Web-Based Simulation Learning Framework to Enhance Students’ Critical Thinking Skills

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Abstract
The purpose of this research is to develop a web-based simulation learning framework that enhances students’ critical thinking based on iterative simulation features social constructivist theory by Honebein (1996), and critical thinking skills. To evaluate the effectiveness of the framework towards enhancing students’ critical thinking skills, several web-based simulations were developed for learning Communication and Networking in Education subject and delivered through an interactive web-based learning environment. A case study involved 21 university students has been conducted to investigate the impact of the simulations on their critical thinking skills and the results showed that the implemented web-based simulation learning framework has positive impact on students’ critical thinking skills.

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Keywords: Web-based simulation, Social Constructivist theory and Critical thinking

1. Introduction

The Internet has played a significant role in the process of teaching and learning in universities, especially in developed countries like the United States, Britain and Europe [1]. There is an increasing growth of web-based learning usage in higher learning institutions with a chance of implementing principles of active pedagogy where students can be self-collaborative [2]. Pastore [3] conducted a survey among the teachers in the United States and found that the Internet can improve the quality of education as an important tool to obtain new information and almost all teachers use the Internet in classes.

Web-based learning resources are essential to maintain competitive learning opportunities in the global education market. On that basis and significance, the university has been working to provide additional materials in the form of web-based learning to students, teachers or lecturers. Learning materials computers (Computer Aided Instruction), known as CAI is suitable for use in teaching and learning process, and this includes a simulation to support active learning [4].

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Web-based learning approach has the advantage in maintaining interest and learning instructions can be presented regardless the learning platform that the students use. A study conducted by Tallent-Runnels et al. [5] stated that the main purpose of online learning is to give students the opportunity to interact with each other. Garrison and Cleveland-Innes [6] added that with the capability of reflection and collaboration techniques, online learning can thus, increased critical thinking. Therefore, the used of web-based instruction in teaching and learning is worth to be explored.

2. Statement of problem

Changing nature of work will directly impact human capital development. Knowledgeable workers (k-workers) are often the employers’ preference to advance their businesses along the economic growth. The impact of global developments in the industry and employment sector reflects the increasing demand not only the employees of qualified academic and having technical skills but also employable employees [7]. Flexible employees, having technical and generic skills such as creative, innovative, and analytical are those that the employer would prefer.

There remained many graduates who do not have the critical thinking skills [8]. Employers will tend to choose potential graduates who are skilful in information technology, innovative and creative. The education system must be able to produce graduates who can meet the market demand. The technique and method of delivery in education at the university level has to be changed, including in the study of computer network and communications. According to Fornaro [9] Telecommunications and Network learning involves the technical factor which is one of the important elements in studying telecommunications. Therefore, students should be exposed to generic skills (soft skills) such as professionalism, values, attitudes, behaviour and ethics, accountability and social concerns, communication skills, information management and lifelong learning, entrepreneurship, and organizational skills including critical thinking and critical methods of teaching and learning. Critical thinking is not only useful for the learning process but it is even more important in daily [10]. Arend [11] stated that problems in critical skills among the students are a common world-wide issue.

The effectiveness of web-based simulation cannot be denied in improving critical thinking skills, where there are many studies conducted by researchers. Therefore, the focus of this study is to see how web-based simulations can influence and enhance the critical thinking among students through supports of existing social sites. Additionally, the study also would like to know the students’ achievement through web-based simulation learning. According to Lefoe [12], constructivism learning through the web is beneficial and it is one of the research branches that require research continuity.

3. Theoretical framework

3.1 Critical thinking

Critical thinking is purposeful, self regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. Critical thinking is a liberating force in education and a powerful resource in one’s personal and civic life [13]. From his study,
he came up with a list of cognitive skills those are at the core of critical thinking: interpretation, analysis, evaluation, inference, explanation, and self regulation.

Critical thinking is a liberating force in education and a powerful resource in one’s personal and civic life [14]. There is more to critical thinking than just the above mentioned six elements of critical thinking but the focus on this study will be, to discuss about the six elements of critical thinking. Good critical thinkers always monitor their own cognitive abilities and at the same time they are maintaining their disposition as a critical thinker.

3.2 Simulation

Simulation through web was first introduced in 1980s by Jack Thorpe and Defense Division, known as Simulator Networking (SIMNET), using a computer system to play a simulation program to train soldiers in military operations. In this system, each computer acts as a simulator that allows users to experience war in a safe and at minimal expenses. Alessi and Trollip [15] categorized four simulations; physical, iterative, procedural, and situational; where iterative allow the learner to run scenarios multiple times, the learner is able to change variables in order to see what happen. Iterative simulation software allows students to engage in real-life situations without a variety of concerns.

According to Erkes et al., [16], based on their experience providing engineering services, the demand for designing and production of web-based was overwhelming and they advised people to think of ways to create web-based learning tool for teaching a large group of students. Fishwick [17] stated that the web will be the future getaway to convey and share information for the sake of knowledge. Rajaei and Barnes [18] also stated that the used of web as a medium of communication will enable the creation of a virtual training environment (Virtual Training Environment (VTE). Web-based simulation can also save a lot of maintaining simulation time compared to maintaining the traditional simulation thus maintaining task can be completed or performed in real time [19].

3.3 Social Constructivist Theory

Koohang and Harman [20] stated that e-learning is the education channel of the other various electronic media and stated that the appropriate instructional design consists of learning theories and principles so that e-learning can be successful. Thus, one of the theories that can be applied to improve the effectiveness of e-learning and critical thinking skills through social interaction over the Internet is the theory being put forward by Honebein [21]. This theory emphasized on seven major steps in providing the experience, understanding, motivation, learning, and indirect means they mix and exchange ideas and knowledge online. According to constructivism experts’, learning is an active process and all knowledge is unique to every individual, whether the knowledge was obtained from teachers and books or through experiences. All learning is closely related to the experience and the experience acquired; no matter how or where the learning takes place [22].

4. The proposed framework for WBS

In this study, a framework of WBS that integrates Alessi and Trollip [15] iterative simulation elements, Social Constructivist Theory [21], and Critical Thinking Elements by Facione [13] was proposed as in Figure 1.
The framework in Figure 1 shows how web-based simulations was developed to continue helping students to improve their critical thinking skills in the Telecommunications and Networking subject. In the following discussions, we will be able to find out how each component or element in the iterative simulations, and the interrelated theoretical thinking critical thinking and social constructivism can improve students’ critical thinking skills.

**Visual, Interpretation and Knowledge**

Visual is the first feature in interactive simulations and the simulation was developed containing a visual connection. When a person views something, visual interpretation of the visual will take place. Students’ visual interpretation can be observed from the knowledge that they developed from the visual. Visuals promote students’ ability to organize and process information. Visuals can also be utilized to challenge students to think on levels that require higher order thinking skills [23]. Form of visual material has been widely used in websites for the purpose of learning [24].

**Response, analysis and experience and appreciation**

Simulations allow interactivity. Thus, students learning with simulations will have to interact by doing activities such as entering variables or giving responses to the simulations. Accordingly, responses from the simulation system will be analyzed by the students, and this type of analysis will provide experiences and therefore students will be learning through experiences. Learning through experiences will initiate the students to relate with their past experiences, and reflect focus on the experience and thus creating new experiences, where the students are now experiencing continuous learning. At the individual level, it was derived from the learners' previous life experiences, engaged the whole person and stimulated reflection on experiences and openness towards new experience and, hence, continuous learning. At the social level
it emphasises critical social action and a stance embodying moral accountability and socio-political responsibility [25].

**Manipulation, realistic and relevant assessment**

Students who used the simulation can manipulate the simulation to obtain the desired results, where while manipulating, students make judgment about the results. The assessment was made realistic and relevant. Recent advances in technology have positioned simulations as a powerful tool for creating more realistic, experiential learning environments and thereby helping organizations meet these emerging training challenges [26].

**Repeatedly, inference and involvement**

The simulation can be used repeatedly, meaning that, students can use it to obtain certain results or any other results being simulated. From the mixed of results, students can create inferences. Indirectly, students will be engaged in using simulations and getting results as well. Yahr [27] reported that his students believed they had learned the materials through simulation as well as in courses that did not include simulation application, while Gosenpud and Washbush [28] found that students exposed to simulation had better test score gains than those who were only exposed to cases and strategic theory. Simulation can also enhance the critical skills when they involved the same students to explore the micro-digital world [29].

**Exploration, description, and various**

Other than the capability for manipulation and repetition simulations allow the students to explain their results obtained from the simulations to their peers and the lecturer with various forms of representation such as using graphics. This is further enhanced by Rose and Meyer [30] who stated that every student bring different needs and skills to the learning task so the learning environment should be designed to both accommodate and make use of these differences. They also identified presentation must be presented in multiple formats and multiple media. Learning environment that utilized the presentation of various technologies such as animation, simulation, or video [31] will provide the opportunity for the students to exchange information and building knowledge.

**Social experiences**

Social experiences only occur when the students log on for the purpose of discussing social or exchanging opinions among the students or students with the lecturers. It was proven by a study conducted by Robinson and Kakela [32] among the environmental students at Michigan State University, where students learned from each other in their comfortable social environment and increased their critical skills in understanding and solving problems. Koory [33] found that some students are more successful when using online materials. Results from interviews showed that the students were more focused, independent, task-oriented and interested in solving problems. Wickersham and Dooly [34] found that the students who studied or discussed in small groups will have levels of critical thinking those are better than the larger groups. Similarly, Chang [35] found that online learning supports and enhances critical thinking.

**Reaction, manipulation and self-discipline**

Simulations can be manipulated to shape students’ reactions or disciplines. Therefore, students will be more alarmed whenever giving responses to their peers while solving problems. This is consistent with the findings of the study by Warren et al. [36] who stated that the level of students’ critical thinking increased when they compared, distinguished and evaluated various views of their colleagues. This allows students to understand more about a subject.
5. Application of web-based simulation: Method of study

The study was conducted in 14 weeks (1 semester) where in the first week students were introduced to Telecommunications and Networking subject through face-to-face meeting. There were 21 students participated in this study. In the second week, the students answered pre-performance test before they used the first simulation which is ‘Basics of Computer Network’. The first simulation was used by the students in the third week. In the fifth week, students used the second simulation and in the seventh week, students were exposed to the third and the following simulations accordingly. During the final week (week thirteen), students used the last simulation and post-achievement test were conducted to investigate students’ achievement when they used simulation and carried out discussion through the social networking site. In the twelfth week, students used the six web-based simulations (simulation 1 to 6) and discussed them through the social networking site, which is the Facebook.

6. Findings and discussions

Developing a system is a complex process, time consuming and requires high cost and it also needs high level of commitment. Since the performance of the system is the main concern of this research, it is necessary to test the effect size and the statistical power of the implemented simulation system to see to what extent the system affects the students' learning. Table 1 displays the results of the paired-sample t-test for pre and post test.

Table 1. Analysis of the mean paired t test for pre and post test

<table>
<thead>
<tr>
<th>No.</th>
<th>Test</th>
<th>Mean</th>
<th>Standard Deviation, SD</th>
<th>p</th>
<th>Effect size, d</th>
<th>Actual power</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Before</td>
<td>17.8571</td>
<td>4.32765</td>
<td>0.00</td>
<td>1.789886</td>
<td>0.9656</td>
</tr>
<tr>
<td>2.</td>
<td>After</td>
<td>30.2381</td>
<td>6.49542</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\alpha=0.05$

The statistical test showed significant results that WBS has an impact on students critical thinking. In the present research, the effect size measures the extent of differences between the mean strength tests before (pre test) and after (post test). According to Cohen [37] effect size equal to or above 0.8 be considered as high which suggests that the statistical power value of 0.9656 was also indicated as high. Power measurements performed by using Gpower, where the sample size used was 21, found that the effect size is 1.789886, while the power is 0.9656. This value is significant at $\alpha = 0.05$ level as shown in Table 1. Based on the analysis performed, the minimum number of samples is 20, while the number of samples in the study were 21 people by that the sample size is sufficient. The analysis clearly shows that the level of student critical thinking increased after using WBS.

The $p$ value in Table 1, shows that there is a significant difference between the mean scores of pre and post test at $\alpha = 0.05$. Based on the findings, this study found a positive impact on students' critical thinking skills upon using the simulation with integration of web-based social networking.

According to Facione [14], the very core of critical thinking elements are: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Therefore, the details of which element of critical thinking was greatly enhanced, paired-sample t-test analysis was carried out as shown in Table 2. The lowest effect size values were at the ‘interpretation’ and ‘analysis’ levels with $d$ value is 0.4485 and 0.3627 respectively. ‘Evaluation’, ‘inference’, ‘explanation’ and ‘self-regulation’ levels (the high level of critical thinking) were beyond the value of 0.8. Therefore, it can be concluded that students’ critical thinking skills improved after using WBS especially at high level.
Table 2. Paired t-test analysis of the respondents according to the elements of critical thinking skills

<table>
<thead>
<tr>
<th>Level</th>
<th>Test</th>
<th>Mean</th>
<th>SD</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interpretation</td>
<td>Pre</td>
<td>4.90</td>
<td>1.30</td>
<td>0.053</td>
<td>0.4485</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>5.71</td>
<td>1.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Analysis</td>
<td>Pre</td>
<td>2.43</td>
<td>1.54</td>
<td>0.111</td>
<td>0.3627</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.19</td>
<td>1.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Evaluation</td>
<td>Pre</td>
<td>3.00</td>
<td>1.30</td>
<td>0.001</td>
<td>0.8481</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4.38</td>
<td>1.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Inference</td>
<td>Pre</td>
<td>3.19</td>
<td>1.47</td>
<td>0.000</td>
<td>1.7089</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>6.90</td>
<td>2.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Explanation</td>
<td>Pre</td>
<td>2.67</td>
<td>1.62</td>
<td>0.000</td>
<td>1.4011</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>6.38</td>
<td>2.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Self-regulation</td>
<td>Pre</td>
<td>1.67</td>
<td>1.53</td>
<td>0.001</td>
<td>0.8234</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.67</td>
<td>2.01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Conclusion

Current model of education is categorized by the freedom to interact and communicate, technology, computer application development, design-based computer application tasks and activities to create a more student-focused critical thinking and constructive knowledge [38]. The main focus of the designed framework is to build up students’ skills and ability of creative thinking, solving problems in the system, decision-making, gathering and disseminating meaningful information at any time and any where through computer simulations as well as for the purpose of sharing information [39, 40]. Therefore the expected framework could be used as a guide in designing teaching materials in e-learning, especially taking into account the advantages of the facilities available in social networking site in combination with the simulation web-based and constructivist learning theory.

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