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Using Computer-Animated Instruction to Enhance Chemistry Conceptual Understanding of Diploma Pharmacy Students

(Penggunaan Arahan Komputer yang Beranimasi bagi Meningkatkan Pemahaman Konsep Kimia Pelajar-pelajar Diploma Farmasi)

KHOR POH YEN* & CHONG LEAN KEOW

ABSTRACT

The objective of this study is to investigate the use of computer-animated instruction to improve students' conceptual understanding in chemistry concepts. The sample consisted of 70 first year Diploma Pharmacy students who were randomly selected. This study used the pre-test-post-test quasi experimental group design. The treatment group was taught using computer-animated instruction, while the control group was taught using white-board drawing instruction. A Conceptual Performance Test consisting of visual and verbal conceptual questions was used to measure students' conceptual understanding. The t-Test was employed to analyze students' conceptual understanding test score. The findings indicated that computer-animated instruction group did not outperform significantly [t(65)=1.50, p=0.15] in the visual conceptual questions compared to whiteboard drawing instruction group.

Keywords: Computer-animated instruction, chemistry concept, pharmacy, visual type conceptual questions, verbal type conceptual question

ABSTRAK

Kajian ini bertujuan untuk mengkaji penggunaan animasi komputer bagi meningkatkan pemahaman konsep kimia. Sampel kajian ini terdiri daripada 70 pelajar daripada tahun pertama, Diploma Farmasi yang dipilih secara rawak. Kajian ini menggunakan reka bentuk kuasi eksperimen ujian pra dan paska. Kumpulan eksperimen diajar dengan menggunakan pengajaran animasi komputer, manakala kumpulan kawalan pula diajar dengan menggunakan lukisan pada papan putih. Ujian Pencapaian Konsep terdiri daripada soalan konsep visual dan soalan konsep verbal yang diguna untuk menguji pemahaman konsep pelajar. Ujian t digunakan untuk menganalisis skor ujian. Dapatan kajian menunjukkan kumpulan pengajaran dengan animasi komputer tidak signifikan [t(65) = 1.50, p = 0.15] atasi pencapaian dalam bentuk soalan visual berbanding dengan kumpulan menggunakan lukisan pada papan putih.

Kata kunci: Pengajaran komputer animasi, konsep kimia, farmasi, soalan konsep visual, soalan konsep verbal

INTRODUCTION

The conceptual understanding (CU) of chemistry involves knowledge of its basic concepts, the ability of the students to translate between and among different chemistry conceptual representations, and their application completely in new situations (Weerawardhana et al. 2006). According to Robinson (2003), representations of chemistry concepts are categorized into three levels, namely the macroscopic, symbolic and microscopic levels. The macroscopic level deals with all the visible phenomena that can be observed by human beings. In comparison, the symbolic level represents matter in terms of formulae or equations. While the microscopic levels of atoms, molecule or ions, however, explanations are offered for chemical formulae, equations and also how a chemical process can occur. Although chemical concepts involve three levels of representations, in actual practice, chemistry instruction occurs predominantly in one of the two areas of representation, that is, either at the macroscopic level and symbolic level. Sadly, the microscopic concept is poorly emphasized. Robinson (2003) argued that a lack of understanding and application of the microscopic level concepts certainly hinder the understanding of why and how a chemical phenomenon occurred. This statement evidenced by various learning problem such as in chemical equilibrium concepts (Weerawardhana et al. 2006), chemical bonding (Wang 2008), solution (Saribas & Köseoglu 2006) and acid base (Rawson & Quinlan 2002). The reason for such occurrences are because students faced clear cut difficulties in visualizing, understanding, remembering and interpreting why and how the dynamic chemical process occur in such a way (Mummer et al. 2005). Research results from Sanger, Phelps and Fienhold (2000) indicate that the use of computer-animated instruction (CAnI) is successful in promoting CU in a lesson of aqueous solution with high school students. They found that students who received instruction using animations of pure substances and mixtures at the molecular level were better off at identifying particulate pictures of liquid, pure compounds, heterogeneous mixtures than students whose instruction did not use any particulate picture at all. Similarly, Sanger and Greenbowe (2000) used computer animation to diagnose the alternative concepts of diffusion and osmosis among college's student found that students who viewed animation less likely to demonstrate misconception of diffusion and osmosis and more importantly, the CAnI found to be able to create a significant conceptual change. These findings were also supported by the findings of a study conducted by Othman Talib, Matthews and Secombe (2005). In their study, these researchers used CAnI to assess conceptual change in Malaysia matriculation students regarding electro-chemistry concepts. They found that computer animation was effective in teaching complex, abstract and dynamic chemical process. However, Donavon and Nakhleh (2001) revealed that the coordination bonding concepts of student who did not use tutorial website were more complete than students who used the tutorial website. Donavon and Nakhleh (2001) argued that the animated-diagrams used in the intervention group distracted weak students understanding and application. Similarly, Li, Grabowski and Barbara (2006) involved 111 college students in their study using web-based animated-instruction in a lesson of the human heart in Biochemsitry found negative impact on CAnI in human heart performance. In contrast, several studies found no superior effect of animation over static visuals (Hegarty et al. 2003; Lewalter 2003). According to Mayer and Moreno (2003), the effectiveness of CAnI in enhancing conceptual understanding is highly dependent on the role of animation, the organization of lesson as well as principles used to select or develop the computer animated diagrams. In attempt to solve the conceptual understanding problem, the researcher has decided to introduce CAnI for teaching eight concepts, namely the formation bonds; the kinetics of reactions; chemical equilibriums; gas behavior; precipitation processes; solution properties; acid and base properties as well as acid and base reactions among a group of Diploma Pharmacy students. These eight concepts were selected because they have been identified as common but essential concepts to be mastered by students (Roche et al. 2000)

Research Objectives:

1. To determine is there any significant difference between the CAnI and the whiteboard drawing instruction methods on the students' CU of chemistry concepts for visual conceptual questions.
2. To determine is there any significant difference between the CAnI and the whiteboard drawing instruction methods on students' CU of chemistry concepts for verbal conceptual questions.

CONCEPTUAL FRAMEWORK

The conceptual framework of this study was designed based on Huitt's Information Processing Theory (2003), Pavio's Dual Coding Theory (1986) and Mayer's Cognitive Theory of Multimedia Learning (1997). The assumption made was that students' CU could be facilitated through CAnI, in order to facilitate CU, controlling the flow of information from the sensory register until the retrieving plays an important role. Firstly, the sensory memory should be activated in order to enhance attention and transfer to the short-term memory. One of the best ways to instruct dynamic, motion and trajectory chemistry concepts is to present it visually by computer animation and verbally by narration. This is because computer animation can clearly show the trajectory and dynamic motion of the microscopic concepts, thus simulating two channels of sensory memory easily (eyes and ears). Thus, in turn will contribute to the effective selection of visual and verbal information, thus form the representative connection between sensory memory and working memory (Figure 1). In addition, the selection animation clips presented to students were supported by the contiguity, signaling, consistency, fidelity as well as segmentation principles. It is believed that these principles are able to help the students in the CAnI group's to attend to and select information effectively for further processing in the short term memory (STM). In the STM, the pieces of verbal and visual information coded from sensory memory are then further organized, where the verbal information will form referential connections to construct the verbal model, while the visual images will form referential connections to construct the visual model. Meanwhile, verbal or visual information will also associate with each other to form the integrated mental model to be encoded in the long term memory (LTM). In other words, verbal and visual information are organized in students' STM through referential and associative process. The processing at the STM is also enhanced by the well controlled instructional strategy which is supported by the pre-training, segmentation, personalization, contiguity as well as coherence principles. Therefore, the possibility of over loaded STM can thus reduced (Figure 1). In the LTM, information form in STM will be further integrated with prior knowledge. It is believed that by controlling the quality of animation and the proper design of instructional steps, a more systematic conceptual framework in LTM can thus formed.

METHODOLOGY

POPULATION AND SAMPLE

The population of the study consisted of 125 first year, 2011 enrolled Diploma Pharmacy students from a private medical university. Seventy students were randomly selected from the population using stratified sampling method. The stratified sampling was used to ensure that the ratio of female and male students involved in the study was representative of the population in both the experimental and control group. Seventy students were

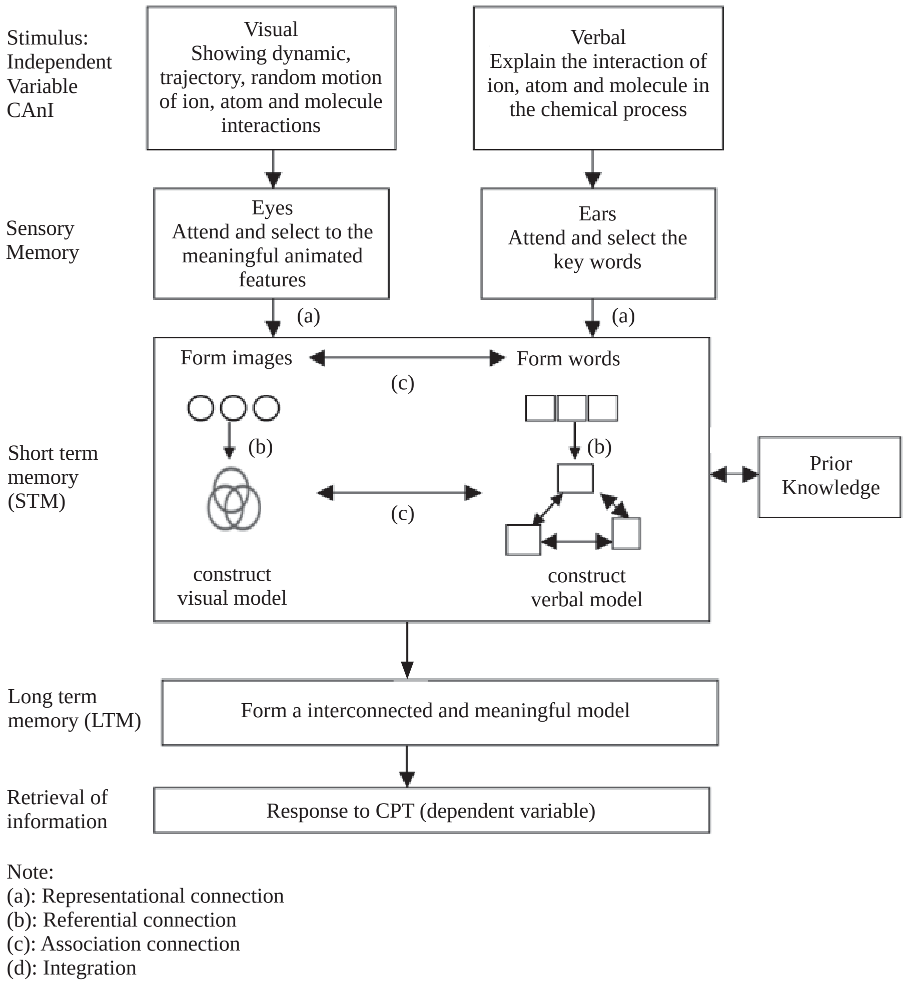

FIGURE 1. Conceptual framework of CAnI

selected to fulfill the minimum number of respondents required for experimental group study (Gay et al. 2006). After random selection of 70 students was done, students were then assigned randomly to the experimental and control groups.

DATA COLLECTION PROCEDURE

The pre-test was conducted before the treatment (computer-animated instruction), while the post-test was administered at the end of the treatment. The instructional period lasted eight weeks, one subtopic per week with each session 90 minutes. The main learning outcome of the lesson is at the end of the instruction, student will be able to apply concepts learned (bonding, kinetic reaction, equilibrium, gas law, acid base) in phenomenon given in CU test.

A lecture-style presentation was delivered to students in both groups. Students in the treatment group viewed power point presentation supplemented with animations inserted into the presentation. The control group also viewed the power point presentations covering same material using the static whiteboard drawing approach. The instruction was carried out using criteria of effective instruction (Table 1).

TABLE 1. Criteria of effective instruction

Step	Criteria of effective instruction
1	Presentation of the meaning of key words or important terms (pre-training principle: Sorden 2005)
2	Use live narration to explain the meaning of concepts and how the microscopic chemical process occurred: Personalization principle (Mayer & Moreno 2003)
3	Narration was one simultaneously by showing computer animation or drawing on the whiteboard to illustrate to the students the chemical process at the molecular level (segmentation principle: Mayer & Moreno 2003)
4	Provide conceptual questions which were related to real world problems for students to respond to (practice principle: Toh 2005)

The animated-diagrams used in the experimental group were adopted from Chang (2003). The researcher selected the animated-diagrams were based on the effective computer animation as reviewed in Lin (2001), Mayer and Mereno (2003) and Weiss, Knowlton and Morrison (2002) (Table 2).

TABLE 2. Criteria for effective computer animation clips

No	Criteria of computer animations selection
1	Provide visualization of trajectory and random motion of atom, molecules and ions interaction (Lin 2001)
2	Animation with contiguity effect (Mayer & Mereno 2003) - On screen text next to the animations
3	Animation with modality effect (Mayer & Mereno 2003) - Without on-screen text
4	Animation with signaling effect (Mayer & Mereno 2003) - Emphasized the important words - Provide 'zoom' in function'
5	Animation with consistency features (Weiss et al. 2002) - Colour and size of the animated object were consistent
6	Animation with segmentation effect (Mayer & Moreno 2003) - Animation are short (15-20 seconds)
7	Animation with coherence effect (Mayer & Moreno 2003) - Only relevant concepts presented - Animation focus on concepts to be learned.

Prior to start of the first session, the researcher explained the purpose of the study to the students, how the lectures were conducted and how the Conceptual Performance Test (CPT) scoring would be done. During the second week, lectures were conducted for both the experimental group and control group. To reduce the threat of experimenter's bias (Gay et al. 2006), another chemistry lecturer was called in to observe the researcher teaching in both classes.

INSTRUMENTATION

Instrument used in this study is Conceptual Performance Test (CPT). The CPT was open-ended pen-and-paper tests. All the items were adapted by the researcher based on two main reference book Hill and Petrucci (2002) and Molly (2000). In order to ensure questions adapted were valid in terms of testing students' CU, questions were further checked by researchers based on the Nurrenbern and Robinsons's (1998) criteria of conceptual questions: justify a choice, predict what happen next, explain why something happen and explain how something happen. Marks allocated for each subtopic in range of 9 to 11 marks, divided into verbal conceptual questions and visual conceptual questions. Verbal and visual conceptual questions were categorized based on Haláková and Proksâ (2007)(Table 3). Total marks for visual and verbal conceptual questions were 35 and 45 marks respectively. The analytical marking scheme was used. The coherency of the marking scheme and the questions were checked and validated by two experience chemistry lecturer. The joint agreement reliability obtained was 98% thus indicating that a high inter-rater reliability had been established (Fleiss 2003). All teaching module and CPT had been validated by Panel of Research Committee from the University.

TABLE 3. Visual and verbal conceptual items in CPT adapted from Haláková and Proksâ (2007)

Types of questions	Criteria
Visual conceptual questions	- Microscopic drawing - Represents atom, ion or molecule by using symbols: H^+ Cl^-
Verbal conceptual questions	- Words explanation in sentences - Involve symbol represent in equations

DATA ANALYSIS

The students' score in CU were analyzed using Independent *t*-Test. All the statistical analysis of the tests were computed at 0.05 level of significance.

RESULTS

There are total of 70 students participated in this study. 10 (14%) were male, 60(86%) were female followed the ratio of actual population of the particular university. After four weeks of intervention, two students in the control group and one student in experimental group dropped out from the study, thus, leaving the number of students in the control group at 33 and the experimental group at 34. Since the number of the students fulfilled the minimum number of subjects required for experimental group study (Gay et al. 2006), the treatment continued till the eight week of instruction.

In order to determine that the two groups of students were equivalent in their CU ability before experiment started, a pre-test that measures the CU was conducted at the beginning of the study. The total mean scores of the pre-test in the experimental group was 25.5±3.45, while the total mean scores for the control group was 25.06±3.16. This indicated that two groups of students achieved similar and low scores in the CPT. The results also show that there is no significant difference between both groups for visual conceptual questions scores [$t(65) = 0.09$, $p = 0.93$] as well as for the verbal conceptual question scores [$t(65) = 0.67$, $p = 0.51$].

After eight weeks of instruction, post-test was conducted. According to Table 4, the experimental group score higher in the experimental group (23.74±1.62) compared to control group (23.12±0.31) in visual type questions. The similar pattern was also found in the verbal type questions. Whereby, the experimental group students (35.97±2.33) also achieved better scores compared to control group (34.82±2.17).

TABLE 4. Mean scores of post-test according to group

CPT	Group	mean±SD
Visual	Experimental	23.74±1.62
	Control	23.12±0.31
Verbal	Experimental	35.97±2.33
	Control	34.82±2.17

According to Table 5, the results show that there is no significant difference between experimental and control group for visual CPT score [t(65) = 1.50, p = 0.15]. However, the verbal CPT score was significant different between experimental and control group [t(65) = 2.09, p = 0.04].

TABLE 5. Independent *t*-test of verbal and visual questions post test

CPT		Levene's test for equality of variance		*t*-test for equality of means		
		F	Sig	T	df	Sig
Visual CPT Score	Equal variances assumed	0.432	0.513	1.459	65	0.15
	Equal variances not assumed			1.467	63.849	0.15
Verbal CPT Score	Equal variances assumed	0.470	0.521	2.093	65	0.04
	Equal variances not assumed			2.096	64.899	0.04

DISCUSSION

The pre-experimental results showed that both groups of students were similar; low in terms of their visual and verbal conceptual ability. This finding is consistent with the Van Driel (2002) studies which indicated that most of the college and undergraduate students were weak in CU. This was because they lacked a wholesome and interconnected mental representation of concepts. Chittleborough, Treagust and Mocerino (2002) also showed that most of the students did learn the facts or concepts but had no mental picture of microscopic nature of chemicals. Another possible reason could be due to their lack of exposure to instruction that facilitated them to think visually and verbally. Pavio (1986), dual coding theory asserts that if individuals attended to both the non-verbal and verbal systems of processing information, the integration, retention and recall of the information is easier.

The findings of this study showed that CAnI group did not outperform significantly in the visual conceptual questions compared to the whiteboard drawing group. The insignificant difference in visual conceptual questions was consistent with the Sanger and Greenbowe's (2000) study. According to these researchers, students who were instructed using computer animation but assessed using visual conceptual questions may over emphasize the visual images formed. The mental images formed by looking at the computer animations might be different from the visual images shown in microscopic drawings for the conceptual questions. Thus computer animation can distract students' interpretation of the visual conceptual questions. This finding is also further supported by the earlier findings of Najjar (1995), who reported that when tested using only words, children who saw words only performed better than the children who saw words with pictures. When tested using only pictures, the children who saw words with pictures correctly named more words than the children who saw only words.

Similarly, in this study, the control group which was exposed to static whiteboard drawing was more likely to outperform in static visual questions. It can be explained by the fact that when our mind stores something in memory, the memory formation is not just about the items being stored alone but also about the context in which the memory formation occurred. According to the Information Processing Theory, it is easier to retrieve a particular event if we are in same context in which event occurred.

However, when tested using static drawing diagrams, the students had to use their imagination based on the diagrams given alone. This resulted in an over emphasis or overlapping of their visual representation thinking thus leading to a diversion or distraction of their thinking when answering conceptual questions. Another possible reason is supported by the findings of Tulving's (1982) study which found that recalling and recognition may be triggered by the elements of the context being presented. It is believed that instruction using static whiteboard drawing makes retrieval easy of those information when it was needed in the same type.

The results of the study also showed that the CAnI group scored significantly higher for verbal conceptual questions compared to the control group. This indicates that CAnI effectively enhanced students' CU related to verbal conceptual questions. This finding supported the idea that the CAnI group was more likely to form clearer image pictures as well as increase retention of those image formed. This finding occurred with that of previous research done by Sanger (2008), Sanger et al. (2000) which found that using computer animation to teach solution properties and osmosis concepts among college students were able to foster significant conceptual understanding. Additionally, more complete and comprehensive interpretation of concepts as shown by the CAnI group was also congruent with the Sanger et al. (2000) study which indicated that students who were exposed to CAnI were more likely to demonstrated more sophisticated understanding of the target concepts and less likely to quote memorized mathematic relationships.

The general reason for this improvement can explained by Daniel and Rohaida Mohd Saat (2000), who determined that computer animation helped the students visualize concepts learned as a whole entity rather than as separate ideas of process. Therefore they were better off in integrating and explaining chemical processes. Besides that, as mentioned by Othman Talib et al. (2005), compute animation was more effective in teaching a complex, abstract and dynamic chemical process compared to white-board drawing method.

In this study, concepts taught such as kinetic, equilibrium and acid base concepts were indicated as complicated and abstract concepts for learning by college students. Using animation may increase the verbal CU by promoting the formation of dynamic mental models of the phenomena. The dynamic quality of animation may also promote deeper encoding of information than that of static pictures. This assumption was made according to Kozma & Russell's (2005) study which concluded that CU can only be reached if students are able to visualize a chemical reaction from a molecular point of view in order to see why and how the changes are taking place. This result is also supported the Pavio's Dual Coding Theory which emphasized that when information was presented verbally by narration and visually by animation, it was possible to activate representation, referential and association processing effectively. According to Pavio (1986), presentation involving visual and verbal mechanisms can simulate visual and verbal representations simultaneously. Hence it will be dually coded and expected to give the students a better recall of information.

Furthermore, Toh (2005) and Wan Mohd Fauzy Wan Ismail (2004) also argued that if information was presented in dual form, it would increase the possibility of retrieving the information more easily as the learner had more cognitive paths to follow when retrieving information in answering conceptual questions. In addition, when animation and narration were presented simultaneously, they supported the referring process, hence increasing the integration of old and new concepts learned before. In turn, this might help students in answering verbal conceptual questions effectively.

Based on the above findings, it can be said that college students may need CAnI to outperform in the verbal conceptual test. The possible reason is that not all college students are able to think about dynamic chemical processes at the microscopic level, as the ability to think and integrate the microscopic concepts in chemical processes are highly dependent on the student's characteristics, such as prior knowledge and spatial ability. According to Mayer (1997), spatial ability is the mental ability to manipulate images. Although this study did not test the students' partial ability, the students' knowledge was tested significantly equally from the pre-test. Hence, it can be argued that, not all colleges level students can be assumed to be able to think at the microscopic level.

CONCLUSION

If the aim of instruction is to enhance students' CU, college or university level instructors should not assume that their students are able to visualize, understand and apply chemical concepts into the chemical process. In turn, computer animation should be used as part of teaching learning activities. Additionally, students should also be given enough practice to answer visual and verbal conceptual questions.

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For more information please contact
Khor Poh Yen
Faculty of Pharmacy
Royal College of Medicine Perak
Universiti Kuala Lumpur,
No. 3 Jalan Greentown
30450 Ipoh, Perak
Malaysia

Chong Lean Keow
Maktab Perguruan Ipoh
31150 Hulu Kinta, Perak
Malaysia

Received: 13 January 2011
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*Corresponding author; email: pykhor@rcmp.unikl.edu.my