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Knowledge Visualization for Self-Regulated Learning

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ABSTRACT

The Web allows self-regulated learning through interaction with large amounts of learning resources. While enjoying the flexibility of learning, learners may suffer from cognitive overload and conceptual and navigational disorientation when faced with various information resources under disparate topics and complex knowledge structures. This study proposed a knowledge visualization (KV) approach to this problem in an online course. The investigation involved the design, development, and evaluation of an enhanced learning system for the course using the proposed approach. The focus was on visualization of domain knowledge structure and integrating the structure with curriculum design, learning resources, learning assessment, intellectual process, and social learning. Survey and interviews with students demonstrated high user satisfaction and acceptance with the developed system and its functions for KV. These findings lay the foundation for further exploration with the system to determine its impact on reducing cognitive load and improving the learning process.

Keywords

Knowledge Visualization, Online Learning, Knowledge Structure, Self-Regulation, E-Learning

Introduction

Due to its flexibility in delivery and just-time access, e-learning has been widely adopted in recent years. In e-learning applications, learners are encouraged to learn through interacting with a wide range of resources to acquire and build their knowledge. While such a resource-abundant and self-regulated learning environment allows learners a great deal of freedom and flexibility in searching for, selecting, and assembling information, learners may suffer from cognitive overload and conceptual and navigational disorientation when faced with massive information online (Tergan, 2005; Kayama & Okamoto, 2001; Miller & Miller, 1999). The challenge is even greater when learning contents are scattered under disparate topics and complex knowledge structures. When faced with this problem, many learners are unable to figure out features and meaningful patterns of various kinds of information, and are easily hampered by limited working memory. This is mainly because novices lack sufficient knowledge and a deep understanding of the subject domain, which is crucial to organizing information and knowledge for retention in long-term memory. Also, traditional education breaks wholes into parts, and focuses separately on each part, and learners are often unable to create the big picture before all the parts are presented. As a result, most online learners, especially novices, become “lost-in-hyperspace”.

This study aims to improve the design of current e-learning systems by dealing with the aforesaid problem. To facilitate cognitive processing and self-regulated learning, learners should be supported with appropriate learning strategies, among which cognitive and meta-cognitive strategies have been well identified (Bransford, 2000, Zimmerman, 2000; Winne, 2001). Learners are helped in their independent learning if they have conceptual knowledge, and learners can become more independent if they have awareness of their own knowledge and ability to understand, control, and manipulate individual learning processes. While these strategies have been found to be effective, few studies have examined how these strategies can be implemented in instructional design, especially in online learning environments. While learning theories or strategies offer guidelines of improving the design of current e-learning systems, it is far more difficult and additional effort is needed to explore effective instructional methods (Reigeluth, 1999).

This study investigates a knowledge visualization (KV) approach to support resource-abundant and self-regulated online learning, which consists of three components. *First*, an explicit representation of conceptual knowledge structure is constructed by capturing key knowledge concepts and their relationships in a visual format. This visualized knowledge structure serves as a cognitive roadmap to facilitate the knowledge construction and high level thinking of online learners. *Second*, abstract concepts are connected with concrete contents by linking knowledge concepts with learning resources. In this way, information processing and knowledge construction, the two key

aspects of the learning process, are well integrated. Learners can easily navigate throughout the resource-abundant, non-linear knowledge space aided by the visualized cognitive roadmap. *Third*, meta-cognitive learning support is provided for learners to regulate and plan their learning process. Assessment materials associated with knowledge concepts are provided for self-evaluation of learning outcomes in granular knowledge components, from which the system generates feedback and guides individuals throughout their learning process.

To implement the proposed approach, an online learning system was developed using computer and Web-based technologies. The system has been designed to help learners transcend the limitations of their minds, not only in cognitive processing, but also in high level thinking and knowledge construction. In doing so, computers are used as electronic pools for reflecting human cognitive processes through visual representations on the screen. These visual representations provide more effective use of learners' mental effort by amplifying, extending, and enhancing human cognitive functions, and engaging learners in representing, manipulating, and reflecting on what they know.

Compared with other related work, this study is unique in the following aspects. *First*, while traditional education breaks wholes into parts and focuses separately on each part, this study aims to help learners see the "whole" before they are able to make sense of the parts. *Second*, instead of asking learners to construct knowledge maps by themselves, this study utilizes expert knowledge structure to help novices build up their thinking and understanding on a solid foundation. This may reduce novices' cognitive overload in advanced thinking. *Third*, instead of using visualized knowledge structure as an isolated instructional instrument, this study uses it as infrastructure and integrates it with curriculum design, learning resources, learning assessment, intellectual processes, and social learning.

Proposed Knowledge Visualization (KV) Approach

This section presents theoretical dimensions of the proposed approach.

Visualization of Knowledge Structure

In facilitating learners' cognitive processing and retaining knowledge in long-term memory, clustering or chunking (i.e., organizing disparate pieces of information into meaningful units) is regarded as a pervasive approach (Simon, 1974; Bransford, 2000). According to psychology theories, knowledge in memory is organized semantically in networks, built piece by piece with small units of interacting concepts and propositional frameworks. These mental semantic networks represent a cognitive structure, which can be used as a learning tool for constructive learning processes (Jonassen, 2000). More importantly, the cognitive structure should be represented in an external format with explicit description. This is because visual methods help externalize and elicit the abstract structure of knowledge (Jacobson & Archodidou, 2000), and human brains have rapid processing capabilities to acquire and retain visual images (Paige & Simon, 1966). Computer-based technologies help further by making it easy for learners to construct, recall, and modify visual representations, and keep them for a long period of time (Jonassen, 2000; Novak & Cañas, 2008).

The KV approach proposed in this study is to incorporate visualized representations of domain knowledge structure into e-learning systems. Relevant functions are developed for creation, storage, display, and revision of knowledge maps. Rather than memorizing the content, learners can use knowledge maps to identify important concepts and their relationships, and generate semantic networks for review and reflection. Moreover, a knowledge map displays intellectual processes involved in the acquisition and construction of knowledge. These become the basis for systemic inquiry, knowledge construction, and high level thinking (Wang et al., 2010).

Integration of Information Processing and Knowledge Construction

Information processing and knowledge construction are closely intertwined in the learning process. Learners need to access information to acquire content knowledge and formulate hypotheses (Jonassen, 1999). Knowledge is constructed through meaningful learning, which takes place when learners deliberately seek to relate (new) information to, and incorporate it into, relevant knowledge that he/she has already possessed (Mayer, 2001).

Objectivism and constructivism offer different perspectives on the learning process, and provide complementary guidelines on how learning should be engendered (Jonassen, 1999; Miller & Miller, 1999). Information processing theory, which regards a human as an information processor or a “mind as computer” (Newell & Simon, 1972), is based on the objectivist paradigm, which assumes that knowledge has an objective and separate existence whose attributes, relationships, and structure can be known, and that learning is transmission of knowledge from teachers to learners (Reynolds et al., 1996). The constructivist paradigm, on the other hand, purports that knowledge is not independent of the learner, but is internally constructed by the learner as a way of making meaning of exercises (Jonassen, 1999). This study intends to integrate and facilitate both objective information processing and subjective knowledge construction in e-learning by linking knowledge concepts in visualized maps with learning resources.

Facilitation of Self-Regulated Learning

Advanced learning acquires over years of experiences and derives from activities of thinking, action, and reflection. Experts have acquired a great deal of well-organized content knowledge, and their organization reflects a deep understanding of the subject matter (Bransford, 2000). Although peer models have been used to guide self-regulated learning, the creation of well-developed and stable cognitive structures for scaffolding advanced learning is noted as a primary instructional goal (Zimmerman, 2000; Reigeluth, 1999). The recognition of expert knowledge has been reflected in both objectivist and constructivist learning theories. Information processing, which is based on objectivist learning theory, requires effective and efficient processing of information and indicates that experts’ knowledge structures help learners acquire information accurately. At the same time, constructivism suggests that guidance and strategies (e.g., modeling, coaching, and scaffolding) from experts provide the necessary support for learners to construct knowledge (Miller & Miller, 1999).

This study utilizes expert knowledge structures for guiding and scaffolding novices’ understanding, thinking, and inquiry in their self-regulated learning. Conceptual understanding of a domain is often not fully expressed in books or learning materials, and knowledge maps can be used to articulate and manipulate such tacit knowledge more effectively. Using the expert knowledge map as the foundation may reduce the chance of misconception and faulty ideas. Although highly structured graphs may seem constraining at times, these templates are good starting points for novices, who have trouble organizing their understanding and are confused in their self-regulated learning (Hyerle, 2000).

In addition to facilitating learners’ cognitive processes, knowledge maps provide meta-cognitive support. As mentioned, learners can become more independent if they are aware of their learning process and have the ability to regulate it. Visual representations are forms of metacognition that graphically display the thinking process (Costa & Garmston, 2002). Knowledge maps display intellectual processes by representing sequences, alternatives, branches, choice points, and pathways that involved in the acquisition and construction of knowledge (Wang et al., in press). To utilize this metacognitive feature, additional functions based on knowledge maps were developed in this study to help learners plan and oversee their learning process. In doing so, assessment materials were collected and associated with knowledge concepts for evaluation of learning outcomes in granular knowledge components, with feedback to learners for correct answers and detailed explanations. At the same time, the system can monitor individual learning progress, based on which learning guidance is provided to individuals such as what to learn in the next step, further effort required for a specific knowledge concept, reminder of prerequisite knowledge to learn before moving on, etc. Individual learning progress can also be reflected in the knowledge map to indicate the knowledge that has been learnt, ready to be learnt, or not ready to be learnt.

Support of Social Learning

To support self-regulated learning, learners are encouraged to participate in social communication, discussion, and sharing. The knowledge structure constructed in this study can also be used as the index or model to organize discussion messages and shared learning resources, with a view to facilitating and steering social communication and knowledge sharing in the social learning community (Wang, in press).

Related Work

To deal with the cognitive load problem, researchers on cognitive load theory have recommended the use of schema to categorize multiple information elements into a single entity (Sweller, 1994). However, with their focus on reducing the number of information elements by organizing them around entities such as categories or examples, these studies did not examine how different types of entities can be identified and constructed, and how learning can be supported by providing a cognitive structure for high level thinking and understanding. Other related research has looked into the cognitive load problem from the multimedia learning perspective (Mayer, 2001). With a focus on simultaneous processing of visual and audio information, these studies recommended that the cognitive load of both channels be managed, and aligned or synchronized for a coherent multimedia presentation.

In relation to KV, concept mapping has been used in education for more than thirty years. It is used mainly for students to demonstrate their understanding and ideas and for teachers to assess students' understanding. Traditional ways of constructing concept maps used paper-and-pencil, and computer-based graphical tools were later developed for expressing knowledge comprising concepts connected by arcs. More recently, the CmapTools software was developed particularly for a Web-based environment, whereby users can construct, modify, and publish their concept maps on the Web (Novak & Cañas, 2008). Although concept mapping has been found to be effective in constructing, communicating, negotiating, and assessing understanding (Tsai et al., 2001; Novak & Cañas, 2008), self-constructed concept maps pose high cognitive demands on learners' ability to analyze and externalize knowledge. Teacher and students need to undergo extensive training to learn how to integrate multiple forms of thinking into a unified, complex weave of interrelated concepts (Hyerle, 2000; Tergan, 2005). This may make the problem of cognitive overload even greater for novices.

In addition to articulation and clarification of understanding, concept maps have been used for curriculum design and planning (Tergan, 2005; Novak & Cañas, 2008). Coffey (2005) described a software program that provided information and knowledge visualization capabilities to foster orientation and learning. Rittershofer (2005) proposed the use of topic maps to support text-based and graphical navigation through huge amounts of information. In these studies, conceptual structures were used to reflect key concepts and principles to be taught in a course, and suggest optimal sequencing of instructional materials. However, these studies have focused on technical implementation, with minimum pedagogical investigation and empirical report on the use and impact of the solutions in learning experience and performance.

Other studies have used concept maps in developing personalized e-learning or intelligent tutoring systems. Hwang (2003) developed a testing and diagnostic system for providing personalized feedback to learners according to test results and the concept model of the subject matter. The relationships between the subject concepts and test items were set up for analyzing learning problems. Zhuge & Li (2006) built up an individualized online learning system, in which tailor-made learning materials and learning instructions were provided based on course structure, and learners' background, preference, and learning status. The course structure was separated from and linked with learning materials for flexible reuse of learning materials for individual demand. The main purpose of these studies was to provide personalized learning content and learning instructions based on course structures and learner profiles. With the focus on the reasoning algorithms, concept maps in these studies were hidden inside the system to support reasoning rather than to present knowledge structures to learners. With these developed systems, learners were facilitated to access relevant learning resources instead of developing systemic thinking and understanding based on knowledge structures.

System Development

To demonstrate the effectiveness of the proposed approach, an online learning platform "JAVA E-Teacher" was developed in this study. An entry-level Java-programming course for novices was developed with the system. The course was designed according to the syllabus specified by National Computer Rank Examination of China (NCRE) (<http://sk.neea.edu.cn/jsjdj/index.jsp>), and the Chinese language was used for the targeted learners. NCRE is an examination and certification system administered by the Ministry of Education of China for evaluation of knowledge and skills in computer operations, computer programming, and network administration. With the increased demand for computer professionals in various fields, NCRE has been well received in China, as evidenced by 28,700,000 participants in various exams from 1994 to 2008, of whom 10,730,000 participants achieved relevant

certificates (<http://sk.neea.edu.cn/jsjdj/index.jsp>). Java is a popular programming language used by most industry segments for various computing systems; there has been a high demand for Java programmers in recent years. However, most universities of China only deliver C or C++ instead of Java as a regular programming course, and many students have to learn Java by themselves. In view of this situation, a pure online Java course was developed in this study for easy delivery and flexible access by learners. The project is currently for research purposes only, with the aim to investigate how e-learning design can be enhanced through KV for resource-abundant and self-regulated learning.

The knowledge structure of the course was built up by inviting two experts in Java Programming, one with intensive teaching experience and the other with more practical skills and experience. The experts defined the knowledge structure according to the syllabus of NCRE in addition to a number of textbooks and references. It was found that it was difficult and inappropriate to include all the knowledge concepts within one map. The cognitive theory suggests that only about seven items or chunks of information can be held in working memory simultaneously (Miller, 1956). Based on this concern and the nature of the course, the course was first broken down into nine chunks/units: Java Basics, Object-Oriented Programming Fundamentals, Data Types and Operations, Work with Objects, Control Statements, Classes and Methods, Java Applets and Web Applications, Input/Output Techniques, and Graphical User Interface. Each unit contained more or less ten key concepts. In this way, learners might have manageable and measurable milestones and might not feel so overwhelmed. Figure 1 describes a visual representation of the knowledge structure for the Unit “Classes and Methods”, in which eight knowledge concepts are specified, together with their relationships such as composite, prerequisite, and confusing mix. In the following sections, this unit is used as an example for further description of the system.

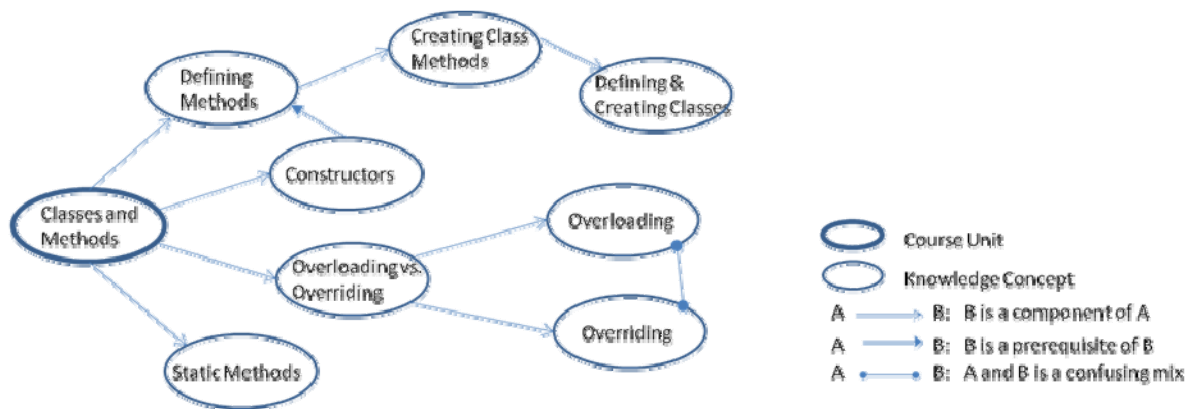


Figure 1. A visual representation of the knowledge structure

To implement the knowledge structure in machine language, Protégé, a free open-source ontology editor developed by Stanford Medical Informatics at Stanford University, was used. Using Protégé, knowledge structures can be easily edited and modified via graphical interfaces. Based on the defined expert knowledge structure, a set of visualized knowledge maps were built up. Figure 2 shows some screenshots of the knowledge map for the Unit “Classes and Methods”. The knowledge map is scalable, interactive, and individualizable. Learners can zoom into/out of the map by clicking “+” and “-” around knowledge nodes. Learners can also drag the nodes to adjust the display of the map based on personal preference. During their learning process, learners may receive updates and guidance generated by the system, reflected in the changed color of knowledge nodes, and pop-up messages. A knowledge node displayed in green, blue or grey indicates that this knowledge has been learnt or accessed, ready for learning, or not ready for learning due to some reason (e.g., the prerequisite knowledge is not yet acquired), respectively. The pop-up messages provide learning guidance, e.g., what to learn in the next step.

Moreover, knowledge maps are linked with relevant learning resources, assessment materials, and Questions & Answers (Q&A) discussion items. Learners can click a knowledge node in the map to access associated lecture slides, audio presentations, reading materials, self-tests, and Q&A discussions. The interface shown in Figure 3 works as a nested learning platform for learners to acquire specific knowledge through reading, testing, inquiring and discussing; or to return to knowledge maps to figure out the position of specific knowledge in the domain, or navigate to other concepts.

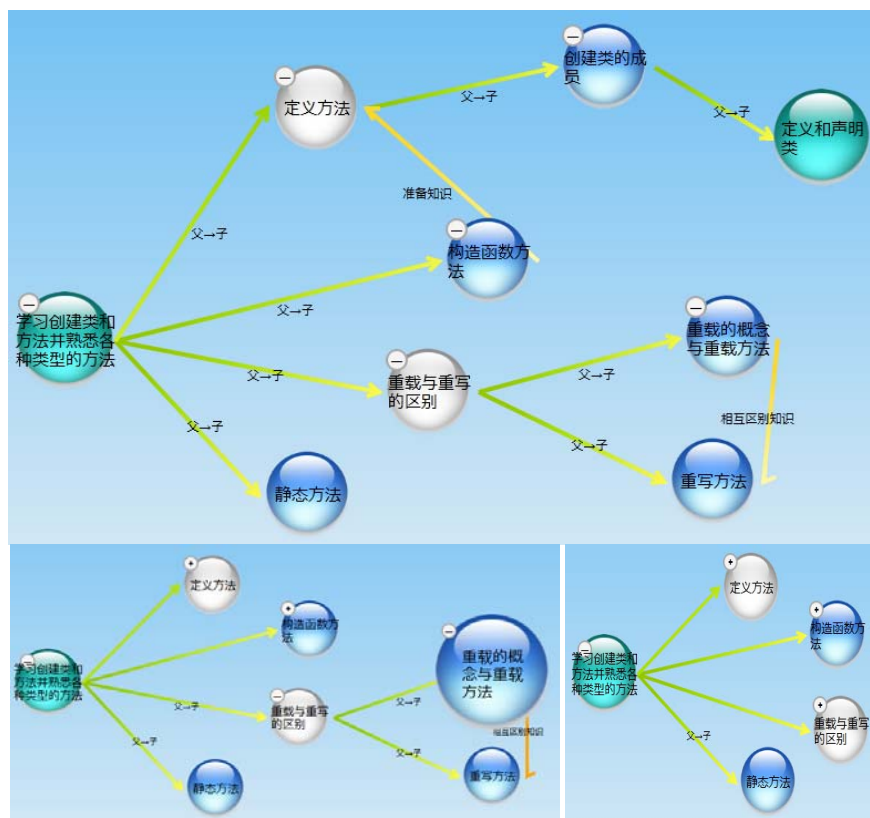


Figure 2. A scalable, interactive and individualizable knowledge map



Figure 3. Integration of knowledge structure with other functions

The assessment questions (most in multiple-choice format) are collected from relevant test databases and references. The questions are reorganized and associated with knowledge concepts to assess learning outcomes in a granular and flexible way. Once a knowledge concept is selected for a test, the test paper will be generated by the system via randomly selecting corresponding questions from the database. Learners may also select to take a test of a unit, for which the system will create a test paper covering all knowledge concepts under the unit. The system will avoid repeated questions when learners take several tests for the same topic. Based on the test results, the system will provide feedback for each question. For a test of a unit, the system will generate a performance report on each knowledge concept in the unit (see Figure 4).

be linked with one or more knowledge concepts by the contributor, and their appearance on the platform is subject to approval by tutors.

Evaluation

To evaluate the proposed approach, a series of experiments and analyses were conducted. At the initial stage of the project, the evaluation was on learners' perceptions and reactions towards the system and its KV related functions, as reported in this section. The assumption is that unless the proposed KV approach is properly implemented to the extent that learners find it acceptable and satisfactory, further explorations into the effect of the approach on learning may not produce reliable and meaningful results. Learner reactions have been found to have a much larger impact on learning in technology-mediated learning environments (Sitzmann et al., 2008).

Evaluation Design

Twenty students from a university in mainland China were recruited as volunteer participants in using the JAVA e-Teacher system. They were final year Bachelor students in the Program of International Business and Trade, with little or no JAVA programming knowledge before participating in this study. Two online tutors (one full time, another part-time) were recruited to provide necessary learning support via the Q&A discussion forum and the online chat tool. It took eight weeks for the participants to complete the online course.

To evaluate the system, a questionnaire survey and an interview were implemented to collect the data on students' perceptions and reactions towards the overall system and its seven functions developed based on visualized knowledge structure. The functions were: *knowledge maps* for conceptual and content learning, *self-tests* around knowledge concepts, *guidance* on learning navigation within maps, *discussion* driven by knowledge maps and concepts, *upload of Q&A* messages with links to knowledge concepts, *presentation of Q&A* items around knowledge concepts, and online *chat and consultation* with tutors for conceptual and content understanding. The evaluation was designed to examine students' responses to five constructs: *perceived ease of use*, *perceived usefulness*, *perceived satisfaction* with the system, *attitudes* to online learning, and *intention* to use online learning systems.

Table 1. Background information of subjects

	Frequency	Percentage		Frequency	Percentage
<u>Gender</u>			<u>Time of using Internet (h/day)</u>		
Male	7	35.00%	0-1 hour	0	0.00%
Female	13	65.00%	1-3 hours	4	20.00%
<u>Age</u>			3-5 hours	9	45.00%
18-24	19	95%	5-7 hours	6	30.00%
25-30	1	5%	over 7 hours	1	5.00%
<u>Number of online courses previously participated in</u>			<u>Internet experience</u>		
0	10	50.00%	0-1 years	1	5.00%
1	4	20.00%	1-3 years	1	5.00%
2	2	10.00%	3-5 years	3	15.00%
5	4	20.00%	5-7 years	10	50.00%
			over 7 years	5	25.00%

The evaluation followed a pre-test and post-test implemented in the following steps. *First*, instrumentation of the evaluation tool was established. The items measuring the five constructs were adopted from related literature (Arbaugh, 2000; Davis, 1989; Venkatesh & Davis, 2000). Responses to the items were ranked on a 5-point Likert scale (1 represented "strongly disagree" and 5 represented "strongly agree"). *Second*, before the students started to use the system, a pre-test questionnaire was administered to gauge their attitudes and intentions regarding using online learning systems. The pre-test questionnaire also collected the subjects' background information, e.g., gender, age, and Internet and online learning experiences (see Table 1). *Third*, after using the learning system, a post-test questionnaire was administered to collect students' feedback. This measured students' perceptions concerning ease of use of, usefulness of, and satisfaction with the system, as well as their post-use attitudes and intentions regarding using online learning. *Four*, quantitatively exploratory data analyses were implemented to obtain the results. *Finally*,

interviews were conducted to collect qualitative feedback from the participants regarding their comments on the system and perceived effectiveness of the system on learning.

Survey Results

Students' responses to the survey were analyzed in the following steps. *First*, Paired-Samples T-tests of pre-test and post-test attitudes and intention were implemented to check the overall effectiveness of the system in changing students' attitudes and intention regarding using online learning systems. The assumption was that students' post-test attitudes and intentions would improve compared to those of the pre-test if the current system was effective overall. *Second*, Boxplots were reported describing the exploratory characteristics, including minimum, maximum, median, mean, and the first and third quantiles of perceived ease of use and usefulness of the overall system and the seven functions. *Third*, the correlations between perceived ease of use and usefulness of the overall system and perceived ease of use and usefulness of the seven functions were presented in bar charts. *Four*, Boxplots depicting the characteristics of students' satisfaction with the overall system, the seven functions, and other three core elements of online courses were reported. In addition to system-related functions, other core elements of online courses such as learning contents, learning support (from tutors or peer learners), and technical support were highly integrated with the online learning environment, influencing learners' satisfaction (Ozkan & Koseler, 2009; Iivari, 2005). These elements were therefore included in the data analysis. *Finally*, the correlations between students' satisfaction with the overall system and students' satisfaction with each individual function and element were given. The results of the statistical analyses are presented as follows.

Attitudes and intention to use

Table 2 reports the results of Paired-Sample T-test for students' pre-test and post-test attitudes towards using online learning systems. The results suggest that using the JAVA e-Teacher system had a positive impact on students' attitudes towards online learning, which signifies that the learning experiences with the current system were clearly positive.

Table 2. Paired-Sample T-test for pre-test and post-test attitudes

	Mean	Std. Deviation	t	df	Sig. (2-tailed)
AT-post ^a	4.32	0.44			
AT-pre ^b	3.82	0.62			
(AT-post) – (AT-pre)	0.50	0.72	3.10	19	0.006

a: post-test attitude; b: pre-test attitude

Table 3 shows the results of Paired-Sample T-test for students' pre-test and post-test intention to use online learning systems. The results show that after using the system the students tended to be more willing to use online learning systems, which means that the current system was effective in enhancing students' online learning intention.

Table 3. Paired-Sample T-test for pre-test and post-test intention

	Mean	Std. Deviation	t	df	Sig. (2-tailed)
ITU-post ^a	4.72	0.53			
ITU-pre ^b	3.95	0.64			
(ITU-post) – (ITU-pre)	0.77	0.85	4.02	19	0.001

a: post-test intention to use; b: pre-test intention to use

Perceived ease of use

Figure 6 presents the exploratory characteristics of perceived ease of use of the overall system and the seven functions. The Boxplot shows that the overall system and the functions were perceived to be easy to use

(means>3.5). The function for uploading Q&A messages with links to knowledge concepts was perceived as the easiest to use, and the knowledge map as the second easiest to use.

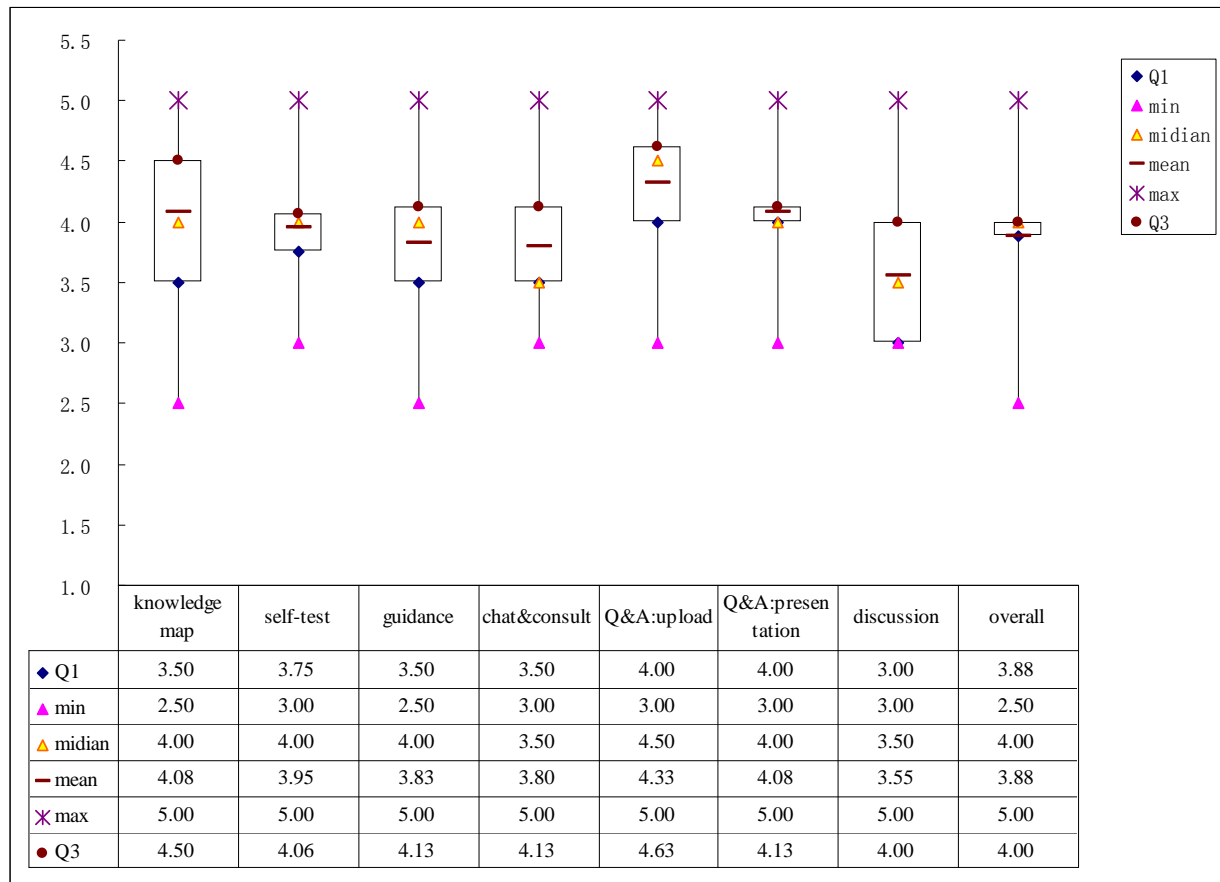


Figure 6. Boxplot of exploratory characteristics of perceived ease of use

Figure 7 describes the Pearson correlations between perceived ease of use of the overall system and perceived ease of use of the functions. A high correlation denotes a high degree of co-variation and association between perceived ease of use of the overall system and perceived ease of use of specific functions. Figure 7 suggests that perceived ease of use of the functions for uploading Q&A messages with links to knowledge concepts (Q&A1-EOU), self-tests around knowledge concepts (TEST-EOU), and guidance on learning navigation in maps (GUI-EOU)” are most highly related to perceived ease of use of the overall system.

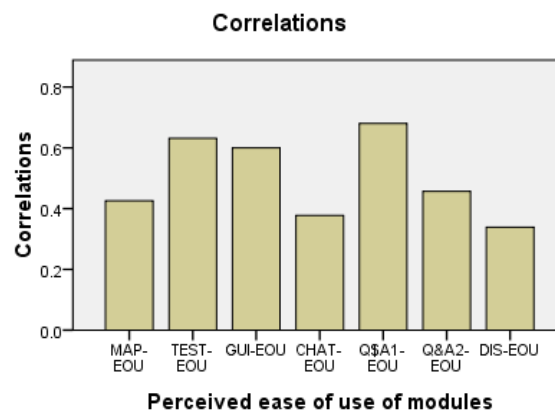


Figure 7. Correlations on perceived ease of use

Perceived usefulness

Figure 8 presents the exploratory characteristics of perceived usefulness of the overall system and its functions. The Boxplot shows that all the seven functions were perceived to be useful for online learning (means>4), and the functions of knowledge maps, self-tests around knowledge concepts, and guidance on learning navigation in maps, were reported to be very useful.

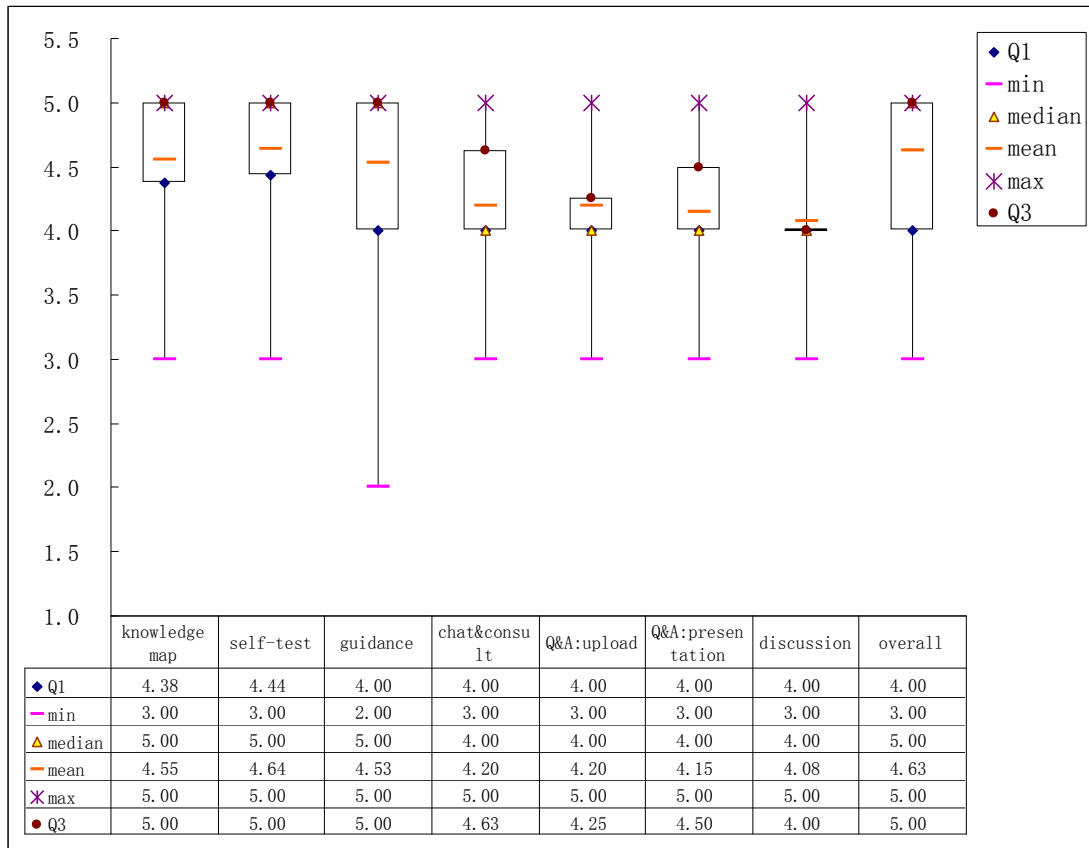


Figure 8. Boxplot of exploratory characteristics of perceived usefulness

Figure 9 reports the Pearson correlations between perceived usefulness of the overall system and perceived usefulness of the functions. The bar chart shows that perceived usefulness of the functions for self-tests around knowledge concepts (TEST-U), knowledge maps (MAP-U), and guidance on learning navigation in maps (GUI-U) were highly related to perceived usefulness of the overall system.

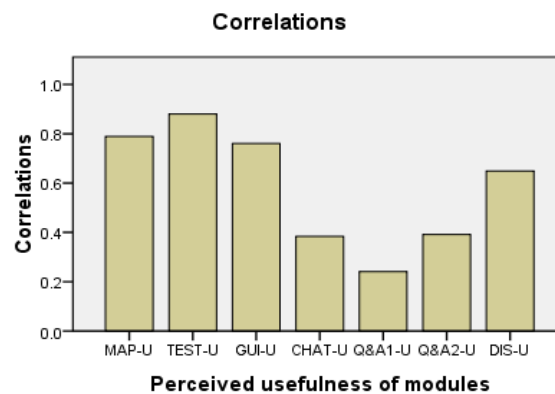


Figure 9. Correlations on perceived usefulness

Satisfaction

Figure 10 presents the exploratory characteristics of students' satisfaction with the overall system, with the seven system-related functions, and with other three core elements of online courses (course content, learning support from tutors and peers, and technical support). The Boxplot shows that the students' responses to satisfaction with all the aspects were very positive. In particular, the students were highly satisfied with the function of guidance on learning navigation in maps and learning support provided by tutors and peers in the online course.

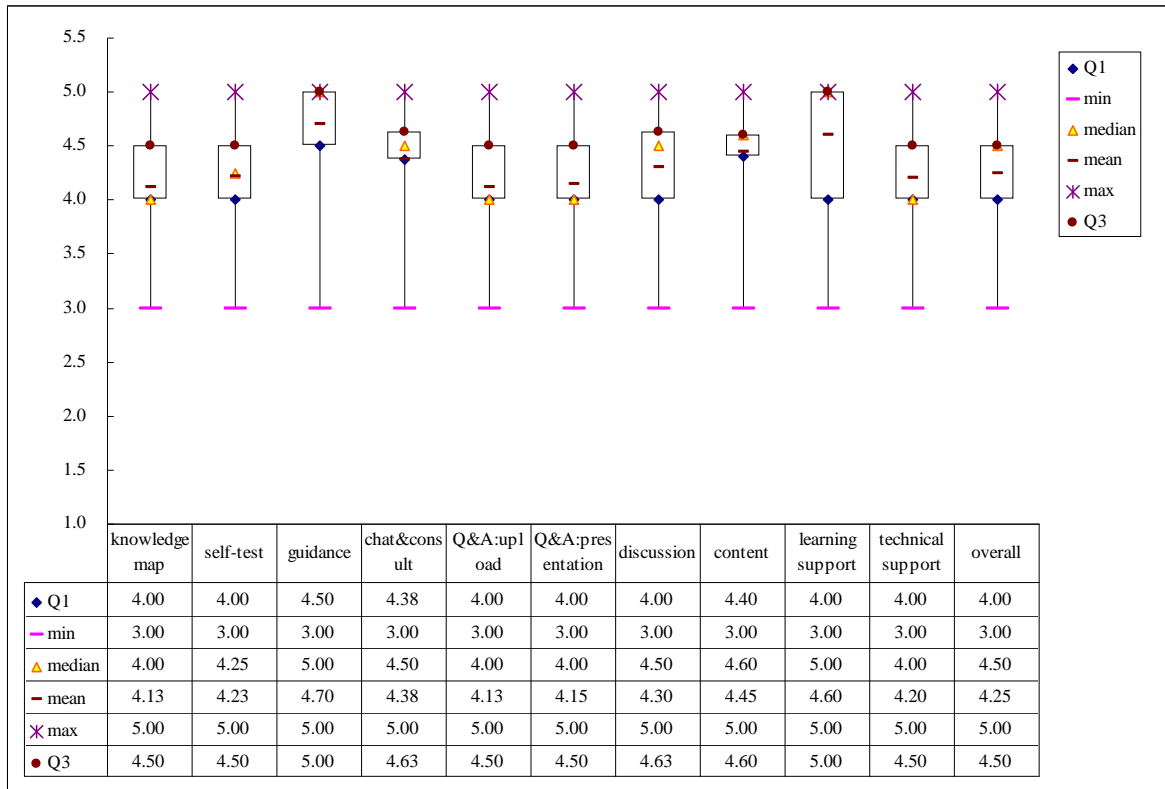


Figure 10. Boxplot of exploratory characteristics of satisfaction

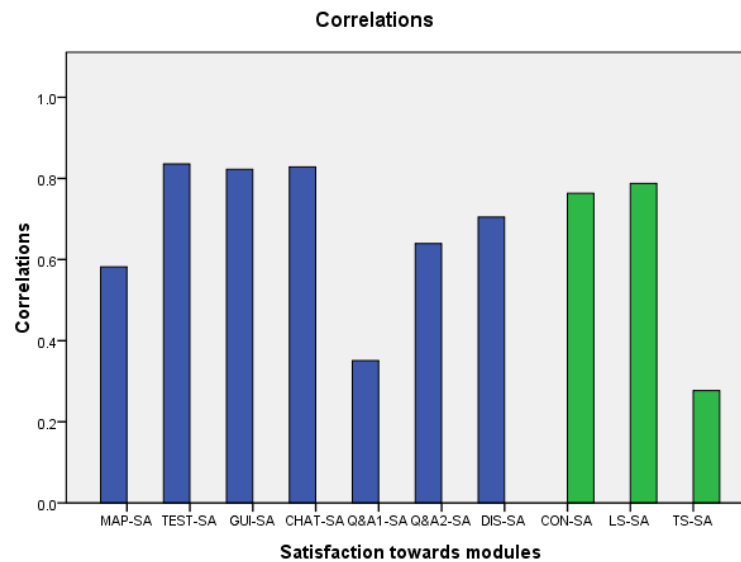


Figure 11. Correlations on satisfactions

Figure 11 presents the Pearson correlations between students' satisfaction with the overall system and students' satisfaction with the system-related functions and course-related elements. The chart shows that students' satisfaction with the functions for self-tests around knowledge concepts (TEST-U), guidance on learning navigation in maps (GUI-U), and online chat and consultation with tutors for conceptual and content understanding (CHAT-SA) were highly associated with overall satisfaction. In terms of course-related elements, students' satisfaction with course content and learning support were found to be strongly related to their satisfaction with the system.

Findings from the Interview

Nineteen out of the twenty participants attended the interview. Each participant was interviewed individually and anonymously for their comments on the system and perceived impact of the system on their learning. Students were encouraged to discuss any issue they felt was relevant. The findings from the interview are reported as follows.

All the participants expressed their clear satisfaction with the system. As one said, "JAVA e-Teacher is the best learning system that I have ever used." In particular, they expressed their strong preference for visualized knowledge maps. They felt that key knowledge concepts of the course were clearly outlined in the maps, providing learners with a preliminary understanding of the course before they started to learn. One student said: "The maps are like a reference system, making it easy for us to engage in a new learning environment with more flexibility." Students mentioned that presenting knowledge components and their links in visual maps helped them memorize important concepts and facilitate high order thinking. As one remarked, "What we learnt from several maps is not less than what we learnt from a large number of texts." Another said, "Learning is usually boring in many situations; however, visual knowledge maps with well-designed and user-friendly interfaces make our learning enjoyable and more fun." While many students liked to drag and move knowledge concepts in a map, one participant felt that this might mess up the presentation by improper moves.

In relation to other functions, most participants commented that it was very convenient to browse the knowledge maps and access learning resources by clicking any topic they want to learn. As one said, "In case I want to know more about specific knowledge, I just click it. It is so simple and direct, saving both time and effort." Participants also recommended that learning guidance generated by the system was helpful. One said, "The system tells me what is basic knowledge, or what I should learn at the current stage. This helps novices like me feel comfortable and learn easily." They also enjoyed the color change in knowledge maps which reflected their individual learning status. Almost all the students liked to use the self-tests and discussion forum. One said: "The tests can pinpoint my weak points at anytime, instead of at the end of the course. This helps me consolidate my knowledge step by step." Another said: "I enjoy visiting the Q&A forum, especially using my knowledge to answer other students' questions, which finally improves my own learning."

At the same time, the participants mentioned some limitations of the system. They expected more practical examples, simulations, different levels of learning materials, and NCRE exam papers to be included in the system. They also suggested using other types of assessment in addition to multiple-choice questions.

Discussion and Conclusion

This study proposed a KV approach to the problem of cognitive overload and conceptual and navigational disorientation in a resource-abundant and self-regulated online learning environment. The approach was investigated through a case study of an online course. The investigation involved the design, development, and evaluation of an enhanced learning system "JAVA e-Teacher" by using the proposed approach. The focus was on visualization of domain knowledge structure and integrating the structure with curriculum design, learning resources, learning assessment, intellectual process, and social learning. Students reported a high degree of satisfaction with and perceived ease of use and usefulness of the system and its functions relevant to KV. Moreover, students' attitudes and intentions regarding using online learning systems were found to have improved after they used the JAVA e-Teacher system, which indicates the overall effectiveness of the system. At the same time, students reported positive feedback in the interviews regarding the effect of the system on learning such as scaffolding conceptual understanding, improving memorization and thinking, facilitating access to learning resources, and supporting individual and social learning.

The evaluation results reflect the success of the system in terms of user satisfaction and acceptance, and effectiveness for learning. In addition, the correlation analyses found that “knowledge maps”, “Q&A discussion around knowledge concepts”, and “online chat for conceptual and content understanding” were important factors in perceived usefulness, ease of use, and satisfaction concerning the overall system respectively; while “learning guidance for navigation” and “self-tests around knowledge concepts” were found important for all the three evaluation constructs. While all these KV related functions played critical roles in the success of the overall system, each of them relied on the construction of visualized knowledge structure, the key element of the proposed approach. On the other hand, learning support for learners and learning contents or information quality (Alkhattabi et al., 2010) were found to be strongly correlated to user satisfaction in this study, a finding to which online learning designers and developers should pay high attention.

Although the study was conducted with a programming course, the approach was directly applicable to other learning programs where the domain knowledge structures can be specified. The evaluation results reported in this paper are limited due to the small sample size. Findings will be revisited in a number of continuous experiments with more participants using the system. Further investigation on the effectiveness of the proposed approach, in particular its effect on reducing cognitive load and enhancing self-regulated learning will be reported in further studies.

Acknowledgements

This research is supported by a UGC GRF Grant (No. 717708) from the Hong Kong SAR Government, a Seeding Fund for Basic Research (No. 200911159142), a Seed Fund for Applied Research (No.201002160030), and a Earmarked Teaching Development Fund from The University of Hong Kong. The authors thank Professor Haijing Jiang for his valuable comments to this project.

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