Original Article

Evaluation of Computer-based Simulation Learning on Knowledge, Learning Approaches and Motivation among Pharmacy Students

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ABSTRACT

Background: With the exponential influence of technology on students' learning, Computer-based Simulation Learning (CSL) has perceived to have great potential in enhancing the training of healthcare professionals including pharmacists. However, limited evidence is available to compare its impacts on knowledge gained and learning approaches to that of conventional lectures. **Materials and Methods:** A total of 168 pharmacy students were randomly assigned to "CSL group" (Group I, intervention group) or "Lecture group" (Group II) in this study. The students' knowledge and deep information processing capabilities were evaluated through a quantitative survey, followed by focus group interviews to obtain an in-depth perspective of the student learning through CSL. **Results and Discussion:** Compared to didactic lecture, CSL significantly enhanced knowledge gained by the students. There was no significant difference between CSL and didactic lecture on students' deep information processing skills, although CSL was more effective at promoting the critical reading domain. On the other hand, didactic lecture had higher impacts on healthcare students' structuring skills. The features to be considered in designing an effective computer-based learning tool were highlighted in this study. **Conclusion:** Both CSL and didactic lecturing have its role in training pharmacy students' knowledge and deep information processing skills.

Key words: Computer, Learning, Knowledge, Information Processing, Pharmacy.

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INTRODUCTION

Simulation is commonly used in professionals training programme including healthcare professionals, pilots and engineers to encourage active learning through application of knowledge and skills using real-world scenarios.[1-4] In healthcare professionals' education, simulation in pharmacy education for learning and mastering clinical skills is less commonly reported as compared to medical education. Nevertheless, simulation in pharmacy education can be found from literature in various forms including simulation with real patients, high fidelity human simulation, simulation using electronic medical record and simulation using standardised patients.[5] There is also growing evidence suggesting the use of computer simulation in pharmacy education to teach specific skills such as dispensing and healthcare analytics.[6,7]

Computer-based Simulation Learning (CSL) refers to as the learning using computer or electronic device in order to gain mastery of knowledge or skills. In science education, it is believed that CSL can affirm students' learning during the simulation sessions, in which the students can understand how the simulated events are caused and their consequences. CSL could be a robust addition to the repertoire of science educators especially as a preparatory learning activity prior to the actual laboratory experiment. It has been reported that the students' performance in a physics course had improved using CSL.[8]

CSL supports a constructivist approach to learning, as the students are given the opportunity to develop, compare and understand multiple perspectives on an issue.[9] Constructive learning, characterised by learning processes that involve knowledge integration and critical analysis, is related to a learning environment that is student-oriented and promotes conceptual connection.[10] This can bring about positive influences on the students' learning approach, learning process and subsequently the learning outcomes.[11] Meanwhile, the deep learning approach is preferred as it promotes complete understanding and long term memory[12] and encourages higher intellectual skills such as reasoning and problem solving.[13] In addition to cognitive learning, the idea that the process of deep learning approach has also been linked to motivation to learn. Deep learning approach was argued to empower students with feelings of enjoyment to learn and students with high intrinsically motivated were also reported to have a deeper approach in learning.[14]

Our previous study, Chemistry and Toxicology are core subjects in training competent pharmacists.[15] The study of environment toxicology is increasingly important with the rise burden of disease and mortality caused by environmental pollutants but is generally not very appreciated among health sciences including pharmacy students. Smog City 2, an interactive air pollution simulation software developed by the United States Environmental Protection Agency could offered as a suitable CSL to promote and stimulate knowledge acquisition in the area of environmental toxicology. Despite reported benefits pertaining to CSL, its values compared to traditional didactic lecture for knowledge acquisition is uncertain. In what we believe is a unique approach to CSL in teaching environment toxicology, this study used CSL in compared to traditional teaching method to prepare pharmacy students to learn environmental toxicology. Building on to our previous findings where academics' integrity and professionalism has an impact to students' skill and competency training, we were interested to determine whether CSL can replace didactic teaching, in order to increase the consistency in teaching by lecturer and to minimise human's errors.[16,17] Therefore, the purpose of this study was to evaluate and compare the effect of CSL and traditional lecture on knowledge, Deep Information Processing (DIP) and motivation among pharmacy students.

MATERIALS AND METHODS

Methods

This study was conducted using intervention mixed-methods comprised of two phases; (1) knowledge and deep information processing survey and (2) focus group interviews at the International Medical University, at Kuala Lumpur, Malaysia. Study approval was obtained from the Centre for Education, International Medical University (Innovative Medical Education Grant ID: ILTIG 16/3).

Study Population

All 179 Year 3 (Semester 6) Bachelor of Pharmacy students were invited to participate in the study. A total of 168 participants (93.9%) provided informed consent prior to inclusion in the study.

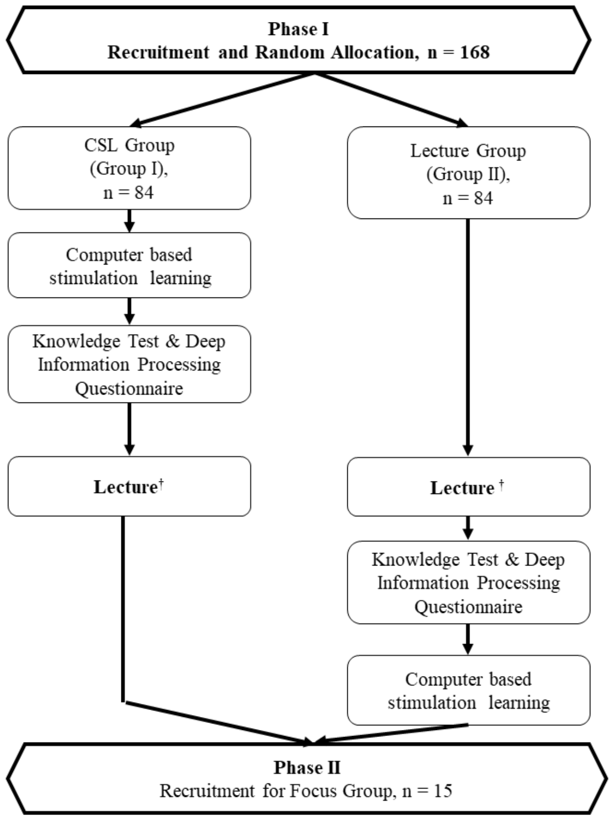
Study Design

All 168 students were randomly assigned to either the traditional lecture group or CSL group (84 students each group, Figure 1) by an independent academic service staff. The CSL group received a 60 min CSL session using SmogCity 2, a computer based learning tool about environmental toxicity. Students were asked to complete the study questionnaire at the end of the session. The lecture group received a 60 min lecture presented by CWM with consistent content with Smog City 2 software. At the end of the lecture, the students completed the study questionnaire.

Study Questionnaire

The questionnaire consisted of two sections; (1) a 20-item knowledge test and (2) a 23-item deep information processing scale (Table 1). The first section of the study questionnaire was developed by authors and content-validated by two pharmacy academics with expertise in environmental toxicity. It comprised of 20 multiple choice items to assess students' knowledge of environmental toxicology. The number of correct answers were added to a maximum of 20 (100%). The items were piloted in 20 final year students and alpha reliability coefficient obtained was 0.670, indicating satisfactory reliability. The findings from the pilot study were excluded from the final analysis.

The second section of the study questionnaire collected data on impact of CSL or lecture on the depth of learning using a validated 23 items instrument adapted from Heijne-Penninga *et al.* (2008), for students' deep information processing (DIP) capabilities.[18] In the DIP instrument, the author characterised deep learning into three dimensions; namely critical reading, broaden



†*Lecture was conducted simultaneously for both groups.*

Figure 1: The Flow Chart of Phase I and Phase II Study Design. A total of 168 participants were recruited and randomized into CSL group or Lecture group.

one's context and structuring, having 9, 8 and 6 items respectively. Critical reading relates to learners' learning to understand the learning material, while broaden one's context relates the learner's learning by elaboration through correlating the learning material with other sources of knowledge. Structuring refers to learners learning through analysis to clarify and verify learning. All items were rated on a 5-point Likert scale (1 = never, 5 = always). A total DIP score and a score for each scale were calculated.

Statistical Analysis

The mean and standard deviation of the scores were calculated using SPSS for Statistics. Statistical significant difference was determined by using 2-independent samples of Kolmogorov-Smirnov Z test ($p<0.05$).

Focus Groups

Following the Phase I questionnaire survey, we invited all participants for focus group interviews to obtain insights about impact of CSL on motivation to learn. Out of the 168 participants, 15 participants were willing to be interviewed. The focus groups were conducted in English using an interview guide consisting of predefined topic and questions agreed by the research team. The focus group topics evolved as the interviews progressed through constant comparative analysis. All interviews were conducted in a private discussion room in the university building.

Table 1: Deep Information Processing (DIP) Scale.

Deep Information Processing Scale
Domain I: Critical Reading
I attentively and critically look at the argumentation.
I understand the meaning of the text very quickly.
I cannot get an overview when the text is long.‡
I read on even when I do not know a certain expression.‡
I quickly distinguish facts from side issues.
I find it difficult to get an overview quickly.‡
I assume difficult things without really understanding them.‡
I cannot distinguish facts from side issues unless I read the text several times.‡
I keep on reading without really understanding the previous parts.‡
Domain II: Broaden Ones Context
I think of questions while I read.
I try to think of counter-arguments.
I try to relate new concepts to concepts that I already know.
I try to relate different courses.
I look for the how and why of statements.
I try to apply things in daily living.
I compare what I read with things I already know.
I think of examples myself.
Domain III: Structuring
I try to find structure in a text by looking at the title and headlines.
I make notes on the most important issues.
I pay attention to titles and headlines.
I pay attention to the paragraph division of the text.
I write down my conclusions on a text.
I also look at other books to gain a broader view of a subject.

‡Reverse scoring was applied since it is a negative statement.

To ensure that the participants were comfortable in voicing opinions freely, the focus groups were conducted by ELL or PSW who were not involved in Environmental Toxicology teaching. All focus group discussions were audio taped, transcribed verbatim and analysed using the General Inductive Approach[19] The first two transcripts were independently coded by ELL and PSW and compared to create a coding list. Based on this list, ELL coded the remaining transcripts. Codes were linked in various relationships to form themes. ELL and PSW continuously discussed with research team members and agreed on the final codes and themes.

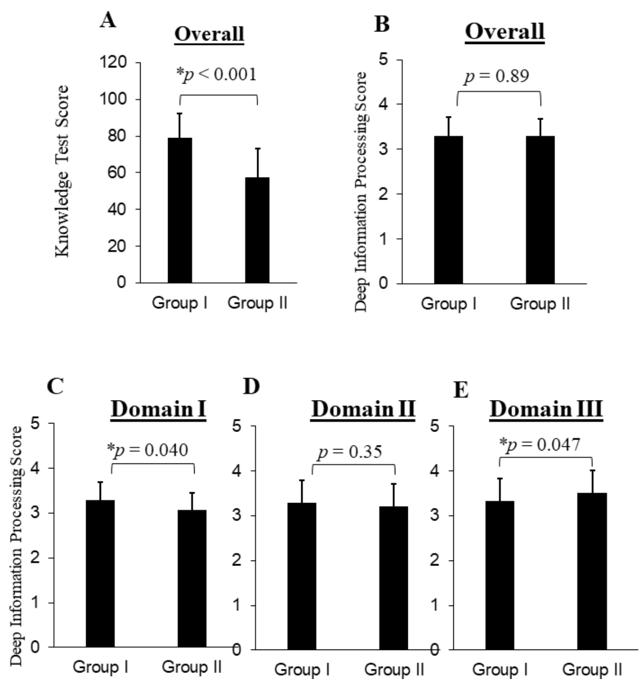


Figure 2: Comparison of Knowledge Test score and Deep Information Processing Scale between Group I and Group II. Results were presented as mean with standard deviation. (A) The average score of Knowledge Test score for Group I and II were recorded. The overall average (B), domain I (C), domain II (D) and domain III (E) of Deep Information Processing Scale were calculated. Statistical significant difference was determined by using 2-independent samples of Kolmogorov-Smirnov Z test (*p* <0.05).

Focus group interviews were conducted until data saturation is achieved where no new themes emerged from the interviews. To enhance readability, some of the main messages in the participant quotes in this study were cleaned by removing words and sounds. Some explanations were also added in parentheses to further enhance the readability of the quotes.

RESULTS

A response rate of 93.84 % was achieved where 168 pharmacy students consented to participate in this study. The consented 168 participants were randomly assigned to CSL group (n=84) or lecture group (n=84) (Figure 1)

Knowledge Test

An average knowledge score of 78.98±14.15% was achieved by CSL group compared to 58.45±15.59% in lecture group (p<0.001, Figure 2A). Students in CSL group achieved a higher average knowledge score compared to lecture group.

Deep information processing (DIP)

Overall, there was no significant difference (p=0.89) in the overall DIP score between participants from CSL group (3.29±0.39) and lecture group (3.30±0.38) (Figure 2B). Figure 2C shows the impact of CSL on participant's critical reading. CSL group (mean score = 3.28±0.81) have a significantly better critical reading score as compared to lecture group (mean score = 3.06±0.43) (p=0.0040). No significant difference (p=0.35, Figure 2D) between found between CSL and lecture groups in the 'Broaden one's context" domain scores. Lecture group (3.51±0.61) has a significantly higher mean score (p=0.047) as compared to CSL group (3.32±0.53) in the 'Structuring" domain (Figure 2E).

Correlation between knowledge test and DIP scores

When correlating data of all participants, no correlation (r^2=0.0203) was found between knowledge gained and participants' DIP capabilities. Segregated analysis of lecture group and CSL group found a relatively better correlation for CSL group participants (r^2=0.13, Table 2) compared to lecture group participants (r^2=0.014). The knowledge gained score were considered poorly correlated (r^2 <0.5) with DIP score of both groups of participants and in each domain of DIP.

Motivation to learn

Fifteen students took part in the focus group interviews. Three main themes emerged: CSL features, individual learning styles and CSL topic. A summary of themes and quotations from the participants (S=Student) are illustrated in Appendix 1.

Participants in the focus groups discussed extensively on the effect features of the CSL on their learning. Majority of them found that they learn and understand better through the CSL compared to lecture. The element that they found most engaging and helpful in learning was the active control of parameters and response on environmental pollution. Such features led

Table 2: Correlation of Deep Information Processing Score and Knowledge Test Score.

	Overall DIP (r^2)	Domain I (r^2)	Domain II (r^2)	Domain III (r^2)
CSL and lecture group	0.0203	0.010	0.00061	0.0075
CSL group	0.13	0.014	0.078	0.0024
Lecture group	0.014	0.019	0.0023	0.000039

DIP=Deep Information Processing Scale; Domain I=Critical Reading; Domain II=Broaden one's Context; Domain III=Structuring; r^2=Correlation coefficient.

Appendix 1:

Theme	Illustrative quotations
Features of CSL	S3: I also enjoy the animation. It's quite clear because if I adjust. For example, I adjust the population to very less so there are no people in the city anymore so I can instantly see clearly that visualize out. S7: For me, I felt like the pollution then can imagine this is what you are facing in daily life so you can relate to the picture that you see in the game then you can see that Oh, it's actually happening in our surrounding so it can make use of it. S9: The scenery doesn't really change. Just the same factory, the cars and the clouds. Just one scenery, one scene like that. Cause in games will be like many things like you fight against people, you fight, you go on adventures and stuff. And then this one is just like a basic Sims game. You know Sims? It's like you playing in one room only. Don't go anywhere else. S12: (The game) Enhance the memory. Because I like the animation, so I will memorize the animation, increase the temperature, increase pollution.
Individual learning styles	S5: I think it depends on what kind of like what the learner type like how do you learn because some of the people actually learn from hearing and then some people actually learn from seeing, something like that. S6: Because I prefer a hardcopy information in front of me instead of looking at animation. Because I don't remember at the end of the session. And I will How to say, because the animation don't have any explanation in voice, audio or what. I would. I would prefer a lecture. S8: Ya. I prefer reading because it's more informative than just adjusting the parameters. Adjusting the parameters itself is not so time time-efficient cost-effective.
Simulation topics	S9: Probably if like maybe they (game) talking about diabetes all those things, maybe I would have went and google to know more about it. But environment like this. I didn't go and search more. S10: No, like what he (another participant) said, because this is relating to environment and then we always have the mind-set that we are just the student, we can't do anything much to help the environment. There no power for us to do so. Like we have those kind of mind-set. S12: Particularly interested about altitude. It's like whether mountain area have like better air condition, I'm quite interested in that. So, I go search something.

S=Student

to better understanding and enjoyment in learning as well helped them to relate to real-world scenarios. Some participants have benefited from the visual changes which aided memorisation of knowledge learnt from the CSL. Nevertheless, some participants expected more advanced features such as including missions for users, varying difficulty levels through the game and reward systems with points or badges to motivate them to continue with the CSL. Technical difficulties such as specific browser set-ups and delays in loading the CSL interface also negatively affected their learning experience. Some students preferred learning through visual displays, while some students felt that they learnt best through listening in lectures. When asked about experiences with learning through CSL in comparison to lecture, some participants disclosed that they took more time to familiarise and learn from the CSL. These students who preferred lecture over CSL explained that they learn better when they listen to the explanations given by the lecturer, which gave them confidence and provided assurance that what they learnt is correct.

Participants were also asked if the CSL activity has motivated them to learn further about environmental pollution after the session. Most participants did not learn or explore further due to lack of interest in the topic. Only one student expressed interest in the study of the environment and had explored further with additional reading on her own. Some participants felt learning from the CSL activity was limited because the topic was not relatable and views that they have no control over the environment and its pollutants in the real world. Among topics that were identified as relevant and relatable to the pharmacy profession were disease-related topics which would prompt our participants to be motivated to learn further. Also, participants explained that they will be more likely read further if there is an assessment of the topic in the form of a quiz or test after the CSL activity.

DISCUSSION

CSL is recognised to provide an active learning environment using different audio and visual materials acting as a stimulus to grab a person's attention and senses for information processing. The results of our study suggest that students have better knowledge acquisition with CSL as compared to lecture, but both CSL and lecture have no different in affecting deep learning approach.

We postulated that the enhanced knowledge could have been contributed by the better understanding with the interactivity of visual effect of CSL which was evident in our focus group interviews. The CSL enabled the students to assess the impact of various pollution parameters on air quality based on simulation of air pollution scenarios. The process involved the Kolb's experiential learning cycle, whereby the students progressed through concrete experience, reflective observation, abstract conceptualization and active experimentation.[20] This is strongly supported by literature which highlighted significant positive benefits of the visual effect on memory and learning.[21-24]

Deep Information Processing (DIP) skills refer to one of higher orders in processing spectrum of mental recall through analysis. It is expected that the visual in CSL would enhance the DIP skills, nevertheless, our findings showed no advantage of CSL over lecture on deep processing information skills. The learning of "critical reading", however, was better among students who have undergone CSL. The greater impact of critical reading is possibly due to the nature of the CSL learning environment. The CSL activity simulates real-life challenges which enhance learning in a safe environment.[25-27] In addition, CSL enhances learners' interactivity and engagement as well as learning experience. With the safe interactive learning experience, students develop stronger critical thinking. This is further supported by literature that engagement in learning has a positive effect in competency and skills.[28]

Our findings found a better 'structuring' among lecture group compared to CSL. Structuring relates to learners learning through analysis to clarify and verify learning, involves systematic order of acquiring knowledge. This could be explained by the nature of traditional classroom setting which is often delivered from one topic to the next and students acquire the knowledge in stages from start at the beginning in any area of study.[29] This conforms to the linear learning that most learners are familiar with. In comparison, CSL provides active and non-linear learning. CSL contains elements of interactive animation and visual elements displayed in response to the learner's actions and hence, the learners do not necessary follow a standard learning path. The lack of significant difference in the domain of "Broaden One's Context" between the two groups could be attributed to the limited context covered during the CSL activity or lecture within the allocated teaching time. Deep conceptual understanding and transfer of knowledge develop through the encounter of the same concept at work in multiple contexts.[30] Real life exposure to varied practices associated with the concepts would be more appropriate to promote context broadening.[31]

Consistent with the literature, our study found that gamification features such as rewards and competition and personal interest in a topic as motivation to learning[32-34] Although participants in our study believed the need to adapt materials or teaching to individual learning styles, there is no evidence for existence of individual learning styles. There is also no evidence on the benefits of adapting learning resources to suit individual learning styles.[35]

There were several limitations in the study. Firstly, the study studied impact of a specific CSL software, hence may limits its generalizability to all type CSL activity. The deep information processing scores were obtained from was a self-reported instrument, may not necessarily reflect true learning behaviours. Nevertheless, to our best knowledge, this is the first study in to evaluate the impact of CSL and lecture on depth of learning in pharmacy education. The results of this study suggest that CSL can be as effective as lecture in promoting knowledge and depth of learning. CSL also has the potential to provide self-directed approach for learning. It is imperative that pharmacy educators continue to evaluate this new technology.

CONCLUSION

Our study found that CSL significantly improved knowledge acquisition over didactic lecturing. Both CSL and lecture-based learning shown different strengths in terms of deep processing information skills. Both CSL and didactic lecturing are equally important in training students' deep information processing skills. With the advancement in computer, the curriculum designer should be reminded to continue to assess the effect of new technology in training the pharmacists.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ABBREVIATIONS

CSL: Computer-based Simulation Learning; **DIP:** Deep Information Processing.

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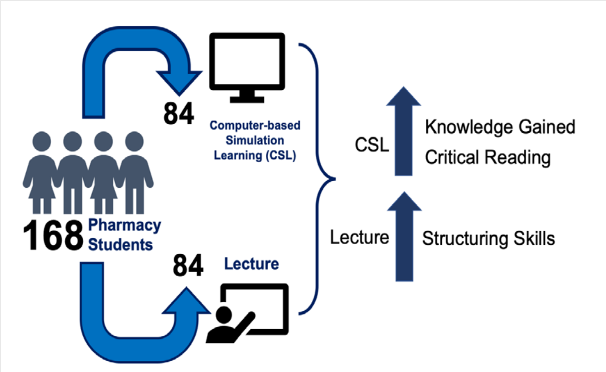
SUMMARY

- Computer Simulated Learning (CSL) improved knowledge gained over conventional lecturing for pharmacy students
- Both CSL and lecturing are equally effective in training pharmacy students' deep information processing skills.
- A better 'structuring' aspect of deep information skills among pharmacy students who were taught using lecture compared to CSL.
- Software features, the learners' individual learning styles and interest in the respective topics should not be neglected in designing an effective CSL tool.
- However, it is equally important to ensure lecturing is not completely replaced by CSL in view of its importance in training deep information processing skills of pharmacy students.

PICTORIAL ABSTRACT



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