



# Design, analysis and user acceptance of architectural design education in learning system based on knowledge management theory

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The major purpose of this study is to develop an architectural design knowledge management learning system with corresponding learning activities to help the students have meaningful learning and improve their design capability in their learning process. Firstly, the system can help the students to obtain and share useful knowledge. Secondly, through extraction, application and creation as well as corresponding learning activities, the students can achieve meaningful learning. Lastly, the system can enable the students to accumulate knowledge and experiences to build their schema automatically and improve their design capability. The technology acceptance model (TAM) analysis results support all the hypotheses of this study, indicating the perceived usefulness and ease of use of the system have a positive influence on the students' willingness to use the system, which also helps to effectively reduce the problem of cognitive overload of the student in their learning process and then improve their design capability.

*Keywords:* cognitive workload, technology acceptance, model, architectural design learning

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## INTRODUCTION

Thanks to the exponential development of information technology, people can now have access to information anytime and anywhere (Wong and Hiew 2005). In recent years, because of its real-time access to information and communicational convenience, e-learning has become widely accepted by learners (Wang 2011). Providing a learning environment with rich information sources, e-learning can enable learners to build their own knowledge via interactions with different information sources and give them ample freedom and flexibility in information access (Anshari, Alas& Guan,2015). However, access to massive amount of on-line information can cause problems of cognitive overload for learners, leaving them with little idea of how to process the massive information and extract from it useful knowledge to build their own cognitive structures and solve design problems in the future (Kayama and Kamto 2001) Architecture design is a knowledge-intensive activity (Rodgers et al. 2001). When learning architecture design, students must rely on the regular revisions and suggestions from teachers in class or in the studio (Schön 1983). In addition, they also have to collect massive amount of external information to solve their own design problems. Design problems are mostly ill-defined and, therefore, students tend not to know how to collect required knowledge and formulate their design problems (Rittel& Webber, 1984). However, they still have to continuously search for helpful knowledge to solve their ill-defined problems before the deadline of their design assignments (An, 2014). In addition, due to the lack of deep and sufficient understanding about architecture design, students often collect or learn fragmented knowledge and cannot retain or organize the knowledge to systematically form cognitive structures about architecture design. All of these challenges can give rise to problems of cognitive overload for students (Cierniak et al. 2009).

For a mainly project-based industry such as the construction industry (Kamara, et al, 2002) knowledge management is a tool to achieve innovation and performance improvement (Egan 1998, Egbu et al. 1999). In the era of knowledge economy, effective knowledge management can be a source of competitiveness for the construction companies, helping them to reduce costs, improve quality and shorten time required for construction projects (Shelbourn et al. 2006). Effective knowledge management can help companies to better manage their resources and maintain their competitive edge in the ever-changing environment (Tiwana 2000, Forcada et al. 2013). The integration of knowledge management into teaching is also a very good method to help learners to improve their learning and problem-solving capability (Michael and Richard 2006).

Most of the existing research on knowledge management focuses on its application in the construction industry but not in education (Forcada et al. 2013,

### *State of the literature*

- *This study is to establish an architectural design knowledge management learning system. With its function modules and learning activities, the students can have meaningful learning through knowledge sharing, extraction, application and creation.*
- *Little research has explored the application of information technology to help students to solve the challenges of cognitive overload and ill-defined design problems in their process of design learning and knowledge acquisition.*
- *The knowledge conversion theory is introduced into the curricular design in this study to build an architecture design learning process model for teaching experiments and then questionnaire surveys are conducted to find out if the digital learning environment based on knowledge management can effectively reduce the challenge of cognitive overload for students and help to promote better learning results.*

### *Contribution of this paper to the literature*

- *With its effective knowledge management functions and learning activities, the system can help the students to reduce their cognitive load and promote their automatic schema construction, making them perceive that the system is useful.*
- *Through their learning, the students can combine their existing knowledge with newly acquired knowledge in their knowledge structure construction.*
- *The students can effectively solve the cognitive overload problem in their learning process and improve their design capability.*

Dave and Koskela 2009). In particular, little research has explored the benefits of knowledge management for students in their learning process of architecture design. This study is intended to help students to solve the challenges of cognitive overload and ill-defined design problems by building a digital learning environment based on knowledge management, encouraging students to accumulate experiences and build their own knowledge structures through the process of knowledge collection, storage, sharing and application.

Previous research on architecture design learning mostly focuses on the application of CAD and hand-drawn design (Bermudez and King 2000, Ibrahim and Rahimian, 2010) or explores the benefits of cooperative design learning from the perspectives of knowledge sharing or game theory (Chiu 2010, Wang et al. 2010). Little research has explored the application of information technology to help students to solve the challenges of cognitive overload and ill-defined design problems in their process of design learning and knowledge acquisition. Therefore, a digital learning environment based on knowledge management is built in this study to help students to have meaningful learning and knowledge acquisition in their process of architecture design learning.

In addition, the technology acceptance model 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. Last but not least, the knowledge conversion theory is introduced into the curricular design in this study to build an architecture design learning process model for teaching experiments and then questionnaire surveys are conducted to find out if the digital learning environment based on knowledge management can effectively reduce the challenge of cognitive overload for students and help to promote better learning results.

## **LITERATURE REVIEW**

### **Architectural Design Learning Process**

Architectural design courses constitute one of the curricular cores of architecture education. With the courses starting from the beginning level to more advanced levels, students need to consider more issues in their designs. In the learning process of architectural design, students acquire their knowledge mainly from the design studio training method.

The typical design studio teaching model is a learning process in which a teacher gives assignments to students, provide individual guidance to each student, and help them to produce their final designs through several revisions of their drafts. It is also a method used in traditional architectural design education.

According to existing research, the design knowledge acquisition, organization and application of students mostly come from the teacher's guidance and teaching; therefore, they are subject to the influence of the teacher's own cognitive structure and experiences (Akin 2002). In this method, students can only acquire knowledge from just one single knowledge source and, as a result, lose motivation of active learning easily.

Architectural design is a kind of knowledge-intensive activity and knowledge is mostly generated through complicated social interactions and experience exchanges. When learning architectural design, students can achieve knowledge construction, concept conversion, and improvement of design capability through peer discussions and information exchanges (Bea 1993).

Based on the above-mentioned discussion, draft revisions and peer discussions are the major and most significant sources of knowledge for students in design studio training. They require teacher-student and student-student discussions and

communications. However, such discussions and communications are restricted in time and space (during course hours and in the classroom). In addition, when having one-on-one discussions with the teacher, some students may feel too nervous to have effective communication or learning. Using information systems such as the blog can enable students to learn from each other by recording their thoughts, posting their works and experiences, and receiving feedbacks from others online (Jarvenpa and Staples 2000). Therefore, it is worthwhile to explore how to help students effectively acquire knowledge of architectural design by providing them with a suitable knowledge management learning system and learning activities.

## Knowledge Management

Since Nonaka and Takeuchi published their book, *The Knowledge Creating Company*, knowledge management has been seen as an effective tool for companies to improve their revenue growth, design/production time, customer/employee satisfaction and many other aspects. Early research on knowledge management focuses on the distinctions among data, information and knowledge. From the perspectives of process and inventory, data can be divided into four different dimensions: data, information, knowledge and wisdom (Nonaka and Takeuchi 1997). Data can be analyzed and converted into useful information to meet certain purposes and demands. Information can be then turned into knowledge after it is intellectually organized and processed (Nonaka 1994). Effective use of knowledge to produce guidance for decision making is wisdom (Nonaka 1994). Therefore, data is the basic element of knowledge. Data alone does not contain any meaning. Information comes from analyzed data to meet certain purposes. Knowledge comes from the value-added process of organizing, analyzing and integrating information.

The so-called “knowledge management” refers to the continuous process of providing the right knowledge at the right time to members who need it to help them take the right action and consequently improve the organizational performance (Wang, 2013). This process is composed of steps starting from knowledge creation, collection, categorization, storage, sharing & access, use & improvement to elimination (Tserng and Lin 2005). According to the formula proposed by Deloitte, knowledge management is composed of people, knowledge and sharing. The formula is  $KM = P + K + S$ . The “P” refers to people, including entry-level employees, senior executives or any other staff members involved in knowledge work within an organization. The “+” refers to technology, information technology in particular, used to help with the knowledge management system construction. The “K” means knowledge, including data, information, knowledge and wisdom. The “S” means sharing. As reflected by this formula, knowledge management is an activity or process in which people use technology to share knowledge to realize multiplier effects of knowledge management. Therefore, knowledge sharing is the key to success of knowledge management.

## TAM

Technological advances quickly change our daily lives and facilitate people's lives in every area; advances in technology continue to make its presence felt in many areas such as communication, health, and the economy. In this context, many educational reforms in the world are based on the integration of technology into the field of education (Tosuntasa et al. 2015).

The technology acceptance model (TAM) was developed by Davis (1986) based on the TRA theory with modifications of the dimensions and their causalities to predict one's acceptance of information technologies by measuring their perceptions (Davis, 1986), beliefs, attitudes and intentions in their use of such

technologies. TAM consists of two main beliefs known as perceived ease of use and perceived usefulness, which Davis, 1989 and Davis, 1993 defined as “the degree to which a person believes that using a specific system would be free of mental and physical efforts” and “the degree to which a person believes that using a specific system would enhance his/her job performance,” respectively (Eunil and Ki 2014). In the TAM theory, the major belief that has an influence on the users’ attitudes is composed of two dimensions: perceived usefulness and perceived ease of use of the technology or system. According to Davis and other scholars, these two dimensions can influence users’ attitudes toward using a technology and then influence their behavioral intention to use the technology. In addition, the intention to use the technology is subject to the influence of both the users’ attitude toward and perceived usefulness of the technology and then the intention has an influence on the users’ behaviors of using the technology.

There are a large number of studies that have looked at how TAM can explain the acceptance of software development products, but researchers have realized that TAM can also be used to explain the acceptance of software development processes. According to TAM, two variables impact adoption: perceived usefulness and perceived ease of use. Perceived usefulness refers to the degree to which an individual believes that using a particular technology would enhance his or her job performance (Hosseini 2015). The validity and reliability of the perceived usefulness and perceived ease of use variables in TAM have been supported by many studies. In addition, the perceived ease of use also has a positive influence on the perceived usefulness and then an indirect influence on the users’ intention. To meet educational purposes and students’ demands, e-learning development emerges to be a catalyst for today educational institutions.

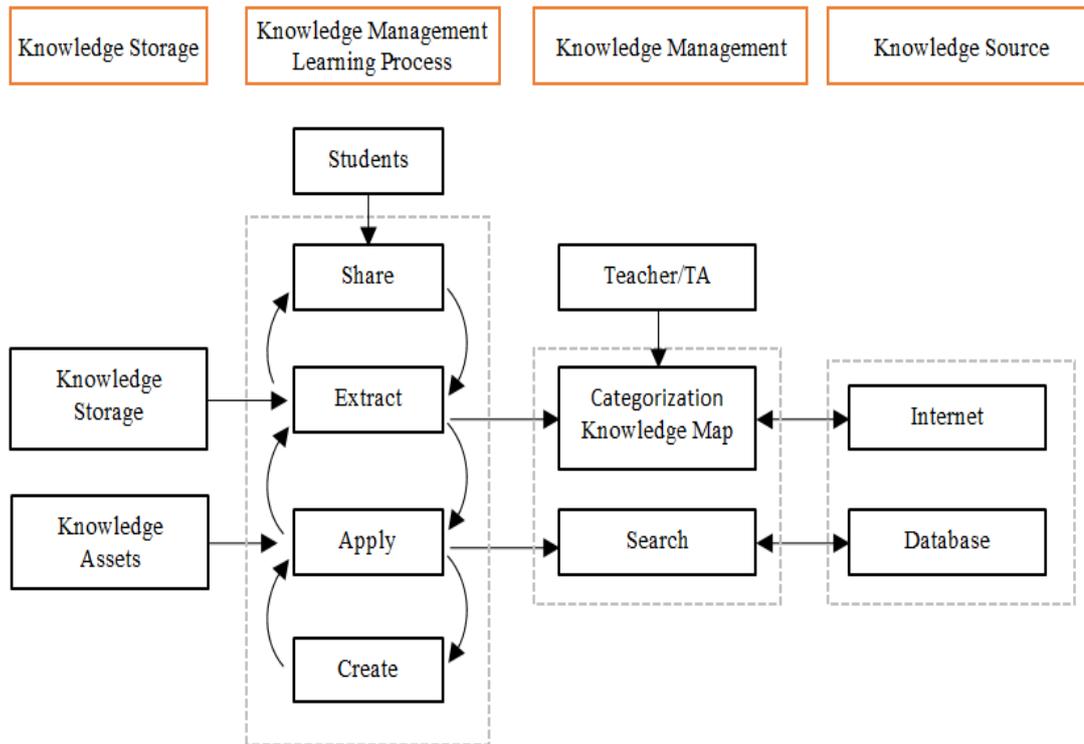
E-learning can be defined as a dynamic and immediate learning environment through the use of internet to improve the quality of learning by providing students with access to resources and services, together with distant exchange and collaboration. E-learning supports learners with some special capabilities such as interactivity, strong search, immediacy, physical mobility and situating of educational activities, self-regulation and self-directed learning, corporate training, personalized learning, and effective technique of delivering lesson and gaining knowledge (Linda and Steven 2014).

## **METHODOLOGY**

### **Architectural Design Knowledge Management Learning System and Learning Activities**

Based on the literature review of existing research about knowledge management at home and abroad as well as in-depth interviews with specialists, a knowledge management learning system is established in this research for students in their architectural design learning process. As shown in Figure 1, this system features dimensions of knowledge management & knowledge source; knowledge storage; and knowledge management and conversion learning process.

Architectural design assignments mostly involve ill-defined problems and have deadline restrictions. Through sharing knowledge, students can have better understanding of the design problems in their assignments and then come up with suitable solutions (Tserng and Lin 2005). However, some students may choose not to share their knowledge or share just parts of their knowledge so that they can have higher scores than their peers. An effective knowledge management system can help to solve this problem.



**Figure 1.** Architecture Design Knowledge Management Learning System and Learning Activities

The extrinsic knowledge of knowledge source can be obtained by organization or team members through the Internet, libraries, exhibitions, teaching materials, magazines and others. The intrinsic knowledge can be obtained through the communications on the Intranet and blogs of the members, work presentations (including drafts and final designs) and self-reflection. Architectural design is highly professional and knowledge-intensive (Johannessen et al. 1999). Effective knowledge management is required to provide effective knowledge sources for learners to achieve meaningful learning and avoid cognitive overload. Therefore, this study develops an effective architectural design knowledge management system. In this system, knowledge managers (teacher/teaching assistant) can have direct management and effective organization of the knowledge sources to help reduce cognitive load for students. The knowledge can also be stored in the database for the reference of students in the present and in the future.

In the knowledge management mechanism of the system shown in Figure 2, the solid lines signify direct connections, i.e., knowledge conversion by the students. The dotted lines signify indirect connections, i.e., effective management and analyses of the knowledge sources based on feedbacks from the students to ensure more effective knowledge acquisition. The system also has the functions of knowledge map and the knowledge is categorized and stored in the database based on keywords to not only enable convenient knowledge access and browsing but also effectively reduce cognitive load for the students.

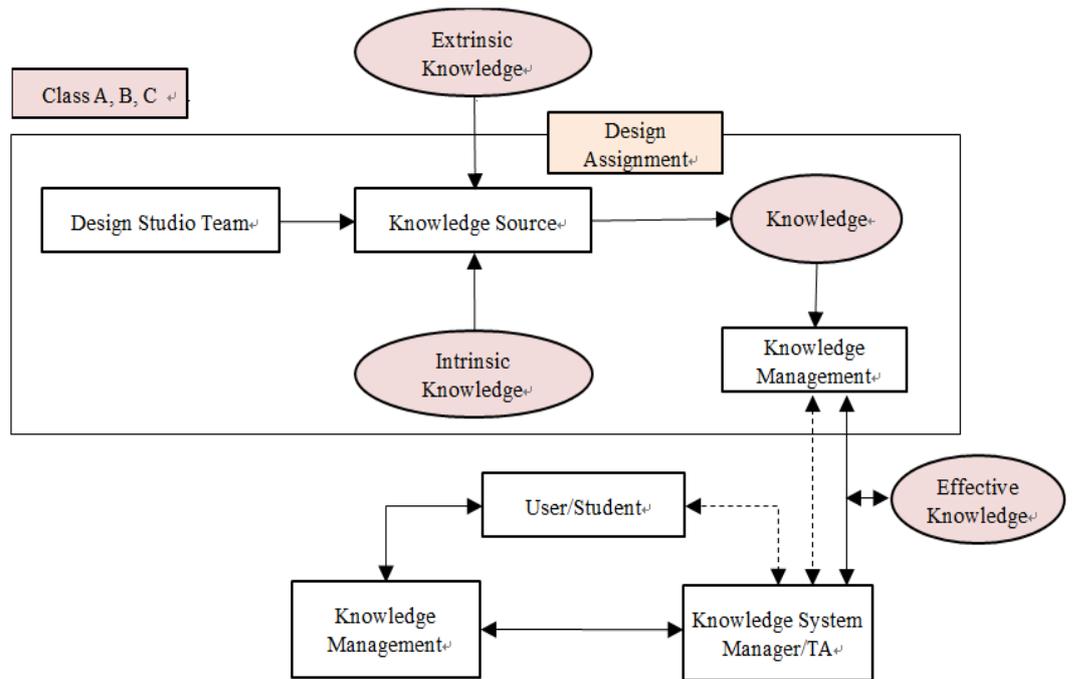


Figure 2. Architectural Design Knowledge Management Mechanism

### Architectural Design Knowledge Management Learning Process

Based on the above-mentioned system framework, an architectural design knowledge management learning process model (see Figure 3) is developed in this study. In this model, different sets of learning activities are designed to help the students with their architectural design learning by using the function modules of the system to share, extract, apply, create, and store/manage knowledge.

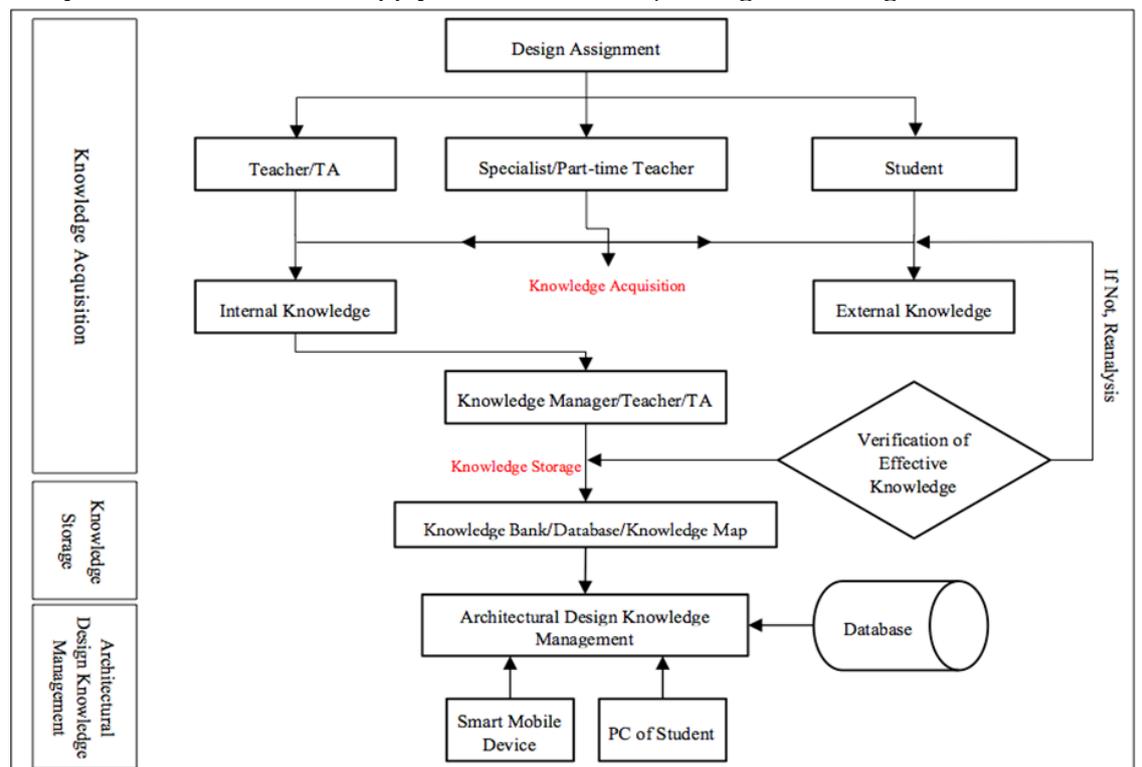


Figure 3. Architecture Design Management Learning Process Model

## Knowledge Sharing

The “knowledge sharing” function modules in this system are “virtual classroom” and “knowledge map” (see in Table 1). With the two modules, the students can obtain just-in-time learning support, have interactive learning and communication with the teacher/peers, observe, and acquire useful knowledge and concepts of architectural design to help them complete their assignments and improve their learning efficiency. In addition, there are also two other functions showing how many of the other students like and have browsed a post to enable more effective and efficient selection of information and reduce cognitive load for the students. Through the learning activities, the students can learn more knowledge and concepts as well as work with the teacher and their peers in knowledge construction.

**Table 1.** Knowledge Sharing

Function Module	Learning Activities
Virtual Classroom	The teacher and students discussing a work or a concept together online without the same restriction of insufficient time as in the real-life classroom
Knowledge Map	The TA categorizing and organizing the data and knowledge in the database based on their knowledge requirement

## Knowledge Extraction

The “knowledge extraction” function modules of this system are “case sharing” and “communityforum” (see in Table 2). In the “case sharing” module, teaching materials and cases responding to the design assignment topics are prepared by the teacher and TA for the students to browse and adapt the subject content. In the “community forum” module, authentic situations of instructional activities are provided, guiding the students to reflect upon and discuss their design assignments by learning from relevant supplementary materials and real-life cases. From the discussion and analysis process, the students can extract knowledge from external data and information. In addition, if the discussions and conversations in the forum contain keywords from the knowledge roadmap, the keywords are underlined in color and linked to the database for the student to access directly relevant contents in the database, extract the knowledge to form useful concepts, and then incorporate the concepts in their designs. This kind of “learning by doing” method is meaningful learning (Ausubel, 1966). It can help the students to reduce extrinsic cognitive load, complete design assignments and construct knowledge.

**Table 2.** Knowledge Extraction

Function Module	Learning Activities
Case Sharing	Providing relevant design works by students of other schools or architects.
Community Forum	Providing guidance for and answering questions from the students about issues or topics they still do not understand after class hours

### Knowledge Application

With the “knowledge application” function modules, this system can help the students in their draft revisions and reconstruction/integration of existing and newly acquired knowledge (see in Table 3). With the function module of “work presentation—draft”, the students can post their design drafts in the system during their design process. The function module of “blog” provides an opportunity for the students to give comments and suggestions on the drafts of their peers. By encouraging the students to observe and learn from each other and apply what they have learned from this process into their draft revisions, the system can help to improve the design quality of the students. However, the students are different in their learning preferences and browse different information. Therefore, they naturally form different learning communities have discussions and exchanges of preferred knowledge or concepts through their emails, blog discussions, forum interactions, messengers or chatrooms. Through such a process of interactive and cooperative learning, knowledge is shared, learned and used to solve problems with the design assignment.

**Table 3.** Knowledge Application

Function Module	Learning Activities
Work Presentation--Draft	Presenting the students’ design drafts in the system so that the students can observe and learn from each other’s designs
Blog	Providing a discussion space for the students to upload any of their thoughts during their learning process so that the student can better reflect upon what they have learned from the process and from their peers

### Knowledge Creation

The “knowledge creation” function modules are intended to help the students complete their knowledge construction. With the “work presentation—final design” module, the students can post their final designs in the system and observe the final designs by their peers to learn from each other. With the “peer evaluation” module, the students can offer critiques on each other’s works and develop the capability of critical thinking (see in Table 4). With the “teacher evaluation” module, the teacher can give comments to the students, grade their learning experience reports, and inspire them to complete their knowledge construction by integrating their existing knowledge with new knowledge they have learned from the comments on their works from the teacher/ peers. This kind of constructive learning method can help the students to achieve learning transfer (knowledge transfer). In addition, from the peer evaluations and interactions, the students can have self-reflection of their learning and adapt their learning accordingly, which can help to motivate the students in their active learning and cognitive development (Cho and Kim 2013).

**Table 4.** Knowledge Creation

Function Module	Learning Activities
Work Presentation-Final Design	The students posting their final designs in the system and receiving comments from their teacher and peers online
Peer Evaluation	The students evaluating each other's works in the system and developing the capability of design critique
Teacher Evaluation	The teacher evaluating and grading the students' works as well as observing and analyzing the students' learning process through their records in the system in order to provide suitable guidance in time

### Knowledge Storage/Management

The functional modules of "knowledge storage/management" are intended to help the students develop good understanding of their learning process and performance. The "learning portfolio" module provides each of the students an account, helping the students to have a clear picture of their learning process and performance by allowing them to store works, thoughts and records throughout the learning process. The "statistical data" module keeps records of the quantity and frequency of the students' participation in discussions, posting comments, uploading drafts, responding to others' comments on their drafts, and responding to others' comments in the blog. The two modules can also help the teacher understand the learning progress of each of the student so as to provide them with in-time supports and suggestions (see in Table 5).

**Table 5.** KnowledgeStorage/Management

Function Module	Learning Activities
Learning Portfolio	Establishing a learning portfolio for each of the students to store their design works, reflection thoughts and other data about their learning
Statistical Data	Keeping track of the quantity and frequency of the students' message posting, discussion participation, assignment completion, and activities in the blog.

## RESULTS

### Research Subjects

The subjects of this study are 150 freshmen from the Day School and Night School of the Architecture Department on the Taipei Campus of China University of Technology. The system developed in this study was used in their "Architectural Design I: Unit III" course. In addition to receiving teaching in the classroom, the students were required to use the system each week to share their works, interact with their peers and have self-reflection on their learning.

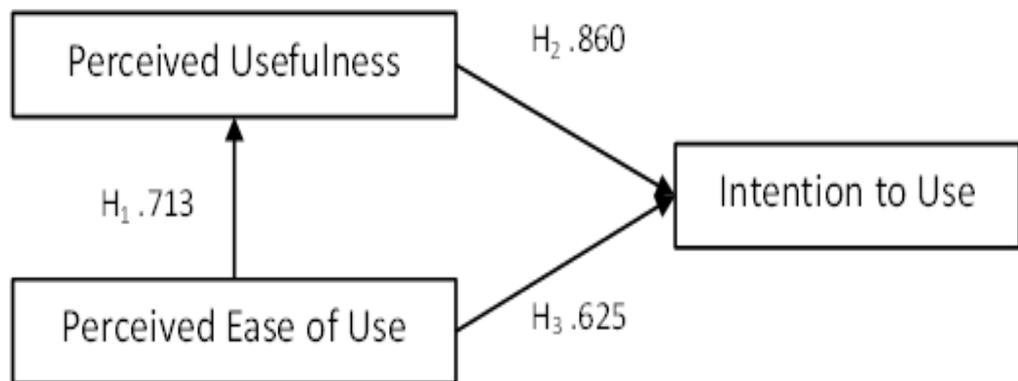
## Research Hypotheses

According to TAM proposed by Davis (1986), perceived ease of use has an influence on perceived usefulness (H1); perceived ease of use has an influence on perceived usefulness (H2); and perceived ease of use has an influence on behavioral intention (H3). The connections among the three hypotheses are illustrated in Figure 4. The major purpose of developing this system in this study is to help students to achieve better learning performance. It is important that this system is found useful by students so that they are willing to continue using this system. Therefore, Hypothesis 1 is first developed in this study:

H1: Users' perceived ease of use of the system has a significant influence on their perceived usefulness of the system. In addition perceived usefulness, another factor affecting users' willingness to continue using a new system is its ease of use. Therefore, Hypotheses 2 and 3 are then developed:

H2: Users' perceived usefulness of the system has a significant influence on their behavioral intention to use the system.

H3: Users' perceived ease of use of the system has a significant influence on their behavioral intention to use the system.



**Figure 4.** TAM Path Analysis of the Students' Acceptance of the System

## Research Analysis

The subjects in this study were senior students in a department of architecture design of a vocational school. Totally 150 questionnaires were given and 120 samples were returned (with a return rate of 80). After excluding invalid samples such as samples with some questions unanswered, there were totally 120 valid samples (with a valid return rate of 80%). The TAM scale used in the questionnaire was revised from the scale designed by Davis (1989). It was five-point Likert scale composed of totally 13 items covering the three dimensions of perceived ease of use, perceived usefulness and behavioral intention. According to the statistical analysis results of the samples, all the Cronbach's coefficients of perceived ease of use (0.921), perceived usefulness (0.945) and behavioral intention (0.853) were all higher than 0.7, indicating sufficient reliability of the TAM scale developed in this study to analyze users' acceptance of the system. Higher Cronbach's  $\alpha$  coefficients mean better reliability. Cronbach's  $\alpha$  coefficients  $\geq 0.7$  means good reliability and Cronbach's  $\alpha$  coefficients  $\geq 0.9$  means very good reliability. In the scale, items with Cronbach's  $\alpha$  coefficients lower than 0.7 were excluded. The statistical analysis results are shown in Table 6.

**Table 6.** Reliability Analysis Results and Standard Deviations of Each Dimension

Dimension	NO.	Item	SD	Cronbach's $\alpha$
Behavioral Intention	1.	The system is worth using.	.877	0.853
	2.	I will consider using this system for my design planning.	.950	
	3.	I will recommend this system to others.	.879	
	4.	In the future, I will continue to use the functions of this system.	.949	
Perceived usefulness	5.	Using this system can enable me to complete the learning of architectural design quickly.	.864	0.945
	6.	Using this system can help me to improve my learning performance of architectural design.	.831	
	7.	Using this system can enable me to complete my learning of architectural design more efficiently.	.761	
	8.	Using this system can help to improve my learning quality of architectural design?	.733	
	9.	Generally speaking, I think this system is very practical and useful.	.805	
Perceived ease of use	10.	I think it is easy to use the system.	.770	0.921
	11.	I think it does not need a lot of efforts and time to search for information on this system.	.733	
	12.	I can easily familiarize myself with this system.	.758	
	13.	I think other users can easily and clearly know how to use this system after they are told the instructions.	.802	

## DISCUSSION

Architectural design is a knowledge-intensive activity. In the design studio type of architectural design education at school, students only learn from the teacher in the classroom and spend the rest of their time learning on their own. Within limited time and space in the classroom, the students are prone to suffering from the problem of cognitive overload for they do not have sufficient time or interaction opportunity to process and absorb the massive amount of information they have received in class (Tosuntaş et al. 2015). The architectural design knowledge management learning system and learning activities developed in this study can provide a dynamic and real-time learning environment and solve the problem of cognitive overload for the students by helping them to achieve effective self-adaptation in learning and then acquire knowledge.

Through this system, architectural design knowledge acquisition and sharing can be effectively managed to reduce information complexity and alleviate intrinsic cognitive load of the students during their learning process.

Since this system can enable the students to learn effectively, collaborate and generate ideas and offer/receive critiques in a non-threatening way, the students feel it is easy to use this system and, therefore, they are more willing to use it in their learning. According to the TAM analysis results, the perceived ease of use of the system has a positive influence the students' willingness to use the system. In other words, the ease of use of the system indeed helps to promote the students' willingness to use the system and, as a consequence, helps to reduce intrinsic cognitive load for the students (Park and Kim 2014, Wallace and Sheetz 2014).

According to Sweller (1994), extrinsic cognitive load can be alleviated through meaningful learning and instructional designs. According to the above-mentioned analysis results, the knowledge management learning system developed in this study can enable the students to learn through the activities of knowledge sharing,

extraction, application, creation and storage. The system can help to promote teacher-student and student-student interactions, effectively enhance the students' learning efficiency, and consequently improve their learning quality. According to the TAM analysis results of this study, the perceived ease of use of this system has a positive influence on the students' willingness to use the system. The high acceptance of the system by the students reflects that the use of this system can help the student to reduce their cognitive load and, therefore, they are more willing to use the system.

## **CONCLUSION**

The major purpose of this study is to establish an architectural design knowledge management learning system. With its function modules and learning activities, the students can have meaningful learning through knowledge sharing, extraction, application and creation. The system can also help to reduce the problem of cognitive overload for the students in their learning process. Last but not least, with the knowledge storage function modules, the system can help the student to accumulate knowledge and construct their schema automatically.

This study also explores the students' willingness to use the system by conducting a TAM analysis. According to the analysis results, the ease of use of the system perceived by the students has a positive influence on their perceived usefulness of the system, which then has positive influence on their willingness to use the system.

## **RECOMMENDATION**

With its effective knowledge management functions and learning activities, the system can help the students to reduce their cognitive load and promote their automatic schema construction, making them perceive that the system is useful. Through their learning, the students can combine their existing knowledge with newly acquired knowledge in their knowledge structure construction. Because of their better learning performance and perceived usefulness/ease of use of the system, the students are more willing to use the system and, as a result, they can effectively solve the cognitive overload problem in their learning process and improve their design capability.

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