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THE LEARNING IMPACTS OF A CONCEPT MAP BASED CLASSROOM RESPONSE SYSTEM

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Abstract

Concept map is a powerful tool to achieve meaningful learning. In order to improve the capabilities of traditional classroom response systems to foster students' higher-order thinking, in this study we propose an innovative Concept Map based Classroom Response System characterized by interactivity, diagnosticity and enjoyment, and empirically evaluate its effectiveness on improving students' cognitive and affective levels in learning. This research entails important pedagogical implications and demonstrates the appropriateness of applying the system into higher education.

Keywords: Concept Map; Classroom Response System; Meaningful Learning; Higher-order Thinking.

1 INTRODUCTION

Classroom Response System (CRS) represents a recent innovation that is being used by an increasing number of educational institutions to help an instructor pose questions and poll students' answers during class. After an instructor poses a question, students can key their responses simultaneously, and the software collects the responses, integrates them, and displays the summary of results to the class. The literature concerning CRSs in higher education has consistently purported that, when used properly, CRSs are beneficial to students' engagement and class interaction, and can achieve positive learning outcomes for participants (Cain & Robinson, 2008; Fies & Marshall, 2006). However typical CRSs work as "voting machines" and students' responses are generally to indicate possible options in multiple-choice questions. Such responses from predetermined choices may constrain students' higher-order thinking. According to Bloom's learning taxonomy (Anderson & Krathwohl, 2000), thinking involving analysis, evaluation and synthesis are thought to be of a higher order, requiring different learning and teaching methods than the learning of facts and concepts. Some CRSs support free-text questions to stimulate students' higher-order thinking, but students are reluctant to response using long text in class, and instructors are difficult to identify key issues if large volume of responses received in a short time.

Therefore in order to improve the capabilities of CRSs to handle open-ended questions in class and foster students' higher-order thinking, this study proposes and evaluates an innovative concept map based CRS which characterized by interactivity, diagnosticity and enjoyment. As a powerful teaching and learning approach, concept map has been widely adopted in various subjects (Karpicke & Blunt, 2011; Novak et al., 2011). Grounded on Ausubel's meaningful learning theory (Ausubel, 1968), the construction of concept maps through hierarchical organization, progressive differentiation, and integrative reconciliation shapes an individual's ability of knowledge assimilation and accommodation, and thus improves the individual's higher-order thinking (Darmofal et al., 2002). A concept map is a pictorial representation of knowledge structure in an individual's memory. With the belief of "a picture is worth more than a thousand words", students may also enjoy drawing pictures than writing long sentences to express their ideas in class and thus improve their learning satisfaction. Consequently, the concept map approach can work complementarily with CRSs and extend their capabilities to improve students' higher-order thinking and learning satisfaction.

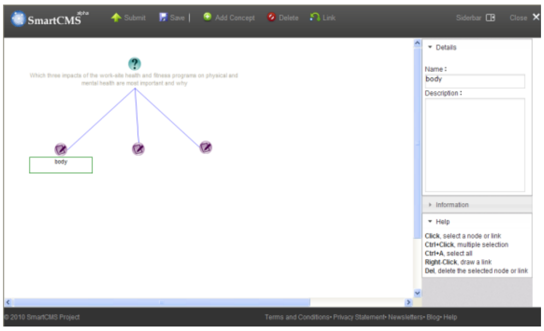
The remainders of the paper are organized as follows: Section 2 provides the theoretical foundations of the concept map based CRS and the hypotheses about its learning impacts compared with a traditional text-based CRS; Section 3 elaborates the methodology used in the study; Section 4 discusses the results and finally Section 5 concludes the paper.

2 THEORETICAL FOUNDATIONS AND HYPOTHESES

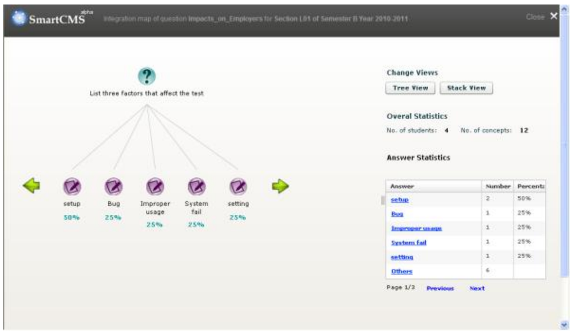
The theoretical foundation of a concept map based CRS is grounded on Ausubel's meaningful learning theory. Compared with rote learning, meaningful learning refers to the concept that the learned knowledge (i.e., a fact) is fully understood by an individual and that the individual knows how that specific fact relates to other facts. When meaningful learning occurs, the facts are stored in a relational manner. When one fact is recalled, the other facts are also recalled at that moment (or shortly thereafter).

Concept maps are remarkably effective tools for meaningful learning (Novak & Gowin, 1984). Firstly, the making and remaking of a concept map is a kind of reflective thinking, involving pushing and pulling of concepts, and putting them together and separating them again. Secondly, a concept map is an explicit, overt representation of the concepts and propositions a person holds. After a learning task has been completed, a concept map provides a schematic summary of what has been learned. Thirdly, concept maps work to make clear to both instructors and students the small number of key ideas they must focus on for any specific learning tasks. They allow instructors and students to exchange views on why a particular propositional linkage is good or valid, or to recognize linkages between concepts that suggest a need for new learning.

The concept map based CRS we have proposed aims to facilitate such practices in thinking with concept maps. In the concept map based CRS, students are allowed to draw their own concept maps to answer instructor's open-ended questions in class as shown in Figure 1 (a). The system can also integrate all the individual maps into one map in which the majority and minority of the students' ideas on a specific theme is displayed with percentage figures as shown in Figure 1 (b).



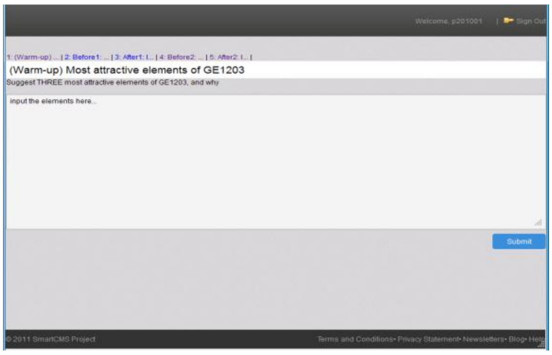
(a) Input interface



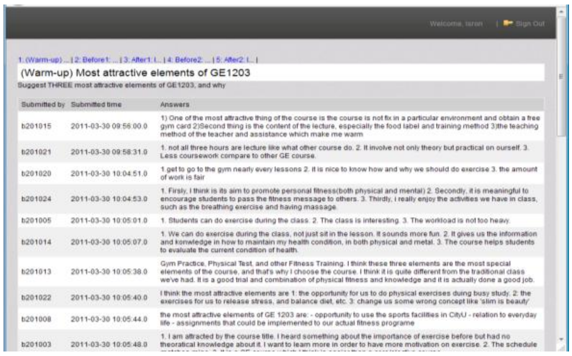
(b) Integration interface

Figure 1. Interfaces of a Concept Map based Classroom Response System.

The study compares the functionality of the proposed concept map based CRS with a traditional text-based CRS. As shown in Figure 2 (a), in text-based CRS, students can only type their ideas using long phases or sentences into textbox to answer an instructor's open-ended questions. The instructor can then browse all students' submitted answers using integration interface as shown in Figure 2 (b), and give out suggestions to help improve students' understandings. A text-based CRS provides a way to improve student's engagement and interaction in class, however students don't like to input long text using textbox and instructors are also difficult to identify the problems exist in students' understandings via the lengthy integrated answer list in a short time frame.



(a) Input interface



(b) Integration interface

Figure 2. Interfaces of a Text-based Classroom Response System.

Therefore we expect the proposed concept map based CRS can further enhance the interaction between instructors and students, improve the learning diagnosticity to understand the themes discussed in the class, and thus foster the students' higher-order thinking capability. We also expect that the concept map based CRS can provide students with an interesting and joyful learning environment so that the students are more likely to satisfy with the learning experience in the class. Herein we summarize the main characteristics of the proposed concept map based CRS as interactivity, diagnosticity and enjoyment.

Interactivity. A high level of interactivity in an information system provides users with autonomy in determining the material they want to examine and the pace at which they want to proceed, as well as providing synchronous feedback that permits users to carry on a two-way communication (Kettanurak et al., 2001). Autonomy and flexibility give users a sense of control, whereas synchronous and suitable feedback provides users with prompt acknowledgement of their input. In a concept map based CRS, students can flexibly label concept, and freely draw nodes and links. While in a text-based CRS, students can only play with text. So we argue that a concept map based CRS are more flexible than a text-based CRS. Further, a concept map provides an easier way to understand a person's domain knowledge than texts (Novak et al., 2011), so an instructor can quickly find out the problems exist in students' understandings via integrated concept maps, and thus provide more instant and pertinent feedback to students about a specific question. Therefore, we hypothesize the interactivity of a concept map based CRS as follows:

H1: The use of a concept map based CRS in class will have a higher level of perceived interactivity by students, compared with the use of a text-based CRS in class.

Diagnosticity. The perceived diagnosticity represents users' perceptions of the ability of an information system to convey relevant information that can assist them in understanding and evaluating peers' opinions on the products (Jiang & Benbasat, 2007). Thirty years of research has confirmed that a concept map is a more effective knowledge representation tool than text for communication and diagnosis (Novak, 2002; Novak & Gowin, 1984). So describing a particular question or knowledge domain by a concept map is easier for people to understand and evaluate. In a concept map based CRS, questions and answers are communicated by concept maps, while in a traditional text-based CRS are by texts, therefore we make the following hypothesis:

H2: The use of a concept map based CRS in class will have a higher level of perceived diagnosticity by students, compared with the use of a text-based CRS in class.

Enjoyment. The perceived enjoyment is used to describe users' affective perceptions of their interactions with the learning system. It refers to the extent to which the activity of interacting with a system is perceived to be enjoyable in its own right aside from the utilitarian value of the system (Jiang & Benbasat, 2007; Qiu & Benbasat, 2010; Wolfinbarger & Gilly, 2001). In the computer-mediated learning environment, the perceived enjoyment with the system plays an important role of leading the students to emotionally immerse in the learning process and get satisfactory with the learning experience. A concept map based CRS adopts concept maps to represent scientific problems. Not only can students input core concepts to solve problems, but also can play with concept maps by adding/deleting/moving concept nodes and links. In contrast, students can only mechanically type texts and/or emotional icons in a text-based CRS,. Therefore a concept map based CRS may provide more interesting learning environment for students and we propose the following hypothesis:

H3: The use of a concept map based CRS in class will have a higher level of perceived enjoyment by students, compared with the use of a text-based CRS in class.

Besides the perceived interactivity, diagnosticity and enjoyment, this study also purports that the use of a concept map based CRS in class may foster students' higher-order thinking and enhance learning satisfaction compared with the use of a traditional text-based CRS.

Higher-order thinking. Higher-order thinking is the cognitive dimension of learning outcomes. In Bloom's taxonomy, skills involving analysis, evaluation and synthesis are classified as higher-order thinking. Higher-order thinking involves the learning of complex judgmental skills such as critical thinking and problem solving. It is more difficult to learn and teach but more valuable because such skills are more likely to be usable in novel situations. Therefore higher-order thinking requires different learning and teaching methods than the learning of facts and concepts. In contrast with a text-based CRS, a concept map based CRS relies on the concept map approach. Students are required to analyse and extract specific concepts from a complex problem situation, evaluate and select concepts to include in a concept map, and integrate and synthesize concepts with links to create a final concept map. What's more, students can also learn from the integrated concept maps, identify the majority and minority propositions, and then revise their own concept maps. The cognitive processes involved in concept mapping approach are more intensive and comprehensive than the text-based learning, and therefore we make hypothesis as follows:

H4: The use of a concept map based CRS in class will lead students to a higher level of higher-order thinking, compared with the use of a text-based CRS in class.

Satisfaction with learning experience. Satisfaction represents the affective dimension of learning outcome. Compared with a text-based CRS, a concept map based CRS can provide students with an interesting and playful learning environment by adding/deleting nodes, adding/deleting links, changing the position of nodes and so on. So students are more likely to satisfy with the learning experience in the class and we provide the following hypothesis:

H5: The use of a concept map based CRS in class will lead students to a higher level of satisfaction with the learning experience, compared with the use of a text-based CRS in class.

3 RESEARCH DESIGN

This study developed a concept map based CRS, as well as a text-based CRS using open source software. The functionality of the two systems was validated by several rounds software development tests. After that, we adopted experiment methodology to validate the proposed hypotheses in Section 2. The research design of this study includes experiment tasks and procedures, subjects, and measures.

3.1 Task and Procedures

The purpose of this experiment was to identify and compare the learning impacts of two learning environments, i.e. a concept map based CRS and a text-based CRS. The task of the experiment was about the topic of "fitness impact on business organization" within a general-education course in a university in Hong Kong. The procedures of the experiments were confirmed through two rounds of pilot study.

The general procedure of the experiment for the concept map based CRS was as follows:

- A brief training on using the concept map based CRS, 15 minutes;
- Students were asked to draw concept maps to answer the first question and submit the concept maps to the concept map based CRS, 3 minutes;
- The concept map based CRS integrated the concept maps from all students, and the instructor showed the integrated concept map and interpreted the answers, 5 minutes;
- Students were asked to revise their concept maps and resubmit to the concept map based CRS, 2 minutes;
- The students and the instructor repeated step 2-4 for the second and third questions, 20 minutes.

The general procedure of the experiment for the text-based CRS was as follows:

- A brief training on using the text-based CRS, 10 minutes;
- Students were asked to answer the first question by using text-based CRS and submit to the system, 3 minutes;
- The instructor showed the text-based scripts from all students and interpreted the answers, 5 minutes;

- Students were asked to revise their answers and resubmit to the text-based CRS, 2 minutes;
- The students and the instructor repeated step 2-4 for the second and third questions, 20 minutes.

3.2 Subjects

There were 25 students enrolled in a general education course participated in the experiment. The ages of students were between 19~24 years old. 10 students were female and 15 students were male. Only 3 students indicated the prior experience on mapping tools and the majority had no such experience. Students participated in the experiment were instructed to complete all the above procedures using classroom computers located in the university Compute Service Centre. After that, students were asked to fill in a questionnaire and report their learning experience.

3.3 Measures

To operationalize the constructs involved in the study, we adopted or adapted the validated measures by prior research. The items to measure interactivity and diagnosticity of the systems were adapted from Jiang and Benbasat (2007). Four items measuring the perceived enjoyment of learning with facilitation of the systems were adapted from Qiu and Benbasat (2010). Based on Bloom's learning taxonomy, four items were created to measure the higher-order thinking after the students were involved in the computer system facilitated learning process. The higher-order thinking includes evaluating, selecting, comparing and judging the discussing themes on the class. Four items were adopted from Du et al. (2010) to measure the concept of satisfaction with learning experience. To mitigate the effects of common method bias (Podsakoff et al., 2003), the measures of perceived interactivity, diagnosticity and enjoyment were designed with 7-point Likert scale and the measures of perceived higher-order thinking and satisfaction with learning experience were with 5-point Likert scale.

4 DATA ANALYSIS AND DISCUSSION

We adopted two quantitative methods to validate our hypotheses. First, Partial Least Squares (PLS) with the bootstrap re-sampling procedure (Cotteman & Senn, 1992) was used to assess the measurement validities. Second, pairwise *t*-tests were conducted to compare the differences of perceptions on the system properties and learning outcomes between the two experimental settings.

4.1 Measurement Validity

The measurement for reflective constructs was assessed by examining convergent validity and discriminant validity (Hulland, 1999). The convergent validity was assessed by examining composite reliability and Average Variance Extracted (AVE) from the measures (Hair et al., 1998). As shown in Table 1, the composite reliability scores (ρ) of the reflective constructs exceed the threshold of 0.70, indicating that our measures are reliable (Nunnally, 1978). The AVE values range from 0.730 to 0.911, exceeding the recommended cut-off of 0.5. Further, all reflective items are significant on their path loadings at the 0.01 level (all above 0.70), providing evidence for convergent validity (Barclay et al., 1995).

Discriminant validity was tested by comparing the square roots of AVE value of each construct to the correlation of the respective construct and other constructs. Table 2 presents the discriminant validity statistics. The square roots of the AVE scores are all higher than the correlations among the constructs, demonstrating discriminant validity (Fornell, 1987).

Construct	Item	Loading	Std Error	*t*-value
Interactivity (ρ=0.926, AVE=0.759)	Int1	0.869	0.040	21.854
	Int2	0.924	0.019	47.734
	Int3	0.767	0.097	7.891
	Int4	0.917	0.023	39.041
Diagnosticity (ρ=0.928, AVE=0.812)	Dia1	0.868	0.045	19.24
	Dia2	0.925	0.020	46.233
	Dia3	0.909	0.024	37.499
Enjoyment (ρ=0.968, AVE=0.911)	Enj1	0.955	0.014	66.916
	Enj2	0.964	0.009	102.24
	Enj3	0.944	0.019	49.305
High-order thinking (ρ=0.921, AVE=0.756)	Hig1	0.837	0.059	14.303
	Hig2	0.826	0.067	12.424
	Hig3	0.894	0.027	33.275
	Hig4	0.895	0.023	38.35
Satisfaction with learning experience (ρ=0.915, AVE=0.730)	Sat1	0.856	0.055	15.522
	Sat2	0.836	0.045	18.493
	Sat3	0.823	0.047	17.61
	Sat4	0.899	0.023	38.524

Table 1. Assessment of Convergent Validity of Constructs

Constructs	1	2	3	4	5
1. Interactivity	**0.871**				
2. Diagnosticity	0.359	**0.901**			
3. Enjoyment	0.261	0.470	**0.954**		
4. Higher-order thinking	0.331	0.674	0.681	**0.869**	
5. Satisfaction on learning experience	0.230	0.518	0.672	0.602	**0.854**

Note: Values on the diagonal are square roots of AVE scores of constructs.

Table 2. Correlations of Variables and Discriminant Validity Assessment

4.2 Hypothesis Test

We conducted a series of pairwise *t*-tests to compare the differences of the learning impacts, including students' perceptions on the interactivity, diagnosticity, enjoyment, higher-order thinking, and satisfaction with the learning process, of the proposed concept map based CRS versus the text-based CRS. The results show that all of the differences are significant; in particular the scores of the concept map based CRS are all higher than the scores of the text-based CRS.

According to Table 3, all *t*-tests are significantly at $p<0.05$ level and therefore all hypotheses (H1 – H5) have been supported. With the facilitation of the concept map based CRS, students had experienced a higher level of interaction with the instructor (mean = 5.740 vs. 5.271, $p<0.05$), and better understanding of the discussing topic in class (mean = 5.681 vs. 4.722, $p<0.01$). The results also indicate that students enjoyed the learning process in the concept map based CRS more than the text-based CRS (mean = 4.904 vs. 4.139, $p<0.01$). Finally, the concept map based CRS was able to lead students to achieve a significantly higher level of higher-order thinking (mean = 4.156 vs. 3.635, p<0.01) and satisfaction on learning experience (mean = 3.917 vs. 3.552, $p<0.01$).

Concepts	Paired Groups	Mean	Mean Diff.	*t*-value	*p*-value
Interactivity	Text-based CRS	5.271	.469	2.264	.033
	Concept map based CRS	5.740			
Diagnosticity	Text-based CRS	4.722	.958	2.949	.007
	Concept map based CRS	5.681			
Enjoyment	Text-based CRS	4.139	.764	2.803	.010
	Concept map based CRS	4.903			
Higher-order thinking	Text-based CRS	3.635	.521	2.855	.009
	Concept map based CRS	4.156			
Satisfaction on learning experience	Text-based CRS	3.552	.365	3.128	.005
	Concept map based CRS	3.917			

Note: 2-tailed tests; Mean difference = Score of Concept map based CRS – score of Text-based CRS.

Table 3. Compared Differences between Concept map based CRS vs. Text-based CRS

4.3 Qualitative results and discussion

After the experiment, we also asked the students to freely comment on the concept map based CRS and the text-based CRS. The question is "*Do you like the concept map based CRS (or the text-based CRS)? Why and why not?*"

Most of the students' comments on the text-based CRS were mediocre. Most of them indicated that the text-based teaching and learning approach was easier but boring. For example, they stated that:

"It is OK for me. It gives me a good chance to communicate with teacher in class and I can type my response through the system. But I have to say it is a little bit boring and makes me sleepy sometimes.

"It's ok because I can type the opinion on the web but I cannot see others opinion to compare what I write."

"Not really when compared with Concept Map system because it's more confusing and hard to see the comparison - all things are massed together."

However, students' feedbacks on the concept map based CRS were quite positive. 22 out of 24 students indicated they liked the system in class. According to the descriptions (see Table 5), most of the students thought the concept map based CRS could facilitate their understandings on the lessons, and some of them pointed out that the concept-map based approach efficiently improved the interaction between instructors and students, and some of them really enjoyed the interesting design of concept map interface.

In summary, students' feedbacks are consistent with our findings in the quantitative tests, further confirming our hypotheses.

Dimensions	Concepts	Students' Comments
COGNITION	Interactivity	*"The box for students to type in brief title for the answer is good because it can give a brief and clear answer to the teacher. For teacher, it is very easy to make comment on the results because it shows the majority choices of those students."*
	Interactivity	*"I like the interaction. Besides, the system is better than Text-based System as it has a bit more graphic element. So it looks better."*
	Interactivity	*"Yes. As I mentioned in the previous question. We can express our opinion via concept map system. Also, teacher can summarize our points and show to our afterward."*

AFFECTION	Diagnosticity	*"I do, it is more interested to use the system, it is better than text-based system because it can provide the percentage and research of the opinion that students tend to choose which aspects. It is easy to summary to various views."*
	Diagnosticity	*"I like the system because the system can let me know more about the general answers of other classmates. I can understand all the ideas better."*
	Diagnosticity	*"Yes, I think it's good! As it provide some concrete data for me to understand the preferences of other students. And that gives us comprehensive information, so that we can have a better understanding."*
	Diagnosticity	*"Yes, I like it very much because it's easy to use and understand - really clear and comparable. I feel quite clear after seeing the map result."*
	Diagnosticity & Interactivity	*"I like the Concept Map system because it is easy to use. I can type in the key word first. And the key word can help me in thinking about the description. Besides, the concept map helps me in thinking. It can enhance the effectiveness of learning and help student in participating actively in class."*
	Diagnosticity & Enjoyment	*"I like the system better because I think it is a good way to have a map rather than just typing everything in a box. It is clear just seeing a key word at the first sight and check the detail information later on. Also it is colorful thus attractive."*
	Diagnosticity & Enjoyment	*"Yes, I do. Compared to the text-based system, I preferred Concept Map. It works more efficiently and we can see the result (both the percentage and detail responses) more clearly. Plus, it is more interesting."*
	Enjoyment & Diagnosticity	*"The format is quite interesting. It looks like a mind map. It helps me find the main point first then explain it and give reason for it."*
	Enjoyment	*"Yes, because the graphical interface is more attractive than text-based system."*

Table 5. Details of Students Comments on Concept map based CRS

5 CONCLUSIONS

Concept map is a powerful tool to achieve meaningful learning. In order to improve the capability of classroom response system to foster students' higher-order thinking, this study proposed an innovative concept map based classroom response system characterized by interactivity, diagnosticity and enjoyment, and empirically evaluated its learning impacts.

At the end of the paper, it is necessary to point out several limitations and future work of this study. The current measurement of the learning impacts are based on subjective questionnaires, thus in the future more objective indicators can be included to ensure the external validity of the study. In this study the sample size is still small, so a large scale study can be planned after the prototype system improves its concurrent connection performance.

Notwithstanding these limitations, the study entails important pedagogical implications and demonstrates the appropriateness of applying the system into higher education. First grounded on the notions of Novak & Gowin (1984), this research proposes an innovative concept map based classroom response system. This system has superior functions and a decent interface. It also overcomes the limitations of typical classroom response system on handling open-ended questions in class, and can be used to foster students' higher-order thinking. The system facilitates the instructor to capture what the students have or have not learnt, enhances the interaction between the instructor and students, and improves the diagnosicitiy and enjoyment of learning processes. Second, the experiment demonstrates the appropriateness of applying the concept map based classroom response system into college courses.

With the fast development of e-learning and mobile learning, the system will have broad application domains in higher education.

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