The use of a computer-mediated environment to promote learning performance through concept mapping in a nanometre course

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ABSTRACT: The purpose of this study was to explore the assessment of college students' learning feedback and the applicability of employing concept mapping instruction for nanometre-related courses. In this research, the data obtained from both qualitative and quantitative research methods revealed the following five essentials: 1) the study has successfully developed a computer-mediated courseware for concept mapping instruction, 2) students had significant positive attitudes towards the courseware design; the instructor's teaching method; and the impact of concept mapping instruction, 3) students affirmed the effectiveness of computer-mediated concept mapping instruction because of its ability to clarify and integrate nanometre concepts, 4) the explanation of course content, and the learning environment, was improved, 5) the quality of courseware design was found to be the mediator between the instructor's teaching methods and students' learning performance.

INTRODUCTION

Concept maps (CMs) have demonstrated to be a powerful instructional approach in the education field over the past decade, having relevance within various subjects, such as English learning [1], engineering [2], microeconomics [3], and physiology [4]. In 2006, Kinchin claimed that concept mapping (CMPING) was explicitly embedded within a constructivist approach of instruction, with the aim of facilitating meaningful learning. Numerous previous researchers also clearly indicated that CMPING had distinct advantages over traditional teaching methods, successfully reinforcing students' conceptual integrated knowledge [3][5]. Thus, adopting a CMPING teaching strategy can inspire students' learning interests to improve their learning achievements and create an efficient learning environment.

CMPING is a type of constructivist learning [6]. The learning primarily is self-driven and aims to urge the learner to find his way through the learning material. Students' reactions to using CMPING as a teaching and learning tool were quite positive [3]. Furthermore, some scholars found that computer-based CMPING instruction did promote students' learning achievements, increased students' positive learning attitudes and enhanced the students' abilities in knowledge construction [7]. However, some of the empirical research has not yet investigated the relationships between students' feedback towards computer-mediated courseware design (CD), the instructor's teaching method (ITM) and the students' learning performance (SLP). Therefore, this research has attempted to investigate which factors among these have exerted the strongest influence on SLP.

An increasing number of scholars take the benefits of CMPING instruction as an important core in science-related subjects because it includes visual learning and computer-mediated tools, such as PowerPoint, animation, video, audio, Web pages, e-books, blogs, and digital courses to stimulate students' learning interests and attitudes [8]. Correspondingly, some scholars claimed that students enjoy a wide variety of teaching methods made possible with computer-assisted learning [9]. Based on the same point, some scholars further explored how visual learning and computer-mediated tools are great helpers for students in clarifying thinking, organising new knowledge and restructuring retrieved cognition to present what they know [10].

This kind of virtual learning style actually offers a student-centred and active learning environment that assists students to become self-directed learners and effective problem-solvers [11]. Given that CMPING conducted in a traditional manner with pencil and paper gradually was substituted with an advanced method of computer-mediated environment, several computer applications were developed to support CMPING instruction [5]. Some scholars developed the Integrated CMPING System software (ICMSys) to assist students in externalising ideas, elaborating concepts, engaging in reflective thinking and breaking concepts boundaries [12]. Similarly, some scholars stated that software and courseware employed in computer-mediated CMPING instruction did change students' learning behaviour and further

influenced their learning performance [7]. Therefore, developing an appropriate courseware prototype within an effective computer-mediated instruction environment is quite important for both instructors and learners.

Taking the above literature into consideration, students' positive attitudes toward computer-mediated material will stimulate the effectiveness of CMPING on SLP in a nanometre course. The aim of this research was to develop a computer-mediated courseware prototype, and to examine the relationships among ITM, CD and SLP in order to enhance the latter by creating an effective CMPING strategy and multimedia technology instructional environment.

OBJECTIVES OF RESEARCH

There is evidence that proves CMPING instruction does stimulate meaningful learning of science-related concepts. However, there is limited evidence in the research literature about students' feedback towards CD and ITM related to SLP in nanometre courses within the computer-mediated instructional environment. Three objectives were the focus of this study.

1. To investigate students' feedback towards CD, ITM and SLP.
2. To evaluate the relationships among CD, ITM and SLP.
3. To discuss how ITM affects SLP when taking CD as a mediator.

METHODOLOGY

This research integrated information technology with CMPING strategy so as to build a superior learning environment. The instructor created 10 concept maps, 10 PowerPoint presentations and 14 animations through hyperlinks. The computer-mediated courseware was developed with a methodology involving five procedures. *Analysis* implied analysing and discussing the content of the curriculum. *Design* meant designing teaching content for CMPING. *Develop* used the courseware to create instructional videos. *Implement* meant teachers implemented the courseware and students used it for review. *Evaluation* indicated the investigating of students' attitudes.

The participants were 49 fourth year university students in a Mechanical Engineering Department in southern Taiwan and the experiment was held for a consecutive period of 18 weeks. Initially, 67 students took the nanometre course as an elective subject and 18 of them dropped the class before the middle of the semester, without giving reasons. The course was conducted three hours a week. Students in the class had no prior nanometre knowledge or concept mapping.

A nanometre course was chosen because it is a difficult and highly abstract topic for the students, which is appropriate for CMPING instruction. Nanometre courses are beginning to be adopted in higher engineering education because nanotechnology has a promising future and a wide range of applications in engineering (e.g. medicine, electronics and energy production). As of August 2009, it is estimated that more than 1,000 manufacturer-identified nanotechnology products are publicly available, with new ones hitting the market at a pace of three to four a week [13].

In this research, a self-developed questionnaire was adopted and then conducted at the end of the course. Two main themes were considered in this questionnaire. First, it aimed to understand the suitability of the courseware. Second, students' feedback was investigated after utilising the computer-mediated CMPING in the nanometre course. Additionally, five experts were selected to establish the *expert* validity of the questionnaire.

The CD was evaluated from four dimensions: graph presentations, animation presentations, written contents expression and courseware overall perspectives. The ITM is assessed along two dimensions; the creation of an effective learning environment and content explanation. Measurement of SLP consists of three components; learning interest, learning attitudes and cognitive perception. Each dimension in the questionnaire was measured with four to six items. Students indicated their agreement from *strongly disagree* to *strongly agree*, on a five-point Likert scale. For reliability, a pilot study was conducted. Cronbach α was applied to establish the internal consistency. The overall reliability was sound, and is presented in Table 1.

Two in-depth interviews were conducted to deepen insights into students' feedback after receiving computer-mediated CMPING instruction. The first took place after midterm and the second at the end of the course. Six students were interviewed according to students' nanometre course grades. Two of the interviewees obtained a high learning score, two were in the middle and two earned a lower result.

This research adopted the semi-structured interview outline as a tool. Three experts examined the content and adaptability of the interview questions in order to establish the content validity of the interview outline. Moreover, Grounded Theory was used to finalise and analyse the interview data. Two coders co-coded all the interview transcripts and obtained an average coefficient of intercoder agreement of 0.72, ranging from 0.59 to 0.83. The average coding reliability is 0.83, ranging from 0.74 to 0.91.

RESULTS

The research analysis was conducted by descriptive statistics and one sample *t*-test. In particular, the mean values of the students' attitudes were compared with a neutral stance (value 3), which is the median of the five-point Likert scales, on each assessment item. The results are presented in Table 1.

Table 1: Descriptive data and *t*-test results for key variables.

Variables	M (Mean)	SD	*t*-test	Cronbach α
Design of Courseware	3.724	0.402	12.614***	0.840
Graph presentations	3.806	0.468	12.046***	0.795
Animation presentations	3.869	0.499	12.190***	0.806
Text descriptions	3.571	0.513	7.799***	0.824
Whole teaching material	3.648	0.473	9.589***	0.726
Instructor's teaching method	3.699	0.512	9.557***	0.836
Learning environment creation	3.600	0.592	7.052***	0.726
Content explanation	3.800	0.508	11.018***	0.726
Students' learning performance	3.671	0.433	10.834***	0.898
Learning interest inspiration	3.735	0.470	10.949***	0.874
Learning attitudes	3.683	0.461	10.392***	0.806
Cognitive perception	3.673	0.461	10.217***	0.882

Note: The t test is one sample *t*-test, comparing the sample mean with 3, which is the neutral point on the five-point Likert scale.
*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$

For CD (see Table 1), students rated the items of graph and animation presentations with higher feedback. However, the written contents expression tended to be viewed with lower satisfaction, and it further lowered the mean score of students' reaction regarding courseware overall perspectives. The *p* value of one sample *t*-test was significant at 0.000, which means students gave significant positive feedback for the variety of CD. These results are in accord with the results of qualitative interview texts that showed the students' visual sense obviously was stimulated after receiving nanometre knowledge through the CD, and it further enhanced their positive learning efficiency.

> *What I experienced was reading the written content and watching Flash animation to gain knowledge, meanwhile, my learning became more efficient. This teaching method impressed me and it was organised. Some concepts were even explicit and not easy to forget (#1048 & #6059).*

> *I agreed that CMPING instruction has abundant teaching potential, especially the animation. Therefore, I think this instructional approach can be applied to all subjects or even for self-application (#5323).*

> *I grade CMPING instruction with the score of 80 because it… (#6285).*

The above information shows that this kind of visually assisted courseware with animation did allow students to gain nanometre knowledge directly, and it also helped students achieve better understanding. However, student interview texts indicated that the written content's design should be improved, and that it was relevant to the quality of display (e.g. the colour expression and the size of characters) and physical environment:

> *The PowerPoint expression is not clear enough, the colour design should be darker and the characters should be large (#3076).*

> *There was too much information in the PowerPoint presentation, I felt tired after staring at the screen for so long, and it definitely affected my learning performance (#4174).*

In terms of the instruction perspective, students had more positive feedback towards course content, explained by the rating of M=3.800, whereas the feedback towards learning environment creation was rated as low as 3.600. Table 1 also demonstrates two reasons that may best explain the variance. In the variable of learning environment creation, the visibility of screen expression earned a mean score of M=3.265 and the interaction with the instructor gained a score of M=3.470. Overall, *p* values in Table 1 were all-significant ($p<0.01$), meaning that all the items were affirmed even though two of the attributes were not as supportive as others. The following results of qualitative analysis show that students did agree that the utilisation of CMPING instruction was an appropriate teaching method, especially for the introduction of new and abstract subjects:

> *CMPING learning should be popularised because it is more active than traditional instruction… (#1137).*

CMPING instruction is a systematic teaching method; furthermore, I think it is also a good way to introduce a new subject to students (#5096).

I prefer that a teacher uses CMPING instruction, especially for a technical abstract subject (#6253).

Most students highly valued CMPING instruction, and even advocated the application of CMPING learning. Nevertheless, some students have doubts about the learning efficiency of a computer-mediated environment. In other words, CMPING with computer-mediated instruction positively raised the instructor's teaching efficiency and the quality of the content of materials. However, students were incapable of absorbing the information completely and claimed to have less interaction with the instructor during the learning process, as noted below.

Sometimes, the teacher just keeps displaying the PowerPoint without paying attention to what we are doing… (#3261).

Some students are easily distracted. If the teacher uses traditional teaching methods, at least the teacher can ask students questions and students might try to respond… (#4166).

Students mostly agree that computer-mediated CMPING instruction indeed enhanced their learning performance. As shown in Table 1, the mean scores of SLP, including *stimulating interest in the learning*, *learning attitude*, and *perception of cognition* all appear to have higher agreement with significant p value (p<0.01). Moreover, students especially rated *stimulating interest in learning* with the highest mean score of M=3.735. This finding corroborates the results of qualitative analysis; students confessed that computer-mediated CMPING instruction did inspire their willingness to learn:

The CMPING approach is interesting and it inspires my interest in Nanometre science. I even searched for other related books to read (#6207).

If it is good …, I like to learn Nanometre science. Especially when the teacher introduced this kind of new subject to us through the CMPING approach, it really made me want to learn more about that subject (#1321).

Apart from the impacts on their learning, students also showed positive feedback on the function of CMPING instruction. From the students' perspective, CMPING was an integrated teaching system with lecturers to direct the learning, and they stated that most received clearer cognition afterwards:

CMPING is a hierarchical structure and it links to each concept meaningfully. I think it extended my ability in many different aspects and did help students to learn (#6099).

CMPING is an integrated teaching system, where the teacher utilised the computer interface to hyperlink different fields or diagrams to guide students to discover the theorems (#5010).

According to the aforementioned result discussions, students did have significant positive feedback on CD, ITM and SLP.

The results of hierarchical regression analysis among courseware design, instructor's teaching method and students' learning performance are presented in Table 2.

Table 2: Hierarchical regression analysis.

Independent	Dependent: SLP					
	Model one			Model two		
	Beta	t	Sig.	Beta	t	Sig.
ITM	0.822	9.903	0.000	0.604	4.544	0.000
CD	-	-	-	0.273	2.056	0.045
R^2 (Adjust R^2)	0.676(0.669)			0.858(0.848)		

**: p<0.05; **: p<0.01; ***: p<0.001*

The Pearson correlation analysis was first adopted to test the relationships among CD, ITM and SLP. The results indicated that all relationships among the three variables were significantly positive. The correlation coefficients were 0.797 between ITM and CD, 0.755 between CD and SLP, and 0.822 between ITM and SLP, respectively. Hierarchical regression analysis was then employed to test if CD had a significant mediating effect on the relationship between ITM and SLP. As presented in Table 2, the Beta value of ITM in Model 1 was 0.822 with a significant p value (p <0.01).

This means ITM had a significant direct influence on SLP. As for Model 2, the Beta value of ITM changed, from 0.822 (p<.001) in Model 1 to 0.604 (p<.001) in Model 2. These results show that the CD had a significant mediating effect on the relationship between ITM and SLP. The medium degree of reduction demonstrates that this mediator is only one of multiple mediating factors. As a result, Table 2 illustrates that the relationship between ITM and SLP was significantly affected by the CD.

DISCUSSIONS AND CONCLUSIONS

An animation function employed in courseware developed for the research received the most positive responses from students. This finding corresponds to the previous study [12]. It demonstrates that this kind of iconography instruction did help learners to acquire a better understanding during the whole learning process. This was especially true with some of the more abstract and complicated subjects, such as nanotechnology, as they are better candidates for development of a virtual learning environment through computer technology, where concepts can be simplified for students. Based on that, this research successfully defined and visualised the abstract concepts into systems and created an effective virtual learning environment for nanometre learners.

According to the findings from the qualitative and quantitative analyses, students' feedback was mostly lower for written contents expression and the learning environment. It was suggested that the computer facilities should be improved, especially the quality of display, such as colour quality and size of characters. Furthermore, the creation of the learning environment deserves more attention. From the students' perspective, they had difficulties in keeping up with the instructor's lectures and could not fully absorb the content. The learning efficiency was doubted. Therefore, it could be suggested that students' lesson study skills need to be fostered and the instructor should facilitate students' discussions in the class in order to increase interaction with them and further monitor students' learning progress.

Based on the quantitative results, the computer-mediated CMPING instruction did stimulate students' learning interests, as it had the highest mean score, and the qualitative results show that the instruction activated the teaching environment and motivated students' sense of acquiring nanometre knowledge. Similarly, a scholar found the same results in previous studies [8]. Students viewed CMPING instruction as a constructive learning approach, which motivates learners to actively construct nanometre knowledge with a greater depth of understanding and systematic thinking, which reflected the findings of previous research [10]. Therefore, it can be concluded that CMPING instruction indeed stimulated students' learning motivation and helped them attain a better learning performance. In other words, students are supposed to have better comprehension, memorisation, concentration, and learning interests through some kinds of visual instruction with animation, such as computer-mediated CMPING instruction. Moreover, the instruction could improve students' reflective skill and make them further obtain better quality performances.

The research found that there are significant positive relationships among CD, ITM and SLP. The strength of the positive relationship between ITM and SLP decreased to a medium degree due to controlling CD. In 2008, some scholars expressed a similar viewpoint on supporting the impact of developed courseware for CMPING instruction [12]. Courseware quality is important in computer-mediated CMPING instruction [7]. In this research, an appropriate courseware was developed for nanometre CMPING instruction. The main purpose was to merge computer technology into teaching design and, thus, further assist students with concepts specialisation, knowledge construction and learning motivation to achieve better learning performance.

Regarding recommendations for further study: first, in a future study the same course would be presented to a different group of students to see if it would yield results different from those in this study. Second, a computer-mediated environment with concept mapping method would be used in industry training new hires and presented to subject matter experts, to see whether it would yield alternative findings. Finally, more research needs to be conducted to determine if there are more mediators of the relationship that represents the generative mechanism through which ITM influences SLP.

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REFERENCES

1. Stoddart, T., Abrams, R., Gasper, E. and Canaday, D., Concept maps as assessment in science inquiry learning - a report of methodology. *Inter. J. of Science Education*, 22, **12**, 1221-1246 (2000).
2. Turns, J., Atman, C.J. and Adams, R., Concept maps for engineering education: A cognitively motivated tool supporting varied assessment functions. *IEEE Transactions on Education*, 43, **2**, 164-173 (2000).
3. Marangos, J. and Alley, S., Effectiveness of concept maps in economics: Evidence from Australia and USA. *Learning and Individual Differences*, 17, **2**, 193-199 (2007).

4. Moni, R.W. and Moni, K.B., Student perceptions and use of an assessment rubric for a group concept map in physiology. *Adv. Physiol. Educ*., 32, 47-54 (2008).
5. Chiu, C.H., Evaluating system-based strategies for managing conflict in collaborative concept mapping. *J. of Computer-mediated Learning*, 20, **2**, 124-132 (2004).
6. Cicognani, A., Concept mapping as a collaborative tool for enhanced online learning. *Educational Technol. and Society*, 3, **3**, 1436-4522 (2000).
7. Kwon, S.Y. and Cifuentes, L., The comparative effect of individually-constructed vs. collaboratively-constructed computer-based concept maps. *Computer & Educ.*, 52, **2**, 365-375 (2009).
8. Kinchin, I.M., Concept mapping, Powerpoint, and a pedagogy of access. *J. of Biological Educ.*, 40, **2**, 79-83 (2006).
9. Rothberg, S.J., Lamb, F.M. and Willis, L., Computer-assisted learning in UK engineering degree programmes: Lessons learned from an extensive case study programme. *European J. of Engng. Educ.*, 31, **4**, 395-406 (2006).
10. Lee, Y. and Nelson, W.D., Viewing or visualizing – which concept map strategy works best on problem-solving performance? *British J. of Educational Technol.*, 36, **2**, 193-203 (2005).
11. Odwyer, D.W., Logan-Phelan, T.M. and Onill, E.A., The development of a web-based virtual environment for teaching qualitative analysis of structures. *European J. of Engng. Educ.*, 32, **6**, 695-709 (2007).
12. Kao, Y.M., Lin, S.J. and Sun, C.T., Breaking concept boundaries to enhance creative potential: Using integrated concept maps for conceptual self-awareness. *Computer and Educ.*, 51, **4**, 1718-1728 (2008).
13. PEN (Project on Emerging Nanotechnologies), Analysis: This is the first publicly available on-line inventory of nanotechnology-based consumer products (2009), 16 December, 2009, www.nanotechproject.org/ inventories/consumer/analysis_draft