in the academia other than in education (Forcada, Fuertes, Gangoells, Casals, & Macarulla, 2013). In other words, few of the existing studies have explored the potential benefits of knowledge management for students in their learning process of architecture design. In this study, a digital learning environment based on the concept of knowledge management is built with the intention of encouraging students to accumulate more experiences through knowledge collection, storage, sharing and application

and, ultimately, build their own knowledge structures and problem-solving capabilities for “ill-defined issues” they frequently encounter in the learning of architecture design.

Little of the existing literature addresses the “ill-defined issues” in learners’ acquisition of knowledge and design implementation with the assistance from information technology in their design learning process. Therefore, the major goal of this study is to establish a digital learning environment for architecture design learners based on the theories of knowledge conversion and knowledge management, helping learners to achieve meaningful learning of architecture design through their internal and external knowledge conversion. A digital learning system (environment) for architecture design knowledge transfer is first established in this study to promote effective learning and problem-solving capability development among students through knowledge socialization/sharing, externalization/extraction, combination/application, and internalization/creation. Moreover, since this digital learning system is a kind of knowledge management technology, TAM3 (Lefievre & others, 2012) is used in this study to explore students’ acceptance of the system and its influence on students’ intention to use the system by analyzing the dimensions of perceived ease of use, computer anxiety and self-efficacy in the process of students’ cognitive acceptance and the dimensions of perceived usefulness, job relevance, job relevance, output quality and result demonstrability in the process of cognitive instrumental process (Faqih & Jaradat, 2015; Venkatesh & Bala, 2008).

LITERATURE REVIEW

Learning process of architecture design

The core of the curricular planning for architectural education is mostly courses of architecture design arranged in different phases, in which the design topics evolve from smaller and simpler ones to larger and more complicated ones requiring more and more functional and design-related considerations. The traditional method of “design studio” is a common component in most students’ learning of architecture design. It is also a major source of knowledge for students in departments of architecture design.

Architecture design is a knowledge-intensive activity. Knowledge is often generated in the process of complicated social interactions and experience sharing. For students of architecture design, discussions with their peers and sharing information with one another in the design process can help them construct knowledge of architecture design and improve their design capability (Bea, 1993).

An online or virtual design studio is similar to a traditional studio of architecture design but different in the fact that it focuses on not only the skills but also on learning and interaction among users. Compared with traditional design studio, a modern online studio is significantly different in the generation and implementation of design concepts (Broadfoot & Bennett, 2003).

According to existing research, students in a traditional design studio learning environment obtain, organize and apply their design knowledge mostly under the guidance and teaching from their teachers; therefore, their learning of design is highly under the influence of their teachers' own cognitive structures and experiences (Akin, 2002). They obtain design knowledge mostly from one single source and, as a result, it is easy for them to lose motivation in active learning.

Therefore, it is a research-worthy topic to explore how to help students learn architecture design and establish their own cognitive structures of architecture design effectively through a digital learning environment of knowledge conversion and knowledge management.

Knowledge creation and knowledge conversion

Knowledge management is regarded as an effective tool for companies to achieve benefits such as more revenue growth, shorter design and production periods, and higher customer/employee satisfaction (I. Nonaka & Takeuchi, 1995). Among related literature, all the existing studies on knowledge management focus primarily on the differences among data, information and knowledge (Carrillo & Chinowsky, 2006).

Knowledge can be divided into two types: tacit knowledge and explicit knowledge. The former is highly personalized and context-related knowledge. It is difficult to transfer to others, visualize, share, duplicate and manage. The latter is knowledge that can be formulated or expressed systematically in form such as written texts or pamphlets (Payne & Sheehan, 2004). These two types of knowledge constitute the source of knowledge and exist in each level of individuals, teams and organizations (Ikujiro Nonaka & Takeuchi, 1995).

According to Professor Nonaka, a person's knowledge conversion and self-improvement is a model composed of four stages: socialization, externalization, combination and internalization. The application of this model in the strategy of knowledge management means a process that starts with the externalization of the tacit knowledge to create new knowledge. Then explicit knowledge is integrated to deepen the knowledge of the organization as a whole and also internalized to allow all the members of the organization to share the organizational knowledge. Finally, the tacit knowledge is socialized to enhance the productivity and competitiveness of each individual within the organization.

The modern society is flooded with an excess of information. It is very important to learn how to filter out irrelevant and unnecessary information. Knowledge internalization is a process of converting useful explicit knowledge into one's own tacit knowledge. When knowledge is socialized, externalized, integrated and then internalized into one's tacit knowledge, it becomes his or her own valuable knowledge asset.

Sub-conclusion

In their learning of architecture design, students often encounter problems of "ill-defined" design requirements while the traditional "design studio" teaching method with

face-to-face teaching and team discussions, though helpful for their learning to a certain degree, is restricted in time and space. In addition, some students may feel intimidated by face-to-face interactions and discussions with their teachers/peers. Based on the theories of knowledge conversion and management, a digital learning system for architecture knowledge learning is established in this study. The system is equipped with functions of data search, case sharing, design work demonstration, and self-review. Students and teachers can also upload their data or materials, which are then organized and categorized either manually by the teaching assistant or automatically by the system, providing design references for students and saving them time for information search and selection. In addition to the “design studio” learning in the classroom, there are virtual communities in this system for students to share, extract, integrate, create, externalize and internalize knowledge for their design production and their architecture design knowledge structure construction.

KNOWLEDGE CONVERSION AND MANAGEMENT DIGITAL LEARNING ENVIRONMENT ESTABLISHMENT

Architecture Design Knowledge Conversion Learning Model

By integrating knowledge conversion and knowledge management process, a model of architecture design knowledge conversion learning with various learning activities is established in this study (**Figure 1**). The architecture design learning process in this study is composed of two stages: design learning and design creation. In the design learning stage, activities of social learning are arranged for design knowledge is tacit knowledge and can be converted and transferred only through sharing and interaction. These activities are designed to promote students to have self-reflection and develop their own design knowledge by absorbing useful knowledge from others. In the design creation stage, students express their design concepts through physical design works. It is a knowledge externalization process in which students extract useful knowledge from their own existing knowledge and the knowledge they have obtained from social learning to form solutions to design problems. Through the creation of their works, students convert their tacit knowledge into explicit knowledge represented through their design works and then integrate the newly acquired knowledge into their existing knowledge to build their own knowledge structures.

System Framework

After the review of domestic and international literature on knowledge conversion and management and the in-depth interviews in this study, a digital knowledge conversion and management learning system is developed particularly for students in their learning process of architecture design. The functional framework of the system is composed of “knowledge storage”, “knowledge management learning”, “knowledge conversion learning”, “knowledge management” and “knowledge source” modules.

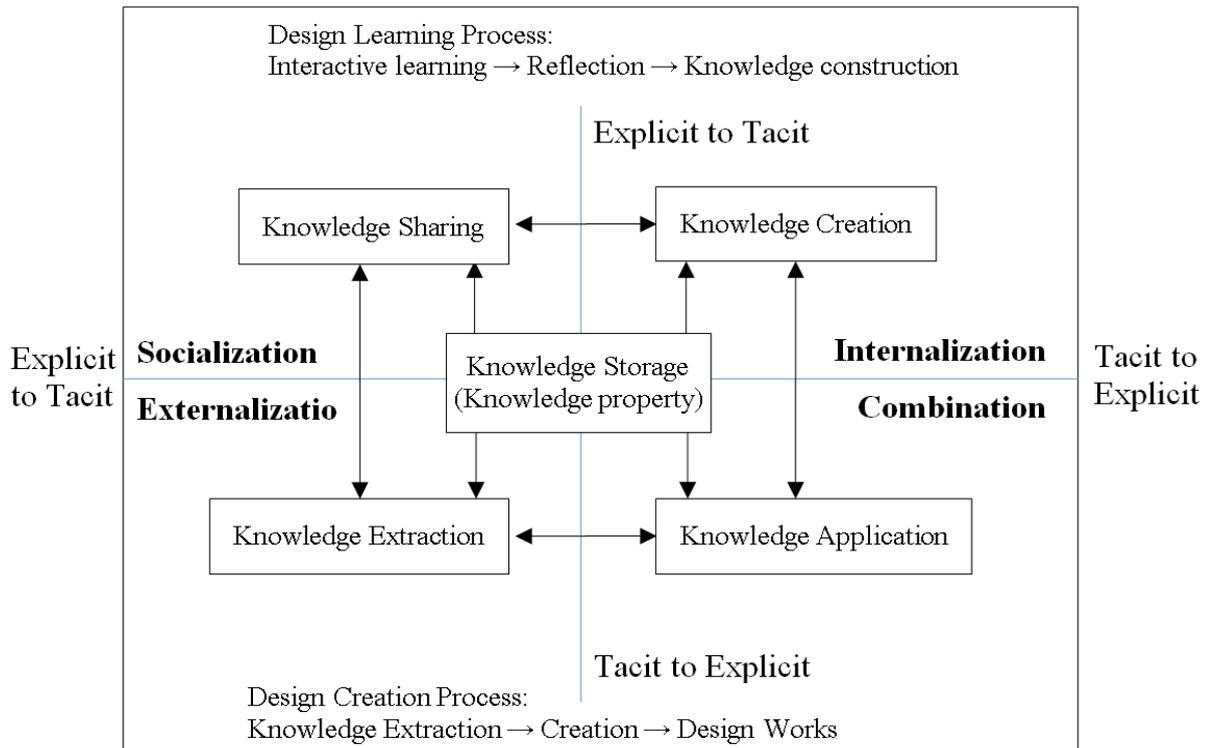


Figure 1. Architecture design knowledge conversion learning model

Table 1. Knowledge Conversion and Management Learning System Functions

Knowledge Conversion Learning Process	Learning System Function		
Knowledge Sharing ↔ Socialization	Teaching Materials Community	Search Engine Blog	E-Mail Bulletin Board
Knowledge Extraction ↔ Externalization	Case Sharing	Work Demonstration (Draft) Blog	Discussion Forum Chatroom Message Board
Knowledge Application ↔ Integration	Work Demonstration (Result)	Log (Self-review)	Discussion Forum
Knowledge Creation ↔ Internalization	Peer Evaluation Teacher Evaluation Learning Portfolio	Log (Self-review)	Chatroom Discussion Forum Chatroom
Knowledge Storage ↔ Cognitive Change		Work Compilation	
Knowledge Management	Statistic Data Knowledge Map	Student Management Search Engine	Internet Management Database

Knowledge conversion system for architecture design learning

Based on the literature review on knowledge management and interview results in this study, a learning platform with its functional modules is developed on the theoretical foundations of knowledge conversion and management.

The screenshot shows the homepage of the 'e-lms' (線上學習資源網) system. The header includes the logo and navigation tabs for '首頁', '評圖', '互動區', '作品區', '部落格', and '留言板'. The main content area features a '最新消息' (Latest News) section with three announcements:

- 1. 自第八週起延後一天計算分數** (Updated: 2014-11-13 23:40:55). Announcement: 應同學要求，自第八週起延後一天計算各位同學的每週分數，若因此而有分數增減，請同學再留言反映囉~~
- 2. 關於作品沒有分數的問題已經修復囉** (Updated: 2014-10-14 00:33:37). Announcement: 各位同學大家好，關於作品沒有分數的問題已經修復囉，請大家去看看你的最新成績吧~~ 此外，應同學要求，系統關閉時間延後一小時，每日上午02:00系統關機，上午09:00開機，請把握時間進行作業囉~
- 3. 新增老師意見與人氣最旺作品** (Updated: 2014-10-17 11:52:18). Announcement: 各位同學大家好，在聽取了各位同學寶貴的建議，老師在這雙十國慶期間，新增了兩個功能，分別說明如下：第一個就是可以顯示出老師給予部落格回應以及作品回應的功能，讓同學知道老師對於你的心得的看法。這樣同學就更能知道老師對妳作品的看法囉。第二個功能就是同學們可以針對他人的作品進行評分，每人可以針對每件作品評分一次，從1分到5分，人氣最旺的作品將會出現在首頁，以及作品區的上方，供同學們參考。

On the left side, there are sections for '關於本站', '網站使用禮節', '建議使用軟體', and '近期訪客'.

Figure 2. Announcements in the virtual classroom on the homepage of the system

Application of knowledge conversion in the learning process and activities of architecture design

Cognitive development is driven by thinking and learning with an emphasis on knowledge acquisition, extraction, application, creation and storage (Daugherty & Mentzer, 2008). Knowledge of architecture design is mainly tacit knowledge and it requires the process of cognitive assimilation and adaptation (i.e. knowledge construction) through social learning activities such as teacher-student and student-student interactions (Stahl, 2000). When the cognitive structure reaches equilibrium, it forms a knowledge asset. Therefore, this study is an attempt to incorporate the theories of knowledge management and knowledge conversion into the learning of architecture design to help learners solve ill-defined design problems.

(1) Knowledge sharing and socialization

The traditional education of architecture design is based on the “design studio” method in which students are like apprentices. The key to their knowledge acquisition lies in experience accumulation through their interaction activities with their teachers and peers such as observation, imitation, demonstration and practice. In other words, they acquire knowledge through social learning. In this study, social learning is incorporated into the learning system in the forms of community forums, virtual classrooms and blogs to promote teacher-student and student-student interactions and knowledge sharing (Figure 2 and Figure 3).

e-lms
線上學習資源網

首頁 評圖 互動區 作品區 部落格 留言板

討論版 >> 103上建築設計作業三討論版

同學發問時，請注意將你的問題濃縮成一句有意義的話，寫在主題的欄位裡面，內容欄位再將你的問題敘述清楚，若是主題不清楚，無法有效表達出問題的內容，會遭到管理員刪除的。若有上述疑慮的發問，請儘速將你的提問修改一下，避免被刪除，無法計入成果。

103上建築設計作業三討論版
對於設計作業三立體單元構成元有任何問題歡迎來此發問喔

本子版共有 8 篇主題，12 篇回應

主題	回覆	最近回應	最近更新	人氣
★.想請問一些模型材料運用與技術...	3	阿吉	2014-12-19 16:20:22	34
★.第四次作業	2	阿吉	2014-12-12 22:28:06	19
★.話說草圖一是下禮拜吧?	4	阿吉	2014-12-05 11:37:58	54
★.作業三立體單元構成元素	0	阿吉	2014-11-28 00:08:06	19
★.刪除時	0	咪咪咪蹦蹦	2014-11-27 19:18:53	9
★.老師第三次作業已經出現了!!!...	1	Kala雞腿堡	2014-10-24 14:55:38	41

Figure 3. Teacher-student knowledge sharing in the community forum

(2) Knowledge extraction and externalization

Architecture design is a process of presenting the design concepts through the actual design works. Through cases and analogical learning, knowledge extraction can convert knowledge into explicit knowledge. In the process of architecture design learning, knowledge extraction and expression can be achieved through knowledge externalization. In the system of this study, the functions of teaching material presentation, case sharing, design work demonstration and knowledge management (search and categorization) are incorporated to help students extract useful knowledge for their design concept development and design work production (Figure 4).

(3) Knowledge application and combination

In the learning process of architecture design, the production of a design by a student is the presentation of his or her explicit knowledge (Davenport & Prusak, 1998). Through knowledge sharing, students can extract useful knowledge, absorb it and then apply and present it in their design works. In the digital learning system developed in this study, there are functions of design work demonstration, self-review and peer evaluation, not only helping students to “learn by doing” but also promoting knowledge sharing, extraction, and systematic establishment of architecture design knowledge structure among them (Figure 5).

e-lms
線上學習資源網

首頁
評圖
互動區
作品區
部落格
留言板

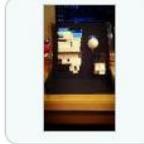
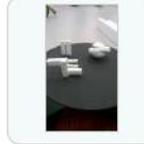
反應力排行榜

	yishalim 34 篇 / 1486 字 / 44
	Simon liu 27 篇 / 2421 字 / 90
	咪咪咪蹦蹦 24 篇 / 1704 字 / 71
	dua922111 23 篇 / 4514 字 / 196
	你看不見我！ 22 篇 / 3003 字 / 136
	Ash 19 篇 / 2466 字 / 130
	阿吉

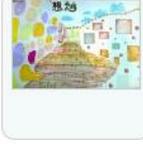
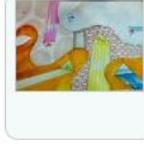
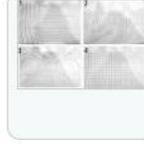
平面單元構成-dua922111 圖片展示

成果
草圖
案例

最近上傳作品 hw4:77 作品，29 回應 | hw3:164 作品，162 回應 | hw2:130 作品，110 回應 | hw1:82 作品，94 回應




平面單元構成dua922111 圖片展示近期評論意見

Figure 4. Students' knowledge extraction through work search and categorization

這件作品很有層次感喔...

可以做出像「逃學威龍」裡的...

這模型像是迷宮般的模樣，如...

這次作品 呈現的感覺真的很漂...

不是說是竹林七賢嗎 你的七賢...

指北，還還是覺得像日晷XD，...

這自由的理念看起來有表現出...

這個設計，以三角形之構件，主...

手工非常的棒，作品呈現雙人...

作品與原圖有符合，但可以把...

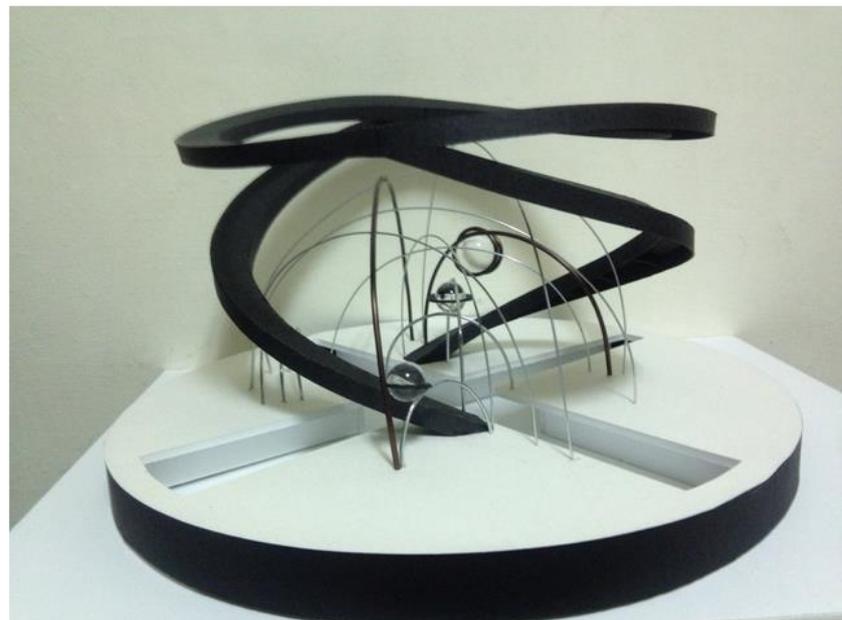


Figure 5. Knowledge sharing among students through peer critiques

The screenshot displays a user interface for a learning management system. On the left, there is a vertical list of student profiles, each with a small profile picture, a name, and statistics for posts and characters. Below this list is a section titled '胡言亂語排行榜' (Nonsense Ranking) with two entries: '天氣' (Weather) and '緣起不滅' (Origin of Nothingness). The main content area features two self-review posts. The first post, titled '創意構築1:1實體', includes a small image of a wooden structure, a link to view the student's work, and two numbered points: 1. Knowledge (把設計做成1:1沒想像中容易, 必須分工合作, 一刻不能鬆懈。) and 2. Skills (選用木板木材來表達作品, 用鋸檯來裁切每一片木板, 為了把握時間其餘人用美工刀裁切, 非常費力, 還要磨懸接處讓兩塊木板能好接合, 這部分非常不容易, 必須團...). The second post, titled '創意構築正模', also includes a small image, a link to view the work, and two numbered points: 1. Knowledge (利用不同材料組合1/20的小模型, 必須考慮外在環境, 結構是否穩固, 與做成1:1是否能容納人活動..等相關條件。) and 2. Skills (配合設計主題利用材料, 我選擇用竹籤, 讓人一眼見到就害怕刺傷的感受, 交接處用亮眼的金線, 表達難以靠近的衝擊。...). Both posts have a '繼續閱讀' (Continue Reading) link and a timestamp.

阿吉
14 篇 / 6613 字 / 472

聖揚
14 篇 / 4368 字 / 312

你看不見我!
13 篇 / 9242 字 / 711

Xsin
12 篇 / 4912 字 / 409

Mei
12 篇 / 4059 字 / 338

Diamond
12 篇 / 2768 字 / 231

胡言亂語排行榜

天氣
2 篇 / 726 字 / 363

緣起不滅
1 篇 / 324 字 / 324

創意構築1:1實體---(6次點閱, 0篇回應)

<<看看他的作品吧!

1.知識:
把設計做成1:1沒想像中容易, 必須分工合作, 一刻不能鬆懈。

2.技能:
選用木板木材來表達作品, 用鋸檯來裁切每一片木板, 為了把握時間其餘人用美工刀裁切, 非常費力, 還要磨懸接處讓兩塊木板能好接合, 這部分非常不容易, 必須團...

繼續閱讀【創意構築1:1實體】全文

更新時間: 2015-01-07 16:43:36
1. 自我省思 (272 個字元)

創意構築正模---(4次點閱, 0篇回應)

<<看看他的作品吧!

1.知識:
利用不同材料組合1/20的小模型, 必須考慮外在環境, 結構是否穩固, 與做成1:1是否能容納人活動..等相關條件。

2.技能:
配合設計主題利用材料, 我選擇用竹籤, 讓人一眼見到就害怕刺傷的感受, 交接處用亮眼的金線, 表達難以靠近的衝擊。...

繼續閱讀【創意構築正模】全文

Figure 6. Students' knowledge internalization through self-reviews

(4) Knowledge creation and internalization

Through the learning process of continuous interactions between tacit and explicit knowledge (I. Nonaka & Takeuchi, 1995), students can internalize their learning results and experiences into tacit knowledge. The system of this study is equipped with the functions of self-review, learning portfolio, and statistic data production for autonomous learning to help students to improve their design capability through self-reviews (Figure 6).

(5) TAM3

Based on the theory of reasoned actions (TRA), the technology acceptance model (TAM) is developed to explain and predict a user's acceptance of an information technology by exploring the connections among external variables and his/her perceptions, attitudes and intentions regarding the technology (Davis Jr, 1986). In the model, the perceived usefulness of a technology or system is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" while the perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free from effort". The addition of external variables would indirectly affect the users' intentions and behaviors. A user's "perceived usefulness" and "perceived ease of use" of a system respectively has an influence on user's attitudes toward his use of the system and

further on his intention to use the system, which then has an influence on his behaviors of using the system. In addition, perceived ease of use has a positive influence on perceived usefulness and further on the intention to use the system (Davis, 1989).

Widely used to analyze user acceptance of technologies of different industries, TAM is further extended to develop TAM2 (Venkatesh & Davis, 2000). Compared with TAM, TAM2 excludes the dimension of attitude toward usage, bringing better understanding of how user behaviors are influenced by perceived usefulness and perceived ease of use. In addition to factors covered in TAM and TAM2, TAM3 also defines external factors that have an influence on users' perceived usefulness of a system (Venkatesh & Bala, 2008). TAM3 is mainly used to predict personal use and acceptance of an information technology or system. The perceived ease of use is correlated with dimensions such as control (including levels of self-efficacy and convenience) and emotions (computer anxiety) (Venkatesh, 2000). The "computer self-efficacy" refers to one's belief in his or her ability to use the computer in the accomplishment of his/her job or assignment. It has an influence on the individual's expectation of the result from the use of the computer (Hosseini, Bathaei, & Mohammadzadeh, 2014). The application of TAM3 in this study is described as follows:

Firstly, the perceived usefulness in TAM3 is used to evaluate the students' use of the architecture design knowledge conversion and management digital learning system as a supplement tool for their learning and explore if the system has sufficient functions to not only satisfy their cognitive needs but also help them increase the completeness of their designs and their design capability by promoting teacher-student and student-student interactions (such as design draft demonstration, communities, blogs and logs).

Secondly, the perceived ease of use in TAM3 is significantly correlated with dimensions such as emotions (computer anxiety) and control (computer self-efficacy). In this study, the influence of the system's functional design on students' acceptance of the system is also explored – if the functional operation of the system is too complicated, it is easy to cause computer anxiety among the students and consequently affect their acceptance of the system.

Based on the above-mentioned discussion, TAM3 is used in this study to evaluate the use of the architecture design knowledge conversion and management digital learning system and explore the influence of external factors on the users' attitudes toward and use of the system. A TAM3 model is built in this study covering all the above-mentioned factors and dimensions for evaluation.

EMPIRICAL ANALYSIS

Research subject

The samples in this study are totally 170 freshmen from the Departments of Architecture in the Day School and the Night School of China University of Technology in Taipei. The experiment was conducted in the "Architecture Design I: Unit 3" course. During the experiment, the subjects were requested to use the digital learning system online each

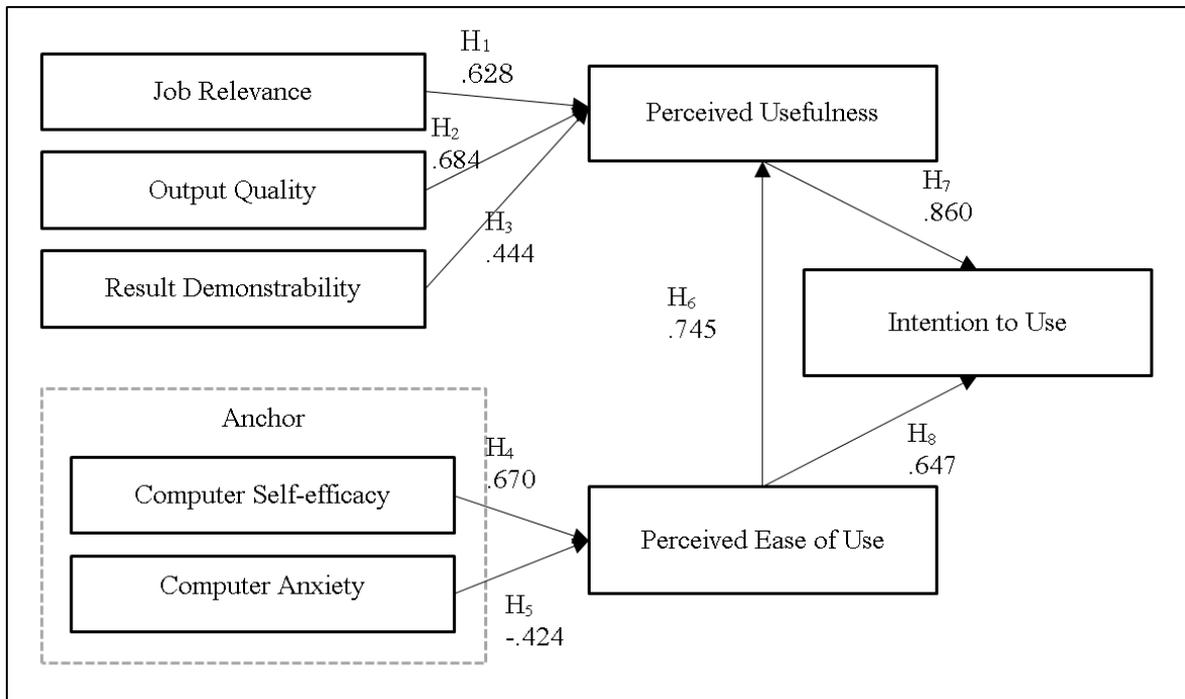


Figure 7. Path analysis result

week as a supplement to their learning in the classroom and share their works, interact with their peers and have self-reviews of their learning in the system.

Research model and hypotheses

Based on the research framework and literature review in this study, totally eight hypotheses about the causal connections respectively between job relevance, output quality, result demonstrability, computer self-efficacy, computer anxiety, perceived usefulness, perceived ease of use, and intention to use were developed.

A path analysis was conducted to evaluate the direct, indirect and overall causal connections among the variables and test the hypotheses. The path analysis results are shown in **Figure 7**.

A descriptive statistics analysis on the three dimensions of the TAM model developed in this study was conducted to explain the distribution of the samples by finding out their mean values and standard deviations. The questionnaire in this research used a five-point Likert scale to measure the user’s perceptions of each factor in the three dimensions (with five points for “strongly agree” and one point for “strongly disagree”). The questions of the questionnaire and the reliability analysis results of each dimension in the questionnaire are shown in **Table 2**.

Table 2. Reliability Analysis Results and Standard Deviations of Each Dimension

Dimension	Item	SD	Cronbach's α
Use Intention	I plan to use this system for assistance with my future learning and job.	.786	0.870
	I will recommend others to use this system.	.836	
	I am willing to spend time learning how to use this system more effectively.	.927	
	I will continue to use this system.	.944	
Perceived Usefulness	Using this system helps me to complete my job quickly.	.866	0.945
	Using this system helps me to improve my performance.	.847	
	Using this system helps me to improve my efficiency.	.759	
	Using this system is helpful for my job.	.737	
	Using this system helps to improve job quality.	.738	
Perceived Ease of Use	It is easy to use this system.	.808	0.930
	It is easy to browse this system.	.898	
	It is easy to operate this system.	.788	
	The interfaces of this system are clear and easy to understand.	.777	
Job Relevance	This system is compatible with my job.	.775	0.837
	This system is suitable for the type of my job.	.948	
	This system is suitable for the way I do my job.	.917	
Output Quality	I think the output contents of this system are good.	.925	0.927
	I think the output contents of this system are problem-free.	.904	
Result Demonstrability	Using this problem can help me to demonstrate what I have learned.	.979	0.672
	The results of using this system are clear and easy to understand.	.906	
Computer Self-efficacy	I can still use this system even if I have not used it before.	1.060	0.867
	I can still use this system on my own without anyone to teach me how.	.877	
	I can use this system only after someone demonstrates to me how.	.960	
	I can use this system with confidence.	.903	
	I can use this system with familiarity.	.966	
Computer Anxiety	It is stressful to use this system.	1.219	0.721
	It is not uncomfortable or restraining to use this system.	1.063	
	Using this system makes me feel it is difficult to understand computer-related technologies.	1.111	
	I fear that using this system makes me dependent on the computer and unable to use my logic reasoning capability	1.114	
	Using this system makes me feel anxious.	1.068	
	I am afraid that the results of this system are irreversible or correctable.	1.200	

(1) Reliability analysis

According to the reliability analysis results, the Cronbach's α coefficients ranged from 0.721~0.945, all larger than 0.700, indicating sufficient reliability of each dimension in the questionnaire (Table 2).

Table 3. Test Results of Research Hypothesis

Hypothesis	Significant
H ₁ : Job relevance has a positive influence on perceived usefulness.	Yes
H ₂ : Output quality has a positive influence on perceived usefulness.	Yes
H ₃ : Result demonstrability has a positive influence on perceived usefulness.	Yes
H ₄ : Computer self-efficacy has a positive influence on perceived ease of use.	Yes
H ₅ : Computer anxiety has a negative influence on perceived ease of use.	Yes
H ₆ : Perceived ease of use of the system has a positive influence on its perceived usefulness.	Yes
H ₇ : Perceived usefulness of the system has a positive influence on users' intentions to use the system.	Yes
H ₈ : Perceived ease of use of the system has a positive influence on users' intentions to use the system.	Yes

(Data source: data compiled in this study)

Table 4. Path Analysis Results of H1, H2 and H3

Dependent Variable	Independent Variable	β	<i>t</i>	<i>P</i>	VIF
Perceived Usefulness	Job Relevance	0.628	10.448	0.000	1.000
	Output Quality	0.684	12.137	0.000	1.000
	Result Demonstrability	0.444	6.419	0.000	1.000

$R^2=0.478$ $F=50.599$

(Data source: data compiled in this study)

$**p<.001$

(2) Validity analysis

Based on the literature review and analysis in this study, the technology acceptance model3 (TAM3) is used to analyze the students' acceptance of the digital learning system developed in this research. TAM3 has been proven many times to have high validity. All the variables and questions in the questionnaire of this study were all designed and revised from questions used in previous empirical studies of TAM3. Therefore, the questions in this study were also of good validity. The questionnaire results were collected and analyzed to test the eight hypotheses of this research and the results are listed in **Table 3** as follows:

(3) Path analysis results

As indicated in the analysis results in **Table 2** and the path analysis results in **Figure 7**, the data and hypotheses in this study are proven to have satisfactory reliability and validity. The following is a further discussion of the path analysis results of the hypotheses.

As indicated in **Table 4**, the H₁, H₂ and H₃ of this study respectively regarding the positive influence of job relevance, output quality and result demonstrability on the perceived usefulness of the system developed in this research all reach the level of significance ($p<.001$). According to the β values, output quality has the strongest influence ($\beta=.684$), followed by job relevance ($\beta=.628$) and result demonstrability ($\beta=.444$).

As indicated in **Table 5**, the H₄ about the positive influence of computer self-efficacy and H₅ about the negative influence of computer anxiety on the perceived ease of use of the

Table 5. Path Analysis Results of H4 and H5

Dependent Variable	Independent Variable	β	t	P	VIF
Perceived Ease of Use	Computer Self-efficacy	0.670	11.684	0.000	1.000
	Computer Anxiety	-0.424	-6.063	0.000	1.000

$R^2=0.470$ $F=74.063$

(Data source: data compiled in this study)

** $p<.001$

Table 6. Path Analysis Results of H6

Dependent Variable	Independent Variable	β	t	P	VIF
Perceived Ease of Use	Perceived Usefulness	0.745	14.486	0.000	1.000

$R^2=0.555$ $F=209.841$

(Data source: data compiled in this study)

** $p<.001$

Table 7. Path Analysis Results of H7

Dependent Variable	Independent Variable	β	t	P	VIF
Use Intention	Perceived Usefulness	0.860	21.814	0.000	1.000

$R^2=0.739$ $F=475.856$

(Data source: data compiled in this study)

** $p<.001$

Table 8. Table 8. Path Analysis Results of H8

Dependent Variable	Independent Variable	β	t	P	VIF
Use Intention	Perceived Ease of Use	0.647	11.009	0.000	1.000

$R^2=0.419$ $F=121.197$

(Data source: data compiled in this study)

** $p<.001$

system in this study both reach the level of significance ($p<.001$). According to the β values, the positive influence of computer self-efficacy on the perceived ease of use ($\beta=.670$) is stronger than the negative influence of computer anxiety ($\beta=-.424$).

As indicated in **Table 6**, the H_6 in this study about the positive influence of the perceived ease of use of the system on its perceived usefulness reaches the level of significance ($p<.001$). The β value ($\beta=0.745$) indicates that the perceived ease of use of this system indeed has a positive influence on its perceived usefulness.

As indicated in **Table 7**, the H_7 of this study about the positive influence of the perceived usefulness of the system on users' intention to use it reaches the level of significance. The β value ($\beta=.860$) indicates that the perceived usefulness of this system indeed has a positive influence on users' intention to use it.

As indicated in **Table 8**, the H_8 of this study also reaches the level of significance ($p<.001$). The β value ($\beta=.647$) indicates that the perceived ease of use of this system indeed also has a positive influence on users' intention to use it.

DISCUSSION

The architecture design knowledge conversion and management digital learning system developed in this study is equipped with the mechanisms of knowledge acquisition and sharing, capable of helping students to effectively and efficiently obtain required architecture design knowledge through designated knowledge sources, manage knowledge sharing, and consequently reduce their cognitive load in the learning process. By making the students feel the system is useful and easy to use, they will have higher intentions to use the system for their learning (Hosseini et al., 2014).

Consistent with the finding of previous research that the perceived ease of use of a technology or system has a significant influence on users' intentions to use it (Alenezi et al., 2010), it is found in this study that the "perceived ease of use" has a significant influence on the subjects' intentions to use the system. It is probably because the students feel the system is easy to use and, therefore, they have lower anxiety (Chow, Herold, Choo, & Chan, 2012) and higher acceptance of the system.

The use of peer interactions such as discussions and mutual critiques can help students to develop the capability of proactively categorizing and organizing the information they have collected, building their schema with newly acquired knowledge, and producing design works with more innovative creativity. For the curricular design of more advanced architecture design courses in the future, it is suggested to challenge students with design assignments of higher difficulty or complexity levels in order to strengthen their knowledge schema of architecture design.

CONCLUSION

With the digital architecture design knowledge conversion and management learning system developed in this study, students can conduct their learning with the digital learning contents and learning activities within the system in accordance with the steps of knowledge sharing, extraction, application, creation and storage. By providing more interaction opportunities for students, the system can effectively promote students' learning efficiency and enhance their learning quality. According to the TAM3 analysis results of the subjects' acceptance of the system developed in this study and the factors affecting their user behaviors, it is found that (1) the perceived ease of use of the system has a significant influence on the students' intention to use the system and (2) the perceived usefulness of the system has a significantly positive influence on the students' intention to use the system. It is probably because the system is equipped with the functions of knowledge sharing and extraction, helping the students to acquire knowledge through social interactions. The students suffer little computer anxiety and improve their computer self-efficacy; therefore, they feel the system is useful and easy to use and they have higher intentions to use the system.

Moreover, in terms of output quality, result demonstrability and job relevance, the information from the knowledge map, learning portfolio and teacher evaluation in this system

can provide helpful references for the students when doing their design assignments while the operational interfaces and functions such as the blogs, chatrooms and work demonstrations in this system are suitable for how the students do their assignments and also provide good output quality. The learning results from using this system are clear and easy to understand, showing the students and others what they have learned and helped them to effectively solve the ill-defined problems in architecture design learning. As a result, the students find the system developed in this study useful and they are more willing to use it. This finding agrees with the conclusion of the research by Venkatesh and Bala (2008): perceived usefulness and perceived ease of use each has a positive influence on users' attitude toward the use of an information technology. To conclude, the digital architecture design knowledge conversion learning system developed in this study is proven helpful for students in their learning of architecture design, establishing their cognitive structures about architecture design, inspiring their design creativity through on-line and off-line learning, and improving their self-efficacy of completing the assignments.

Due to the learning technology that applied to the learning experiment in this study may have the limitations on the dependency of learning context and cultural difference. Future studies could attempt to examine the influence of the emerging learning technologies such as mobile internet applications (Haaren & Moes, 2016), social media (Hong et al, 2016), augmented reality (Haddad & Baglee, 2015) on the learning strategy of students' knowledge acquisition and knowledge convention. Due to the use of the technologies that mentioned above are much popular and closer to the activities of current day students. Therefore, whether the findings of this study can be applied to these new learning technologies directly still need to be investigated.

REFERENCES

- Akin, Ö. (2002). Case-based instruction strategies in architecture. *Design Studies*, 23(4), 407-431.
- Alenezi, A. R., Karim, A. M. A., & Veloo, A. (2010). An empirical investigation into the role of enjoyment, computer anxiety, computer self-efficacy and internet experience in influencing the students' intention to use e-learning: A case study from Saudi Arabian governmental universities. *TOJET: The Turkish Online Journal of Educational Technology*, 9(4).
- Angeli, C., & Valanides, N. (2009). Instructional effects on critical thinking: Performance on ill-defined issues. *Learning and Instruction*, 19(4), 322-334.
- Bea, F. (1993). Aluminosity dependent fractionation patterns in differentiated granite-leucogranite systems. *EOS*, 74(16), 343.
- Broadfoot, O., & Bennett, R. (2003). Design studios: Online? Comparing traditional face-to-face design studio education with modern Internet-based design studios.
- Carrillo, P., & Chinowsky, P. (2006). Exploiting knowledge management: The engineering and construction perspective. *Journal of Management in Engineering*, 22(1), 2-10.
- Chow, M., Herold, D. K., Choo, T. M., & Chan, K. (2012). Extending the technology acceptance model to explore the intention to use Second Life for enhancing healthcare education. *Computers & Education*, 59(4), 1136-1144.

- Daugherty, J., & Mentzer, N. (2008). Analogical reasoning in the engineering design process and technology education applications.
- Davenport, T. H., & Prusak, L. (1998). *Working knowledge: How organizations manage what they know*. Harvard Business Press.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319-340.
- Davis Jr, F. D. (1986). *A technology acceptance model for empirically testing new end-user information systems: Theory and results* (Doctoral dissertation, Massachusetts Institute of Technology).
- Faqih, K. M., & Jaradat, M. I. R. M. (2015). Assessing the moderating effect of gender differences and individualism-collectivism at individual-level on the adoption of mobile commerce technology: TAM3 perspective. *Journal of Retailing and Consumer Services*, 22, 37-52.
- Forcada, N., Fuertes, A., Gangoelle, M., Casals, M., & Macarulla, M. (2013). Knowledge management perceptions in construction and design companies. *Automation in construction*, 29, 83-91.
- Haaren, F. V., & Moes, N. C. (2016). Shareworks-a ubiquitous online learning platform for project-based learning and networking. *International Journal of Computer Aided Engineering and Technology*, 8(1-2), 179-197.
- Haddad, K., & Baglee, D. (2015, September). Using Augmented Reality in Manufacturing Firms and its Impacts on Knowledge Transfer. In *European Conference on Knowledge Management* (p. 1037). Academic Conferences International Limited.
- Hong, J. C., Hwang, M. Y., Szeto, E., Tsai, C. R., Kuo, Y. C., & Hsu, W. Y. (2016). Internet cognitive failure relevant to self-efficacy, learning interest, and satisfaction with social media learning. *Computers in Human Behavior*, 55, 214-222.
- Hosseini, S. A., Bathaei, S. M., & Mohammadzadeh, S. (2014). Does self-efficacy effect on knowledge sharing intention in e-learning system? A motivational factor analysis in Open University Malaysia (OUM). *Kuwait Chapter of the Arabian Journal of Business and Management Review*, 3(11), 35.
- Lefievre, V. (2012, May). Gender differences in acceptance by students of training software for office tools. In *14th Annual International Conference on Education*.
- Lee, Y. H., Hsieh, Y. C., & Chen, Y. H. (2013). An investigation of employees' use of e-learning systems: applying the technology acceptance model. *Behaviour & Information Technology*, 32(2), 173-189.
- Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford university press.
- Nonaka, I. (2008). *The knowledge-creating company*. Harvard Business Review Press.
- Payne, J., & Sheehan, T. (2004). Demystifying knowledge management: A best practice guide for the construction industry. *Constructing excellence*.
- Rittel, H. W., & Webber, M. M. (1973). 2.3 planning problems are wicked. *Polity*, 4, 155-169.
- Sharma, S. K., & Chandel, J. K. (2013). Technology acceptance model for the use of learning through websites among students in Oman.
- Stahl, G. (2000). A model of collaborative knowledge-building. In *Fourth international conference of the learning sciences* (Vol. 10, pp. 70-77). Mahwah, NJ: Erlbaum, 2000a.
- Tergan, S. O. (2005). Digital concept maps for managing knowledge and information. In *Knowledge and information visualization* (pp. 185-204). Springer Berlin Heidelberg.
- Venkatesh, V. (2000). Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information systems research*, 11(4), 342-365.

- Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision sciences*, 39(2), 273-315.
- Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management science*, 46(2), 186-204.
- Wang, M. (2011). Integrating organizational, social, and individual perspectives in Web 2.0-based workplace e-learning. *Information Systems Frontiers*, 13(2), 191-205.
- Wu, Y. W., Huang, C. F., & Weng, K. H. (2014). A Study of an Architecture Design Learning Process Based on Social Learning, Course Teaching, Interaction, and Analogical Thinking. *Mathematical Problems in Engineering*.

<http://iserjournals.com/journals/eurasia>