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Virtual Science Laboratory (ViSLab): A Pilot Study on Signaling Principles towards Science Laboratory Safety Training

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Abstract

The purpose of this study is to investigate the effect of Virtual Science Laboratory (ViSLab) on signaling principles towards science laboratory safety training. It is because students' laboratory practices and attitudes were lacking when traditional approaches to safety training seem like ineffective. Therefore, the design and develop of VR tools with signaling representation in 3D and constructivist learning environment would increase the potential of the way people acquire new knowledge by physical manipulation of objects and concepts, which in turn, allows the learner to physically see causal relationships between action and result. The lesson of the science laboratory safety is developed in two different modes, Virtual Reality with Signaling (VRS) and Virtual Reality Non Signaling (VRNS). A 2×2 quasi experimental factorial design is adopted in this research. The independent variables were the two modes of courseware. The moderator variable is the spatial ability. The dependant variable is the post test score. The study sample consisted of 31 students. Analyses of covariance (ANCOVA) were carried out to examine the main effects as well as the interaction effects of the independent variables on the dependent variable. The pre-test scores are used as the covariate variable. The findings of this study showed that the use of Virtual Reality with Signaling (VRS) treatment mode helped pupils perform significantly better than Virtual Reality Non Signaling (VRNS) in learning science laboratory safety. Overall, Virtual Reality with Signaling (VRS) needs to be considered in the design and development of Virtual Science Laboratory (ViSLab) to promote more effective learning.

Keyword: Virtual Reality, Science Laboratory Safety; Signaling Principles.

1. Background of Study

Malaysia has make an effort to strongly push for full economic and industrial development has framed the Occupational Safety and Health Master Plan for Malaysia 2015 (OSH-MP15) to establish a safe, healthy and productive pool of human capital towards a sustainably safe and healthy work culture in all places. Schools must be regarded not only as a place to study but also as a workplace. In the case of schools, the working people are students, teachers, administrative and other support staff. It is required to begin OSH culture with the young generation in any country. Unfortunately, students' laboratory practices and attitudes were lacking when traditional approaches to safety training were followed; these traditional methods include: introductory presentations to laboratory safety rules on the first week of lesson or presentations by instructors of experiment specific safety concerns, and brief safety quizzes based on as-signed reading (Alaimo et al., 2010). It is because there were reports of

accidents in schools, involving teachers, students and staff arising from ceiling fans in classroom, collapse of building structures, goal posts as well as accidents in school laboratories and school toilets over the years.

What are schools doing to ensure a safe environment for students? It is increasingly important for educators to properly maintain equipment, provide instruction in safety, and adequately supervise students engaged in laboratory activities (Connors, 1981). Safety and health considerations are arguably as important as the content taught in the school science laboratory, it is because we could not predict where and when accident will happen. Therefore, both technical skills and safety knowledge of all students must always be considered to avoid accidents (Schofield, 2000).

Safety is a critical component of any workplace. Science laboratory has earned a reputation of being highly hazardous place in the institution because of the high incidence and fatality rates (Zulhisyam et al., 2011). Schools are held responsible for taking all the necessary safety precautions to maintain a safe learning and working environment in the laboratory. This is because laboratory dealt with numerous chemicals, electrical, mechanical, procedures and operations that required safety precaution, laboratory safety, fire safety and other safety related issues. There are many science activities that present potential hazards in science laboratory, for that reason realistic and prudent safety practices are greatly reduced the likelihood of accidents (Bruton, 1999). Moreover, knowing about possible hazards, taking precautions are the bases for creating a safe learning environment. Table I shows the common hazard in science laboratory.

Table 1 Common Science Laboratory Hazard (Zulhisyam et al., 2011).

Hazard	**Sources**
Physical hazard	Heating device, noise, projectiles, fire, cold, etc
Electrical hazard	Fire and electrical shock
Mechanical hazard	Moving Machineries
Airborne hazardous materials	Vapors, dust, etc
Ergonomic factors	Standing, repetitive motion

Safety is always the prime concern in conducting practical work and investigations in science. In order to maintain a high standard of laboratory safety, students should bear in mind that knowing and following safe practices is a part of learning in science. To promote students' awareness of laboratory safety, schools should deliver lessons on laboratory safety, particularly at the beginning of each school year, to remind students the importance of laboratory safety, and the general safety practice and precautions in the laboratory. Well entrenched safety awareness and practice will keep the number of laboratory accidents to a minimum. Therefore, students must practice safety culture in school, especially in science laboratory.

It is well known that people keep in mind things that they experience first-hand much longer and more clearly than things that they simply read or hear because an experience worth a thousand words (Dale, 1969; Kolb, 1984). Therefore, student who has ever experienced accident in science laboratory will remember that experience much longer than those who never experience before. Messner et al (2003) point out experience and experimenting with the process is very important but it is difficult to provide this opportunity to the students in an

educational setting. Students can experience virtual accidents through the use of VR if authority cannot involve students in actual accidents just to call attention to the importance of safety (Aukstakalnis, Steve & David, 1992; Emerson, Toni & Debra, 1992; Larijani, 1994; Pimental, Ken & Kelvin, 1995; Stampe et al., 1993; Youngblut, 1998). These virtual accidents will not have the same impact as real accidents, but the ability to work practical and view objects from multiple viewpoints using VR can potentially deepen learning and recall for a student because the student is experiencing the construction of new knowledge (Salzman et al., 1999; Dede et al., 1999; Barab, Barnett & Squire, 2001).

In Malaysia, many research study about safety in laboratory, for example, Zulhisyam et al. (2011), Bahram et al. (2013) and Anuar et al. (2008). Unfortunately, learning of science laboratory safety in Virtual Reality (VR) environment is still very least in Malaysia even though VR is started using in education since last century. There is a gap in the previous researches because not enough information exists to make an effective decision about the inclusion of VR tools with signaling representation in constructivist learning environment to make a difference in the learning of science laboratory safety. Some studies did slightly attend to the matter but did not contain enough statistical data, feedback, or other evaluative data to provide the crucial piece of information of how virtual reality environment could increase the understanding of science laboratory safety. Therefore, the design and develop of VR tools with signaling representation in constructivist learning environment would increase the potential of the way people acquire new knowledge by physical manipulation of objects and concepts, which in turn, allows the learner to physically see causal relationships between action and result (Shelton & Hedley, 2004).

Virtual Science Laboratory (ViSLab)

In this study, the researcher will design and develop a Virtual Science Laboratory (ViSLab) to create a virtual environment for teaching science laboratory safety through customize simulations of science laboratory layouts, dynamic process operations and comprehensive virtual environments and allow users to move within the Virtual Science Laboratory (ViSLab), making operational decisions and investigating processes take a quick look. The consequences of correct and incorrect decisions are sent instantaneously back to the trainees, giving them the opportunity to directly learn from their mistakes. ViSLab provides the advantage of a 3D interface with near real-world representation for applying learning-by-doing and case-based reasoning approaches. The content covered in the ViSLab include chemical and biological hazards, electrical, fire control, flaming, cut, handling glassware, personal protective equipment and physical safety. The objective of ViSLab is to combine safety content with programming to create an interactive, cognitive engagement and multimedia learning. It is believed that these three factors can influence learning via visualization in line with principles associated with mental model.

VR can best be described as “a way for humans to visualize and interact with the artificial 3D environments created using computer graphics” (Aukstakalnis & Blatner, 1992). Interactive 3D visualization is significant and unique features of VR because a properly designed virtual experience can significantly improve and simplify several learning tasks. VR systems are real-time computer simulations of the real world in which visual realism, object behavior and user interaction are essential elements (Denby & Schofield, 1999; Filigenzi et al, 2000; Schofield et al, 1994). Besides that, interactivity in a virtual world allows the user to affect change in that world (Sherman & Craig, 2003; Salzman et al., 1999).VR also provide an interface that allows certain level of autonomy and virtual feeling of reality for the manipulation of 3D objects in Virtual Science Laboratory (ViSLab).

VR especially when used for drill and practice as a tool for teaching allows students to take control of the rate of learning and helps them to avoid embarrassment by allowing them to learn and make mistakes in a non-public manner (Koedinger et al., 1997). Moreover, VR provides feedback at once which leads to reductions in learning time. This is very likely to be main aspects in making students feel more confident on top of leading to better attitudes towards learning. Such feedback reduces student displeasure and provides a sense of achievement (Koedinger et al., 1997). The feedback and self-pacing aspect of VR is not only beneficial to students, whereas, teachers also benefit from the VR program. This frees them up to provide more individualized facilitate to students with particular needs (Koedinger et al., 1997), which in turn benefits students with special needs and who are at risk.

Research Purpose and Hypothesis

The aims of this study are to determine the effects of using virtual reality (VR) in learning science laboratory safety among students in school. The objective is to compare the effectiveness of using VR-based test between the two learning modes (Signaling and non-Signaling) in learning laboratory safety.

This study attempts to answer the following research questions:
Is there a difference in posttest mean score (as measured by the posttest minus the pretest) for the VR-based test between the two learning modes (Signaling and non-Signaling)?

Theoretical Framework

This study is designed based on the following theories and models, namely: (a) The Cognitive Affective Theory of Learning with Multimedia (Moreno & Mayer, 2007); (b) Sweller's Cognitive Load Theory; (c) Cognitive Theory of Multimedia Learning (Mayer, 2001); and (d) Constructivist Learning Environments (Jonassen,1999) ;.These theories form the theoretical framework of this study. The learning materials will be constructed in accordance to Alessi and Trollip's instructional design and development model (2001). Figure 1 showed the theoretical framework of this study.

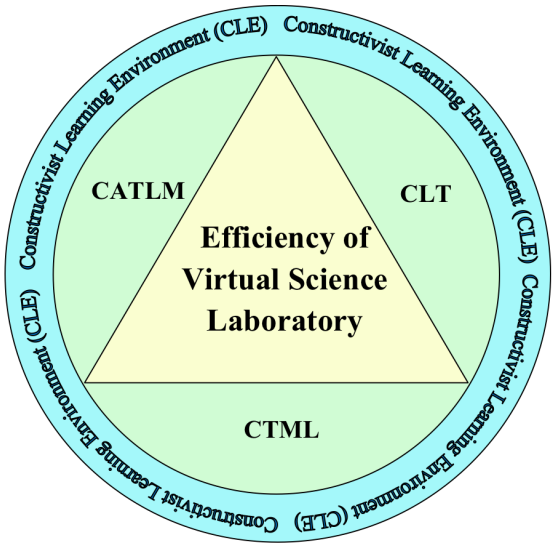

Figure 1 Theoretical Framework

2. Research Methodology

2.1 Population and Sample of Study

There were 31 samples involved in this pilot study. The respondents had been taught laboratory safety concept and possessed a fundamental knowledge of laboratory safety. The two programs were saved on computer and then the two treatments were given numbers (VRS treatment - no.1, VRNS treatment - no.2). All the subjects were randomly assigned to one of the two modes of courseware (VRS and VRNS). Figure 2 showed screen fire happen in the ViSLab.

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*2.2 **Variables***

The independent variables were the multimedia instruction employed to teach Science Laboratory Safety. The two instruction methods employed were the VR with signaling (VRS) and VR with non-signaling (VRNS). The dependent variables were the students' achievement score, Mental Effort Rating Scale and motivation score. The moderator variables were Spatial Ability. Students scoring above the group mean in the Space Relation Test were classified as the High Spatial Ability (HSA) students and while those scoring below the group mean in the Spatial Ability Test were classified as the Low Spatial Ability (LSA) students.

2.3 Research Instruments

The Pretest and posttest questions consisted of 30 objective questions constructed. Both the pretest and the posttest were conduct using online which consisted of 30 objective questions based on the learning outcomes for the Science laboratory safety. The tests were administered to all the subjects involved in this study. The time allocation for the pretest and posttest is given 30 minutes. In this study, the pretest and posttest were achievement tests to measure the criterion variable of students' performance which includes their acquisition/test score, the number of problems solved and the mean errors. The two sets of tests were identical except for the order of the questions. The pretest and the posttest were administered before and after the treatment respectively.

3. Result

Descriptive and inferential statistics were conducted to analyze the collected data. Analyses of covariance (ANCOVA) were carried out to examine the main effects as well as the

interaction effects of the independent variables on the dependent variable. The pre test scores are used as the covariate variable. The level of significance α=0.05 was used in this study.

Table 2 ANOVA of Pretest Scores of Students

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	194.097	1	194.097	10.207	.003
Within Groups	551.467	29	19.016		
Total	745.564	30			

Table 2 showed ANOVA of Pretest Scores of students. A pre-test was administered before the beginning of the study. An ANOVA was used to determine if there were significant differences in students' pre-test mean scores between VRS and VRNS groups at a 0.05 significance level. The values F(1,29) = 10.207, Mean Square = 194.097, and p = 0.003 showed that there were no significant difference in the pre-test scores between VRS and VRNS groups. This implies that students across the two groups were equivalent in their prior knowledge of science laboratory safety.

ANCOVA of Post Scores of Students in Various VR Groups

In order to reduce the error and increase the statistic ability, the pre-test scores as the covariate variable, a comparison was made among the two groups (VRS and VRNS) again using the ANCOVA procedure (Table 3).

DependentVariable:POSTTEST

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	347.798[a]	2	173.899	6.901	.004
Intercept	362.575	1	362.575	14.389	.001
PRETEST	208.781	1	208.781	8.285	.008
VR	306.697	1	306.697	12.171	.002
Error	705.557	28	25.198		
Total	217778.000	31			
Corrected Total	1053.355	30			

a. R Squared = .330 (Adjusted R Squared = .282)

Table 3 indicated the results of ANCOVA test of statistical significance on the differences observed in the mean scores of the post-test for the various treatment groups with $F(1,28)=12.171$, Mean Square=306.697, and p=0.002. Therefore, these differences in the Posttest scores were significant.

4. Discussion

This study revealed that students using the Virtual Reality with Signaling (VRS) attained significantly higher Posttest score than students using the Virtual Reality Non Signaling (VRNS) in learning of science laboratory safety. It was supported by Chen (2005) and Awaatif & Wan Ahmad Jaafar (2015), they found that students who were using VR with signaling are significantly better than students who were using VR without signaling. According to Mayer (2009) cognitive theory of multimedia learning, signaling is another technique for reducing extraneous processing because it provides cues to the learner about what to attend to and how to organize it. On the other hand, signaling also can help learner to solve the problems when the lessons having too much extraneous material by draw learners' attention towards the essential material. The significantly positive effect of Virtual Reality with Signaling (VRS) on students' achievement might because of signaling can help guide what the leaner pays attention to (the process of selecting) and can help the learners to mentally organize the key material (the process of organizing). Without guidance on how to carry out appropriate cognitive processing, the learner is more likely to engage in extraneous cognitive processing such as processing extraneous material and trying to organize it with the rest of the material. According to Mohamed et al. (2012), signaling principles also can help to reduce the cognitive load and relieve the students in mastering the learning process. Therefore, students using of Virtual Reality with Signaling (VRS) could understand the concept of science laboratory safety easily.

5. Conclusion

This study found that the use of Virtual Reality with Signaling (VRS) treatment mode helped pupils performed significantly better than Virtual Reality Non Signaling (VRNS) in learning of science laboratory safety. The superiority of the Virtual Reality with Signaling (VRS) could be due to signaling principles provides cues to learner and helping to reduce learner's cognitive load. In short, the study strongly indicated that Virtual Reality with Signaling (VRS) was effective in learning of science laboratory safety. It was suggested that Virtual Reality with Signaling (VRS) should be integrated into all courseware on the learning of science laboratory safety.

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