บทความวิจัย

AN EXPERIMENTAL STUDY OF VCL AND CSCL TO ENHANCE STUDENTS' LEARNING ACHIEVEMENT AND ENGAGEMENT IN CHEMISTRY

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ABSTRACT

Virtual Chemistry Labs (VCLs) are among the emerging technologies being used in education today. Of the various educational uses of this pedagogy, the focus of this research targeted two objectives; first, comparing the students learning achievement using VCL together with computer-supported collaborative learning (CSCL) to that of real labs (RL) and secondly investigating students' learning engagement using VCL together with CSCL. A quantitative research method mixed with a qualitative study was used to measure the students' learning achievement and engagement respectively during chemistry lessons. The results of the post-test indicated that students' learning achievement significantly increased after performing virtual chemistry lab experiments. The average post-test mean score of the experimental group was 34.25 as opposed to pre-test 26.65 before VCL and CSCL were applied to carry out the study. The significance level obtained from comparing post-tests of the two groups was 0.000. This is a statistically significant figure implying that the experimental group had a better performance from the post-tests than the control group. Similarly, observation results also indicated student engagement. In fact, 80% of the time was spent by students actively engaged in VCL activities and collaboratively working together with their peers.

In addition to this research, possible directions for further research in the use of VCL were discussed.

Keywords: Computer Supported Collaborative Learning, Learning achievement, Virtual Chemistry lab, Engagement, Chemistry.

INTRODUCTION

In the 21st century, technology has impacted every single aspect of our lives: what we eat, the way we dress, how we communicate, and how we process information. Learning modalities and teaching tools are obviously no exception to this impact. As educators seek to expand options for teaching and learning in the digital age, many have found it surprisingly challenging to choose the best tools for their students that will both maintain the clarity of classroom objectives and expectations and keep students highly engaged. In this article, the values of using Virtual Chemistry Labs (VCL) together with Computer-Supported Collaborative Learning (CSCL) as tools for enhancing students' learning achievement and engagement in chemistry will be assessed. VCLs are computer-based simulations with tremendous potential for applications in chemistry education. These simulations help chemistry concepts come to life in a hands-on lab environment that is shown on the computer screen, rendering safety concerns and equipment needs obsolete.

The advancement in implementation of VCL as a potential venue for chemistry experiments is not occurring at the speed that some who are already engaged in this endeavor might expect. Like other technology-based educational tools, VCLs have encountered a few obstacles, some of which include a general apprehension to incorporate technology by many educators, lack of support from administrators, little or no investment in high speed internet by schools and the fear expressed many educators that VCLs might replace traditional labs. While the impediments to this technology have been discussed by many, there are various advantages to using VCLs in chemistry education.

Literature Review

1. Virtual Education

Learning in a virtual world environment provides learners with an opportunity to build a community that is unlike any other. In their study, Bronnack, Riedl, &

Tashner, (2006) acknowledged that virtual environments support constructivist learning. Virtual world education provides the learner with several advantages, some of which include: developing constructivist learning, engaging learners in active learning and enhancing learners' interactions.

Developing Constructivist Learning

Constructivists believe that "learning occurs when one constructs both mechanisms for learning and his or her own unique version of the knowledge, colored by background, experiences, and aptitudes" (Roblyer, 2013: 37). Early psychologists in education generally believed that learners could actively learn and could develop new knowledge based on prior knowledge. Research pioneers in education such as Dewey (1916); Piaget (1973); and Vygotsky (1978) all came to this conclusion.

Dewey (1916) explained that situations represent the experiences of the environment affecting the learner and interaction takes place between the learner and his or her environment. From his point of view, it can be reasoned that knowledge is based on active experience. Dewey described a teacher's role as a guide rather than a director since learning necessitates creativity on the part of the learners and allows for learners' interactions amongst themselves and with the teacher. These approaches are more effective than those based solely on preset outcomes. In fact, Dewey (1916) and Piaget (1973) both believed that a teacher's role relies on guiding and shaping the learners' real experiences in the environment.

Practices of constructivism require the ability of the learner to solve real life problems. Problem-solving and discovery seem to go hand in hand. Problem-solving as a process of learning can be difficult. In fact, consequently Vygotsky (1978) generated the idea of the Zone of Proximal Development (ZPD). This idea is the backbone of most of collaborative problem solving strategies. Having reviewed what the early psychologists believed, we can now look at the subsequent research of the American Council of Education (Oblinger & et al., 2001). Girvan & Savage (2010) suggested that the obvious pedagogy for use in a virtual setting like VCL, learners are provided with the flexibility to build learning objects and activities rather than relying on memorization of typical knowledge and skills. This learning setting (VCL) provides the opportunity for learners to explore their own personal cognitive process in order to integrate and construct knowledge in their own way.

Engaging Learners in Active Learning Experiences

Student engagement is a "student's willingness, need, desire and compulsion to participate in, and be successful in, the learning process promoting higher level thinking for enduring understanding" (Martin, 2008). Students who are actively engaged are more motivated to complete tasks successfully, are more focused on the task at hand, ask follow-up questions more often, are willing to try and take risks, and more often take part in rich, content-based discussions with their peers.

The Biosciences Lab at the University of East London has perhaps demonstrated the most remarkable way in which active learning can be incorporated using a virtual environment. In their breakthrough, Cobb, Heaney, Corcoran & Henderson-Begg, (2009) created a Polymerase Chain Reaction (PCR) experiment in a virtual environment. This example shows that if the virtual laboratory is well designed, it can enhance active learning experiences and therefore increase understanding and retention of the concepts.

Figure 1 below is a good example of a learner's level of engagement in the VCL environment. This Figure 'a VCL flame test workbench' is an active learning piece that keeps students engaged throughout the entire experiment. On the top right corner, there is stockroom where students can find the procedures for various experiments, as well as the appropriate chemicals for those experiments. Above the periodic table on the top left corner, there is a guide that students can select if they need help with instructions, chemicals, or using an electronic lab-book.

Figure 1 VCL Flame Test workbench

Enhancing Learners' Interactions

Student interactions in virtual education can be achieved through forming groups where students work together on a particular assignment, research project and experiments. This approach facilitates collaborative learning and in-depth discussion amongst students. Adreas et al. (2010) suggested that collaborative assignments in virtual worlds are a powerful tool of achieving students' interactions. Additionally Burgess & et al. (2010) indicated that real-world collaborations enhance cognitive, social, and teaching presence.

For example, to identify the flame colors in VCL students must work together, identify the appropriate chemicals for the experiment, observe the color changes of flames, and note these observations in the electronic work-book. This must also be accompanied with a logical conclusion. This kind of exercise increases teamwork skills, like understanding each other and respecting each individual's opinion.

It should be noted that there are a number of additional advantages to teaching and learning in a virtual environments that are not mentioned here as the scope of this research is limited. Therefore this research should be regarded as one aspect of pedagogy with wide breadth.

2. Computer Supported Collaborative Learning (CSCL)

The concept of collaborative learning has been widely researched and is generally accepted as beneficial for critical thinking, student satisfaction, learning enhancement and performance (Gokhale, 1995). Collaborative learning involves social (interpersonal) process by which a small group of learners work together on problem-solving task (Dillenbourg, 2008).

Computers have become important tools in this century, with governments of different countries setting goals of increasing student access to computers and the Internet. The idea of encouraging students to learn together in small groups has also become increasingly emphasized in the broader learning sciences. However, the ability to combine these two ideas (computer support and collaborative learning, or technology and education) to effectively enhance learning remains a challenge.

3. Advantages and Challenges of CSCL

Technology offers the kind of potentials for learning which are very different from those available in other contexts. Research has revealed a variety of the promises and reported benefits of computer use for collaboration;

One self-evident benefit is that the use of computer breaks down the physical and temporal barriers of schooling by removing time and space constraints.

Making thoughts visible by writing should help students to reflect on their own and others' ideas and share their expertise.

Sharing space and interaction can offer multiple perspectives and zones of proximal development (ZPD) for students with varying knowledge and competencies. There are also other various advantages of CSCL revealed in Stahl & Hesse (2013) research.

Research Objectives

The current analysis of previous research in this area has shown that the studies indicate mostly compelling and positive feedback about virtual world pedagogy from both learners and educators. However, little has been done on combining CSCL with this pedagogy to measure students 'achievement and engagement, particularly in the use of VCL. For this reason, the current study aimed at measuring the students' learning achievement and engagement in a chemistry class. VCL together with CSCL as tools to increase student leaning achievement and engagement in chemistry were used. The following research questions were investigated:

1. To compare the students' learning achievement using VCL together with CSCL to Real Labs (RL).

2. To investigate the students' engagement using VCL together with CSCL.

Conceptual frame work of the study

Figure 2 is a conceptualized framework, which gave the researcher guidance during the research. Virtual Chemistry labs together with Computer Supported Collaborative Learning, were implemented to enhance students' learning achievement as well as engagement. Combining these two allowed the researcher to explore exciting new opportunities.

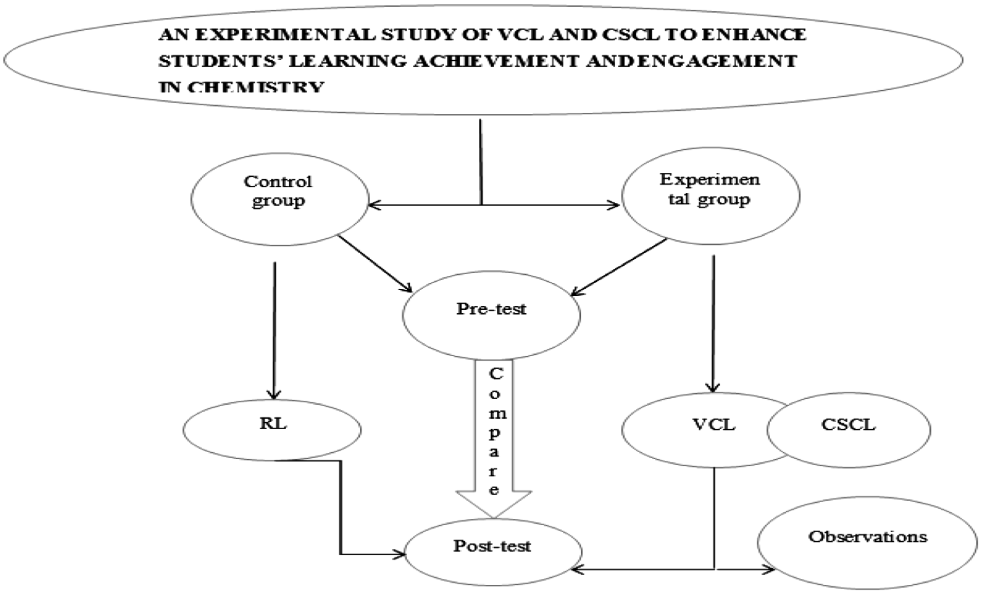


Figure 2 Conceptual Framework Source: Nouredine, 2018

RESEARCH METHODOLOGY

1. Research Instruments

A quantitative research mixed with a qualitative study was used by the researcher. Qualitative data was collected through pretests and post-tests whereas qualitative data was obtained from the classroom observations consequently answering research problems of this study which were to; compare the students' learning achievement using VCL together with CSCL to Real Labs (RL) and investigate the students' learning engagement using VCL together with CSCL respectively.

1.1 Pretest and posttest

The research involved a quantitative research method mixed with a qualitative method to collect data. Pre-tests, post-tests and observations were used for data collection purposes. It was expected that these two methods would provide varying insights into the student learning achievement and engagement from the perspective of the researcher. Forty multiple choice questions about the periodic table were prepared for the pre-test and these were given to students prior to the research. Similarly, the same questions with the same level of difficulty but interchanged and arranged differently were given in the post-test at the end of this research. The results from pre-test and post-test of both groups were assessed and then compared by the researcher.

1.2 Observations

Observations were used to collect information from the experimental group on how the use of VCL together with CSCL engaged the participants.

Unobtrusive observation. The researcher simply recorded how the different participants were behaving and interacting during experiment.

To avoid bias during observations, the researcher used a double-entry notebook. This type of observation log helped the researcher to separate the observations (the facts) from feelings and judgments about the facts.

Descriptions of student behaviors, and interactions from the double-entry notebook and overall conclusion about classroom events were written by the observer.

1.3 Lesson plans

Eight lesson plans based on Computer Supported Collaborative Learning (CSCL) theory were used to teach the experimental group. The experimental group is the group who worked with computer simulations in a collaborative manner and CSCL lesson plans were used for this group only. The control group was taught in the traditional way. Both groups were taught twice a week for four weeks. Regular lesson plans were used to teach the control group. Each lesson lasted for about 50 minutes.

1.4 Participants

The participants involved in this study were all grade 10 students of two classes in a Private Bilingual School in Pathumthani Thailand as seen in Table 1 below.

Table 1 Demographic information of the subject

		Experimental Group	Control Group
Gender	Male	12(60%)	11(55%)
	Female	8(40%)	9(45%)
	Total	20(100%)	20(100%)
Age Range	15-16	20(100%)	20(100%)
	Total	20(100%)	20(100%)

2. Data Collection Procedures

2.1 Approval and Ethics Concern

Because participants in this research were below 18 years, a consent letter was given both to the participants and their parents to sign. Similarly, the names of the participants were not revealed throughout the study.

2.2 Data Analysis

2.2.1 Test Scores Results

The scores from the pretest and posttest were calculated for the mean and standard deviation. A comparative statistical analysis using paired sample t-test was done within the group i.e. analysis of pretest and posttest of experimental group as well as control group. The comparison between pretests and posttests scores of the two groups was done by conducting independent t-test. The value of 2-tailed significance value (P) was referred to determine the significance difference between the means.

Table 2 Pretest and Posttest Comparison of the control group

Group	Test	Mean	Mean Difference	Standard Deviation	Sig (2-tailed)
Control	Pre-test	25.70	25.75-25.70 = 0.05	7.51210	0.982
	Post-test	25.75		6.64019	

Significance level (p): 0.982-Significant > more than 0.05

Table 3 Comparison of Pre-test and Post-test of the Experimental group.

Group	Test	Mean	Mean Difference	Standard Deviation	Sig (2-tailed)
Experimental	Pre-test	26.65	34.25-26.65 = 7.6	7.85577	0.001
	Post-test	34.25		5.57131	

Significance level (p) :0.001-Significant < less than 0.05

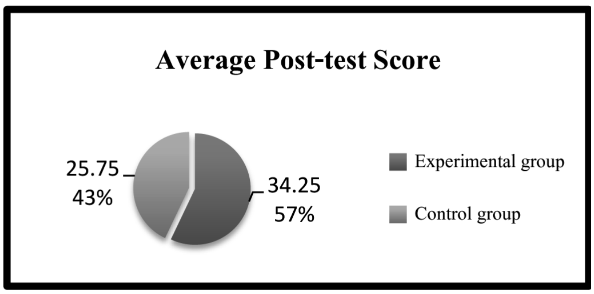
Table 4 Comparison of Pretests between the Control and Experimental groups.

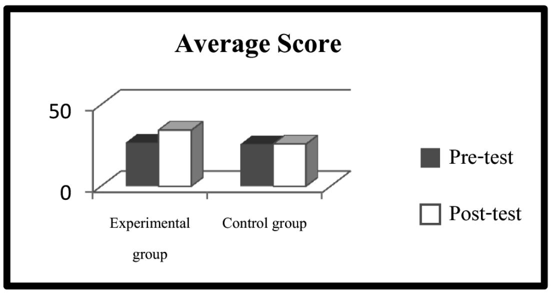
Group	Test	Mean	Mean Difference	Standard Deviation	Sig (2-tailed)
Control	Pre-test	25.70	26.65-25.70 = 0.95	7.51210	0.698
Experimental	Pre-test	26.65		7.85577	

Significance level (p): 0.698-Significant > more than 0.05

Table 5 Comparison of Posttests between the Control group Experimental groups.

Group	Test	Mean	Mean Difference	Standard Deviation	Sig (2-tailed)
Control	Post-test	25.75	34.25-25.75 = 8.5	6.64019	0.000
Experimental	Post-test	34.25		5.57131	





Significance level (p): 0.000-Significant < less than 0.05

Figure 3 The average post-test score

Figure 4 The average test score of both groups

2.2.2 Analysis of test score Results

The first objective was to compare the students learning achievement in VCL together with CSCL to that of RL. Pretest and posttest were administered to both the experimental and control groups to determine the differences in their learning achievement.

A comparative statistical analysis using paired sample t-test was done within the group. The mean of the pretest and posttest of the experimental group were 26.65 and 34.25 respectively as shown in Table 3. The mean of pretest and posttest of the control group were 25.70 and 25.75 respectively as shown in table 2. The mean difference of experimental group was 7.6 while the mean difference of control group was 0.05. Results from the experimental group in Table 3 show a significance level of 0.001, a value less than 0.05; this indicated that there was statistically significant increase in the scores of posttest than that of pretest in the experimental group. However a significance value was 0.982 which was more than 0.05 for the control group in Table 2. This indicated that the mean difference in pretest and posttest was not statistically significant thus a significantly low improvement in their test score.

2.2.3 Student Observation Results

The researcher constructed a coding system to describe students' on-task and off-task behavior. DeMunck and Sobo (1998) implied that it is important for researchers to construct a coding system that is a true structure of the process they are studying. During research period, the researcher made notes while observing students' on/off-task behavior. Despite the fact that they were working in groups, the researcher observed each students' individual on-task/off-task behavior.

Observation results revealed that students were actively engaged as well as passively engaged. At the beginning of the lesson students listened to the teacher's instruction and throughout the research they interacted with their peers, they planned and discussed the learning material and activities together. They worked on the VCL experiments together. The researcher also observed that students listened to their peers and valued their opinions they planned and executed the tasks given to them together. The researcher paid more attention to whether the students were interacting and sharing ideas about the task given but no other unrelated material on the computer.

Table 6 below summarizes the students who were off-task.

Student	Non-engagement behavior			
A	TA	TS	LA	
B	TS	TA		
C	LA	TA	LA	LA
D	LA	LA	MN	MN
E	TT	TS		
J	LA	TA	MN	
K	TA	TT	TA	
L	TT	MN		
S	TT	TS		
T	TS	TT		

KEY

TA: Turning his body away/ head down fidgeting in seat

TS: Touching another student

LA: Looking around room/ turning away

MN: Making noise quietly/loudly

TT: Talking at inappropriate times

Student C and student D showed off-task behavior four times. This was the most frequent from the group. Both of them looked around and turned away from the computer at least two times, Student C turned his body away and fidgeted in his seat while student D made noise two times. Other non-engagement behavior from other students included talking at times they were not supposed to talk, and touching each other. Five students were off-task only two times and three students were off-task three times. On the other hand, 10 students were not involved in any kind of non-engagement behavior.

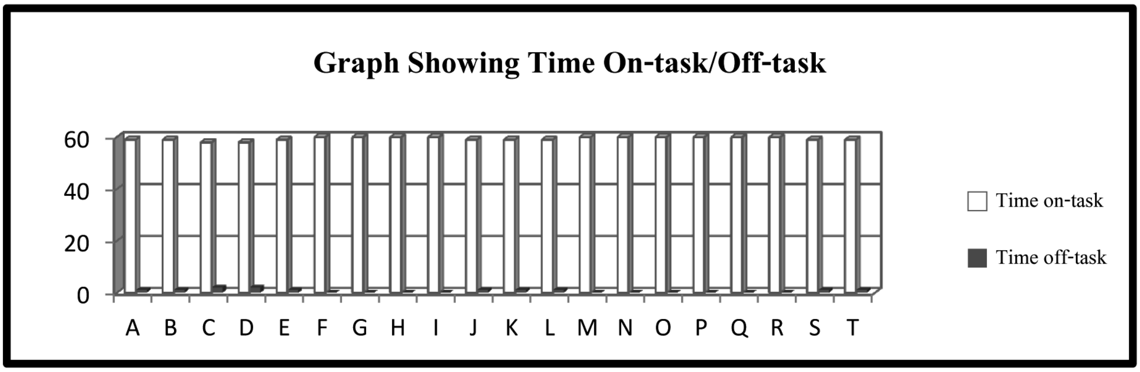


Figure 5 Time in Minutes Each Student was On-task or Off-task.

The graph above shows the total time the students were on-task or off-task during VCL experiments. It can be noticed that students mostly were on-task. Only two students were off-task for two minutes and eight students for one minute. A total of 10 students were 100% on task they didn't show any off-task behavior.

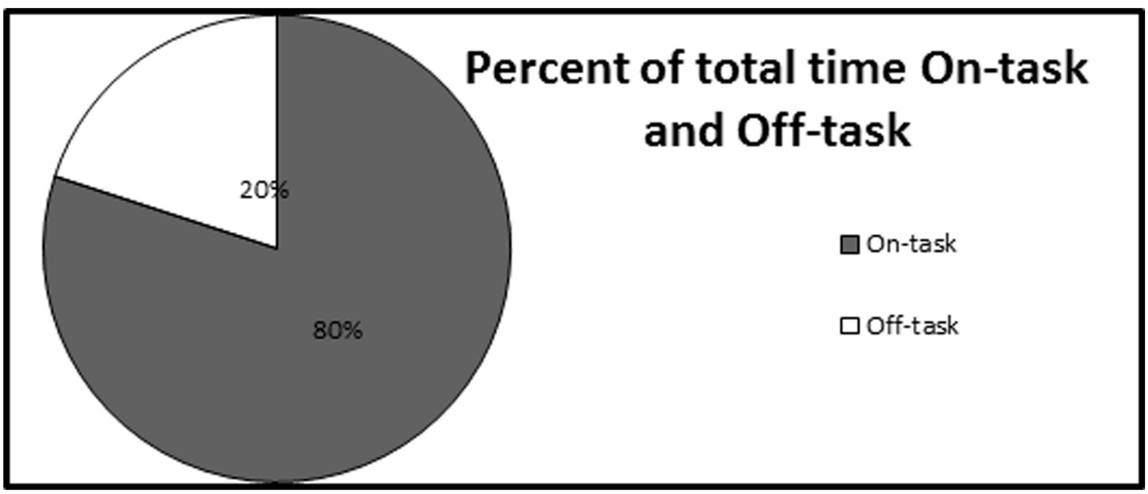


Figure 6 shows the percentage summary of the total time that was spent on-task and off-task during the VCL experiments.

From the graph above it can be noticed that 20% of the time was spent on off-task behavior and 80% of the time was spent on-task meaning that VCL experiments and working together in groups kept the students engaged.

2.2.4 Analysis of Student Observations

The second objective of the study was to investigate whether student learning using VCL together with CSCL were engaged. Based on the observation results that revealed remarkable student engagement, it can be concluded that students that learned in VCL together with CSCL were actively engaged and thus the results strongly supported the second hypothesis of this research.

DISCUSSION AND CONCLUSION

The study revealed two findings. Firstly, it was found that learning using VCL together with CSCL improved the students 'learning achievement and secondly, that these students were engaged. On the other hand, there was no significant improvement in the students' learning achievement using RL.

1. Learning Achievement Test

No students were below average on the tests from both groups. It can be argued that students from both groups were at the same level at the start of this research because their pretest mean score was almost identical 25.70 and 26.65 for control and experimental respectively. However the significant increase in mean average score of 34.25 for the experimental group showed that teaching students in VCL together with CSCL improved their learning achievement. These findings were parallel to the studies carried out by; (Feisel & Rosa, 2005), which showed the effectiveness of the virtual lab in developing the academic achievement of the female students of 2nd secondary grade, in chemistry. (Slater & Usoh, 1993), their project aimed at using virtual labs as a learning environment to support the learning process in the academic achievement of science course intermediate school. The study revealed that using virtual labs encouraged students to modify the wrong concepts and ultimately improved their learning achievement

2. Students Observations

Observations results revealed that students were actively engaged during this study. Table 6 summarizes the students' non-engagement behavior. Ten students were involved in non-engagement behavior as reflected in Table 6. For example, two students looked around for at least two minutes during the experiment.

One student made noise two times while another one turned his body and moved out of his seat two times. These were some of the non-engagement behaviors that the students were involved in. It should be noted however that 10 students were not involved in any sort of off-task or non-engagement behavior. Figure 6 shows that 20% of time was spent on off-task behavior and 80% of the time was spent on-task which can be concluded that VCL experiments and working together in groups kept the students engaged. These findings were in line with the studies carried out by; (Palincsar & Brown, 1984), learning by design; this research showed that CSCL emphasized deep engagement with the learning materials as well as collaboration. Hwang, Chen, Shadiev, Huang, and Chen (2014) found that the students in the technology-supported situational learning group wrote more sentences, interacted more, engaged more and developed better writing skills.

These findings are parallel with early scholars in education. For example, in John Dewey's experiential learning theory; he mentions that everything occurs within a social environment. Knowledge is socially constructed and based on experiences. This knowledge should be organized in real-life experiences that provide a context for the information. VCLs are a perfect example of real-life experiences. Take Hudson & Degast-Kennedy (2009) research for example; they demonstrated student engagement in their experiment which involved the creation of a Canadian border simulation. The results of this impressive creation indicated that the students gained real life experience where a real scenario would not be possible, and also developed key interview skills. Their post-class interviews revealed that students were highly engaged and satisfaction in the learning experience was achieved. More importantly, those who actively participated achieved a remarkably high exam grades than those who did not.

3. Recommendations

This study revealed that the use of VCL together with CSCL improved the students' learning achievement and also kept the students engaged in learning the periodic table during a chemistry lesson therefore it can be recommended that the use of this pedagogy should be encouraged in the teaching and learning of chemistry other science related subjects.

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