THE EFFECTS OF VISUAL SIGNALLING PRINCIPLE IN A DESKTOP VIRTUAL REALITY BASED LEARNING ENVIRONMENT ON STUDENTS' PERFORMANCE, COGNITIVE LOAD AND PERCEIVED MOTIVATION

WONG AI CHIN

UNIVERSITI SAINS MALAYSIA
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by

WONG AI CHIN

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LIST OF ABBREVIATIONS

VR	Virtual Reality
VRS	Virtual Reality with Signalling
VRNS	Virtual Reality with non-Signalling
ViSLab	Virtual Science Laboratory
SLST	Science Laboratory Safety Test
IMMS	Instructional Materials Motivation Scale
SAT	Spatial Ability Test
LSA	Low Spatial Ability
HSA	High Spatial Ability
CLT	Cognitive Load Theory
ARCS	Attention, Relevance, Confidence and Satisfaction
OSH-MP15	Occupational Safety and Health Master Plan for Malaysia 2015
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
3D	Three Dimension
VRML	Virtual Reality Modelling Language
CATLM	Cognitive Affective Theory of Learning with Multimedia
CTML	Cognitive Theory of Multimedia Learning
CLT	Cognitive Load Test

KEBERKESANAN PRINSIP ISYARAT VISUAL DI PERSEKITARAN PEMBELAJARAN REALITI MAYA DESKTOP TERHADAP PENCAPAIAN PELAJAR, BEBAN KOGNITIF DAN PERSEPSI MOTIVASI

ABSTRAK

Penyelidikan ini bertujuan untuk mengkaji keberkesanan pembelajaran konsep keselamatan makmal sains dengan prinsip isyarat visual di dalam persekitaran realiti maya terhadap pencapaian pelajar, beban kognitif dan persepsi motivasi di kalangan pelajar yang mempunyai tahap hubungan ruang yang berbeza. Suatu reka bentuk eksperimen kuasi dengan faktorial 2×2 telah diaplikasikan dalam penyelidikan ini. Pembolehubah bebas dalam pembelajaran konsep keselamatan makmal sains terdiri daripada dua mod koswer, iaitu persembahan realiti maya dengan prinsip isyarat visual (VRS) dan persembahan realiti maya tanpa prinsip isyarat visual (VRNS). Pembolehubah moderator adalah tahap keupayaan ruangan pelajar. Pembolehubah bersandar adalah pencapaian pelajar, beban kognitif dan motivasi. Sampel penyelidikan ini terdiri daripada 141 orang pelajar yang dipilih daripada tiga sekolah. Setiap pelajar ditempatkan secara rawak kepada salah satu daripada dua mod persembahan. Statistik deskriptif dan inferens digunakan untuk menganalisiskan data yang terkumpul. ANOVA digunakan untuk menentukan perbezaan signifikan di antara pencapaian pelajar, beban kognitif dan motivasi serta kesan interaksi yang disebabkan oleh pembolehubah bebas terhadap pembolehubah bersandar. Dapatan kajian ini menunjukkan pelajar yang menerima mod VRS menunjukkan pencapaian yang lebih baik secara signifikan berbanding dengan mod VRNS. Selain itu, Prinsip isyarat visual juga dapat mengurangkan beban kognitif

intrinsic dan beban kognitif *extraneous* dan dapat meningkatkan motivasi pelajar semasa menggunakan koswer *ViSLab.* Pelajar bertahap keupayaan ruangan rendah menunjukkan pencapaian yang lebih baik, memperolehi beban kognitif *intrinsic* dan beban kognitif *extraneous* yang lebih rendah, dan menunjukkan motivasi yang yang lebih tinggi berbanding dengan pelajar bertahap keupayaan ruangan tinggi dalam mod VRS. Sebaliknya, pelajar bertahap keupayaan ruangan tinggi menunjukkan pencapaian yang baik, beban kognitif yang rendah serta motivasi yang tinggi semasa menggunakan mod VRNS. Secara kesimpulan, VRS patut dipertimbangkan terhadap pelajar yang bertahap keupayaan ruangan rendah dalam reka bentuk dan pembangunan bahan pembelajaran terutamanya daripada pandangan beban kognitif supaya dapat mengurangkan masa latihan dan mengurangkan daya mental supaya mewujudkan pembelajaran konsep keselamatan makmal sains yang lebih berkesan. Sebaliknya, VRS tidak harus digunakan secara berlebihan terhadap pelajar yang bertahap keupayaan ruangan tinggi, supaya pembelajaran serta perhatian mereka tidak diganggu.

THE EFFECTS OF VISUAL SIGNALLING PRINCIPLE IN A DESKTOP VIRTUAL REALITY BASED LEARNING ENVIRONMENT ON STUDENTS' PERFORMANCE, COGNITIVE LOAD AND PERCEIVED MOTIVATION

ABSTRACT

The purpose of this study was to investigate the effect of learning science laboratory safety using visual signalling principle in a virtual reality environment on students' performance, cognitive load and perceived motivation among students with different spatial ability. A 2×2 quasi experimental factorial design was adopted in this research. The independent variables used in the learning of science laboratory safety were the two modes of courseware which is virtual reality with signalling (VRS) and virtual reality with non-signalling (VRNS). The moderator variable was the spatial ability. The dependant variables were the students' performance, cognitive load and perceived motivation. The study sample consisted of 141 students from three schools. All the subjects were randomly assigned to any one of the two modes of courseware. Descriptive and inferential statistics were used to analyze the collected data. ANOVA was used to determine the significant differences of the students' performance, cognitive load and perceived motivation between the two groups, as well as the interaction effects of the independent variables on the dependent variable. The findings of this study showed that the use VRS has shown better effects when compared to VRNS on students' performance. More to the point, visual signalling has also rallied round in reducing students' intrinsic and extraneous cognitive load and helps to increase students' perceived motivation when using ViSLab courseware. Low spatial ability (LSA) students significantly performed

better, having lower intrinsic cognitive load and extraneous cognitive load, and received higher perceived motivation when using mode VRS. On the contrary, High spatial ability (HSA) students significantly performed better and had lower cognitive load and higher perceived motivation when using mode VRNS. In conclusion, VRS should be considered for LSA students, especially with regards to the design and development of more effective and efficient instructional multimedia materials from the cognitive load perspective in order to reduce training time and less mental effort to attain better learning and transfer performance than conventional instructional methods in the learning of science laboratory safety. However, VRS may cause HSA students split attention. Therefore, signalling principle should not be overused during the development of instructional material as it will grow to become redundant for them.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Desktop VR is a technology innovative and a powerful computer tool that can be used for scientific visualisation because it provides engaging, interactive and multimedia learning that helps to increase students' performance (McLellan, 1998). Desktop VR gave perceptions on processes that are impossible to carry out in the real world by converting the abstract into concrete (Darrow, 1995; Osberg, 1995). As a result of using Desktop VR technologies, the learner's cognition will move from representational learning to conceptual learning through the experiential learning process (Winn, 1993; 1997). If this experiential learning process does not occur, the learner will stays on the stage of representational learning, which is analogous to rote memorization (Barab, Barnett & Squire, 2001; Novak & Gowan, 1984). Utilizing rote memorization as an educational strategy is no longer an option as, students' accomplishment may depend upon their ability to imagine and manipulate abstract multidimensional information spaces in many educational areas (Alkhalifa, 2004; Gordin & Pea, 1995).

Recent literature reviews of published research had proven the effectiveness of VR as a learning medium in a variety of settings (Ausburn & Ausburn, 2004, 2008a, 2008b; Ausburn et al., 2007; Ausburn et al., 2006; Awaatif, 2015; Chen, 2005, Zahira et al., 2012). VR has been extensively used in applied fields such as medicine, architecture, engineering and aviation, and it had also begun to edge its way to schools and higher education institutions in recent years (Strangman & Hall, 2003).

In desktop VR, users perceived a synthetic environment instead of their immediate, physical surroundings, and they are included as part of the simulation (Thurman & Mattoon, 1994). Therefore, students are getting interested and willing to explore the new VR technology in the learning process, consequently increase their perceived motivation. Chiou (1995) supports this claim by defining a learner could act like an active participant and an active constructor, not like an outside observer in a virtual environment as a simulated environment generated by reality technology. Desktop VR is an interface that allows the student control over what they see, thus offering them a certain level of autonomy and virtual feeling of reality by the manipulation of 3D objects in virtual space (Hanson & Shelton, 2008). Hence, desktop VR becomes not only technology, but to a certain extent from a psychological point of view, the users' minds can engage their motivation and awareness in a way alike to that of real environments (Keppell & Macpherson, 1997).

Moreover, the relationship between desktop VR and spatial ability was studied in this study to check how learners from different spatial ability have the capability to manipulate and visualise 3D in VR environment. There were many research studied showed positive result on desktop VR and its relationship with Spatial Ability, such as Awaatif (2015), Chen (2005), Elinda, Kok & Chun (2009), Huk (2006) and Zahira et al. (2012). Interaction outcome was found between the learning mode and spatial ability with regard to the performance in the study on learning with desktop VR showed that low spatial ability (LSA) learners are more positively affected.

Furthermore, Cognitive Load Theory (CLT) is one of the theories that successfully explained the relationship between learning and human cognitive architecture (Sweller, 1994). Plass, Moreno, and Brünken (2010) asserted that the objective of CLT is to allow researchers to predict learning outcomes by taking into consideration the capabilities and limitations of human cognitive architecture. It has been designed to provide guidelines intended to assist in the presentation of information in a manner that encourages learner activities that optimize intellectual performance (Sweller, Van Merrienboer, & Paas, 1998). Therefore, mental effort can be diminished when desktop VR applied into the learning of science laboratory safety.

Besides that, signalling principle also applied in this research as a technique for reducing extraneous processing because it provides cues to the learner about what to attend to and how to organize it according to the cognitive theory of multimedia learning from Mayer (2009). Signalling helps the learner to solve the problems when the lessons have too much extraneous material by drawing learners' attention towards the essential material. Signalling can help guide what the learner pays attention to the process of selecting and can help the learners to mentally organize the key material the process of organizing. Consequently, extraneous cognitive load will reduce in the learning process.

The objective of virtual science laboratory (ViSLab) courseware in this study 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 the mental model (David, 2005).

1.2 Background of Study

Desktop VR is being used in educational settings and for training purposes because it provides interactive and complex 3D structures in a highly realistic manner (Inoue, 2007; Lee & Wong, 2008). Desktop VR can be easily applied in the classroom by teachers without high cost. Besides, desktop VR can help users understand and learn safety rules, standards, and regulations. Desktop VR can also help the identification of errors, and the opportunity to correct them is a necessary strategy in complex learning environments such as school science laboratory (Winn & Windschitl, 2001).

Science laboratory has earned a reputation for being a highly hazardous place in any institutions because of the high incidence of accidents and fatality rates (Zulhisyam et al., 2011). Schools are held responsible for taking all the necessary safety precautions to preserve a safe learning and working surroundings in the laboratory. This is because the laboratory holds numerous chemicals, electrical and mechanical tools as well as procedures and operations that involve safety precautions, laboratory safety measures, fire safety and other safety related issues. In science, it is exclusively essential to train students in appropriate and safe work practices, as they might be exposed to toxic chemicals, hazardous biological materials, and possibly risky instrumentation. Despite that, it is regularly complicated to develop the essential safety knowledge in students (Iwona & Ewa, 2011). Desktop VR can be used as training tools to evaluate the degree to which students acquired skills after taking safety classes.

Besides, school laboratories were found that students' laboratory practices and attitudes needed to be addressed especially when traditional approaches to safety training were followed. These traditional methods include the introductory presentations to laboratory safety rules at the beginning of the lesson or presentation of experiment particular safety concerns by teachers and brief safety quizzes based on the the material provided (Alaimo et al., 2010). Furthermore, students' consciousness is still lacking, with the increasing availability of virtual prototypes, safety training can benefit from desktop VR during all phases of the life cycle of a product, integrating the computer generated information with the physical environment.

Desktop VR makes it possible to teach in virtual environments that are impossible to visualize in physical classrooms, like accessing into virtual laboratories, visualizing machines, industrial plants, or even medical scenarios. The huge possibilities of accessible virtual technologies will make it possible to break the boundaries of formal education.

Therefore, a virtual science laboratory (ViSLab) courseware has been designed and developed in this research to investigate the effect of using visual signalling principles in desktop VR environment on students' performance, cognitive load and students' perceived motivation in learning of science laboratory safety in school.

1.3 Problem Statement

In a science laboratory, students' safety practices have not been widely included in science education and other training programs (Schulte et al., 2005). Moreover, safety preparation and attitudes were lacking when traditional approaches to safety training were followed (Alaimo et al., 2010). In a science laboratory, we could not predict where and when an accident will happen. Students are highly exposed to dangerous hazards and experience untoward incidents, injury and damage. For that reason, it is essential to increase students' knowledge and understanding of science laboratory safety, so that the students can be alert and take the necessary precautionary steps when conducting the experiment in the school science laboratories.

Evidence provided by the researchers suggested that the current approaches to safety training have had a limited impact on students' safety awareness (Iwona & Ewa, 2011). They identified students' 'false sense of security' as the most persistent problem. Additionally, Zulhisyam et al. (2011) also found that the level of safety knowledge among students is still considered at an immature stage. Therefore, it is important to find the best way to increase students' safety knowledge and skills to avoid any accidents happen.

Additionally, low spatial ability (LSA) students cannot imagine and visualise the actual incident due to low cognitive load (Mayer, 2009). Desktop VR has been lauded as an outstanding visualisation tool for training (Philbin, Ribarsky, Walker, & Hubbard, 1997). Thus, desktop VR can be used in safety training to assist users to be aware of and study safety rules and regulations, due to its ability to furnish complex interactive visual and auditory stimuli. The ultimate goal of desktop VR is to produce simulations so realistic and believable that users cannot distinguish them from reality. According to Thurman et al. (1994), users make out an artificial environment instead of their instantaneous, physical surroundings, and they are included as part of the simulation. Visualization can provide an experience that some scientific explanations in economically workable ways that cannot otherwise be accomplished.

Furthermore, cognitive overload is one of the issues facing learners. When the instructional material is poorly constructed, an extraneous load is generated because the learner is unfocused from schema acquisition and used up precious working memory resources by trying to deal with a suboptimal learning environment (Sweller et al., 1998). One of the challenges ViSLab designers faced is how to keep extraneous cognitive to a minimum. This is necessary, not only to keep extraneous cognitive load to a minimum but also to raise the intrinsic cognitive load to the most favourable level. The more the extraneous burden is eased, the more scope remains for the intrinsic cognitive load to be processed. According to Mayer (2009), signalling principle is the way to reduce the extraneous cognitive load.

Additionally, students with limited working memory can hold fewer pieces of discrete information in their mind at any given moment (Sweller, 1994). Therefore, it is hard to learn and recover input knowledge and skills if the learners can only hold on for a limited amount of information in their memories at one time. They hear what you said, or see what is presented, but as more information overwhelms their memory system, it will cause cognitive overload, and they lose previous information needed to successfully complete the task. Sequentially, if cognitive overload takes place, then learners will be more likely to make errors, not fully engage with the subject materials, and provide poor efforts overall. Finally, it will affect their performances in all the subject areas.

Moreover, students' lack of motivation to learn laboratory safety, as the way they have been taught they perceived it as boring and uninteresting. The motivation to learn is strongly dependent on the learner's confidence in his or her potential for learning. These feelings of competence and belief in his or her potential to solve new problems are derived from the first-hand experience of the mastery of problems in the past, and it is much more powerful than any external acknowledgement and motivation. By experiencing the successful completion of the challenging tasks, learners gain confidence and motivation to embark on more complex challenges.

Therefore, ViSLab was designed to increase the learners' level and source of motivation for learning.

Besides, there are numerous researches on laboratory safety in Malaysia; for example, Zulhisyam et al. (2011), Bahram et al. (2013) and Anuar et al. (2008) have carried out various surveys on laboratory safety. Unfortunately, none of the research on science laboratory safety in desktop VR environment in Malaysia can be found even though desktop VR has been used in education since the last century. Yet, there is still a gap in the learning about science laboratory safety using desktop VR as a safety training tool. Hence, the researcher would like to design and develop a courseware to investigate the effectiveness of ViSLab to students' performance, cognitive load and perceived motivation in this study.

1.4 Research Objectives

The objectives of this study are to determine the effects of using visual signalling principle in the VR environment in learning science laboratory safety among students in school. In order to accomplish the main purpose of the research, the following specific objectives are required to be achieved. The objectives are:

i. To investigate the effects of using Virtual Science Laboratory (ViSLab) with Virtual Reality with Signalling (VRS) & Virtual Reality with Non Signalling (VRNS) on students' performance in learning laboratory safety.
ii. To investigate the effects of using ViSLab with VRS & VRNS on students' cognitive load in learning laboratory safety.
iii. To investigate the effects of using ViSLab with VRS & VRNS on students' perceived motivation in learning laboratory safety.

iv. To investigate the interaction effects of using ViSLab with VRS & VRNS on students' achievement, cognitive load and perceived motivation among students with difference spatial ability.

1.5 Research Questions

This study attempts to answer the following research questions:

A. What are the effects of using ViSLab with VRS & VRNS on students' performance in learning laboratory safety?

i. Is there any significant difference in students' performance score using ViSLab with VRS & VRNS?

ii. Is there any significant difference in students' performance score using ViSLab with VRS & VRNS between the low spatial ability (LSA) learners?

iii. Is there any significant difference in students' performance score using ViSLab with VRS & VRNS between the high spatial ability (HSA) learners?

iv. Is there any significant difference in students' performance score using ViSLab between the two different spatial ability learners of the VRS?

v. Is there any significant difference in students' performance score using ViSLab between the two different spatial ability learners of the VRNS?

B. What are the effects of using ViSLab with VRS & VRNS on students' intrinsic load in learning laboratory safety?

i. Is there any significant difference in students' intrinsic load using ViSLab with VRS & VRNS?

ii. Is there any significant difference in students' intrinsic load using ViSLab with VRS & VRNS between the LSA learners?

iii. Is there any significant difference in students’ intrinsic load using ViSLab with VRS & VRNS between the HSA learners?

iv. Is there any significant difference in students’ intrinsic load using ViSLab between the two different spatial ability learners of the VRS?

v. Is there any significant difference in students’ intrinsic load using ViSLab between the two different spatial ability learners of the VRNS?

C. What are the effects of using ViSLab with VRS & VRNS on students’ extraneous load in learning laboratory safety?

i. Is there any significant difference in students’ extraneous load using ViSLab with VRS & VRNS?

ii. Is there any significant difference in students’ extraneous load using ViSLab with VRS & VRNS between the LSA learners?

iii. Is there any significant difference in students’ extraneous load using ViSLab with VRS & VRNS between the HSA learners?

iv. Is there any significant difference in students’ extraneous load using ViSLab between the two different spatial ability learners of the VRS?

v. Is there any significant difference in students’ extraneous load using ViSLab between the two different spatial ability learners of the VRNS?

D. What are the effects of using ViSLab with VRS & VRNS on students’ perceived motivation in learning laboratory safety?

i. Is there any significant difference in students’ perceived motivation using ViSLab with VRS & VRNS?

ii. Is there any significant difference in students' perceived motivation using ViSLab with VRS & VRNS between the LSA learners?

iii. Is there any significant difference in students' perceived motivation using ViSLab with VRS & VRNS between the HSA learners?

iv. Is there any significant difference in students' perceived motivation using ViSLab between the two different spatial ability learners of the VRS?

v. Is there any significant difference in students' perceived motivation using ViSLab between the two different spatial ability learners of the VRNS?

E. The interaction effects of using ViSLab with VRS & VRNS on students' achievement, cognitive load and perceived motivation among students with difference spatial ability.

i. Is there any interaction effect between two different presentation modes (VRS & VRNS) and students' spatial ability on students' performance score?

ii. Is there any interaction effect between two different presentation modes (VRS & VRNS) and students' spatial ability on students' intrinsic load?

iii. Is there any interaction effect between two different presentation modes (VRS & VRNS) and students' spatial ability on students' extraneous load?

iv. Is there any interaction effect between two different presentation modes (VRS & VRNS) and students' spatial ability on students' perceived motivation?

1.6 Hypothesis

Based upon the literature reviews alternate directional hypotheses were designed for this study. The probability level of 0.05 is used to test statistical significance.

A. The effects of using ViSLab with VRS & VRNS on students' performance in learning laboratory safety.

$H_{0.A.1}$: There is no significant difference in students' performance score using ViSLab with VRS & VRNS.

$H_{0.A.2}$: There is no significant difference in students' performance score using ViSLab with VRS & VRNS between the LSA learners.

$H_{0.A.3}$: There is no significant difference in students' performance score using ViSLab with VRS & VRNS between the HSA learners.

$H_{0.A.4}$: There is no significant difference in students' performance score using ViSLab between the two different spatial ability learners of the VRS.

$H_{0.A.5}$: There is no significant difference in students' performance score using ViSLab between the two different spatial ability learners of the VRNS.

B. The effects of using ViSLab with VRS & VRNS on students' intrinsic load in learning laboratory safety.

$H_{0.B.1}$: There is no significant difference in students' intrinsic load using ViSLab with VRS & VRNS.

$H_{0.B.2}$: There is no significant difference in students' intrinsic load using ViSLab with VRS & VRNS between the LSA learners.

$H_{0.B.3}$: There is no significant difference in students' intrinsic load using ViSLab with VRS & VRNS between the HSA learners.

$H_{0.B.4}$: There is no significant difference in students' intrinsic load using ViSLab between the two different spatial ability learners of the VRS.

$H_{0.B.5}$: There is no significant difference in students' intrinsic load using ViSLab between the two different spatial ability learners of the VRNS.

C. The effects of using ViSLab with VRS & VRNS on students' extraneous load in learning laboratory safety.

$H_{0.C.1}$: There is no significant difference in students' extraneous load using ViSLab with VRS & VRNS.

$H_{0.C.2}$: There is no significant difference in students' extraneous load using ViSLab with VRS & VRNS between the LSA learners.

$H_{0.C.3}$: There is no significant difference in students' extraneous load using ViSLab with VRS & VRNS between the HSA learners.

$H_{0.C.4}$: There is no significant difference in students' extraneous load using ViSLab between the two different spatial ability learners of the VRS.

$H_{0.C.5}$: There is no significant difference in students' extraneous load using ViSLab between the two different spatial ability learners of the VRNS.

D. The effects of using ViSLab with VRS & VRNS on students' perceived motivation in learning laboratory safety.

$H_{0.D.1}$: There is no significant difference in students' perceived motivation using ViSLab with VRS & VRNS.

$H_{0.D.2}$: There is no significant difference in students' perceived motivation using ViSLab with VRS & VRNS between the LSA learners.

$H_{0.D.3}$: There is no significant difference in students' perceived motivation using ViSLab with VRS & VRNS between the HSA learners.

$H_{0.D.4}$: There is no significant difference in students' perceived motivation using ViSLab between the two different spatial ability learners of the VRS.

$H_{0.D.5}$: There is no significant difference in students' perceived motivation using ViSLab between the two different spatial ability learners of the VRNS.

E. The interaction effects of using ViSLab with VRS & VRNS on students' achievement, cognitive load and perceived motivation among students with difference spatial ability.

$H_{0.A.1}$: There is an interaction effect between two different presentation modes (VRS & VRNS) and students' spatial ability on students' performance score.

$H_{0.B.2}$: There is an interaction effect between two different presentation modes (VRS & VRNS) and students' spatial ability on students' intrinsic load.

$H_{0.C.3}$: There is an interaction effect between two different presentation modes (VRS & VRNS) and students' spatial ability on students' extraneous load.

$H_{0.D.4}$: There is an interaction effect between two different presentation modes (VRS & VRNS) and students' spatial ability on students' perceived motivation.

1.7 Significance of the Study

The significances of the study are as follows:

i. The body of knowledge in the principles of multimedia learning in a VR environment, especially the visual signalling principle in ViSLab.

ii. It will disclose the benefits of ViSLab courseware towards bridging theory to practice, particularly in the learning of science laboratory safety.

iii. Furthermore, it will examine the advantages (and/or disadvantages) of using multimedia towards learners with different spatial abilities.
iv. It will add to the arsenal of literature in science laboratory safety for secondary school's students
v. It will also provide a reflection of VRML platform in supporting ViSLab courseware for training purposes.

1.8 Theoretical Framework

This study is designed based on the following theories and models, namely:

i. Cognitive Affective Theory of Learning with Multimedia (Moreno & Mayer, 2007);
ii. Cognitive Load Theory (Sweller, 1994) ;
iii. Cognitive Theory of Multimedia Learning (Mayer, 2001);
iv. and ARCS Motivation Model (Keller, 1983).

These theories formed 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), which has elaborated in Chapter Four. Figure 1.1 showed the theoretical framework of this study. For further information, please refer the details of the theories and models used in Chapter Two.

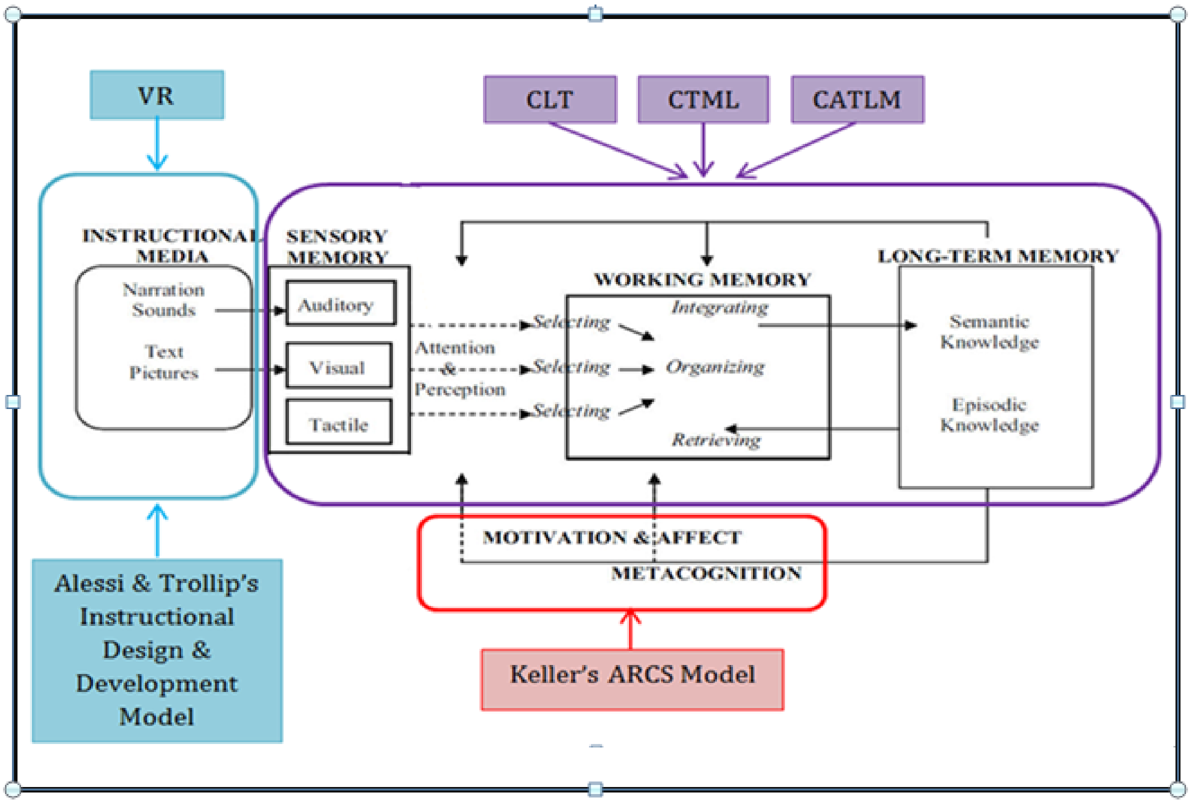

Figure 1.1: Theoretical Framework

1.8.1 Cognitive Load Theory

Cognitive architecture consists of a limited working memory with partially independent processing units of visual and auditory information, which interacts with an unlimited long-term memory. Cognitive load theory is concerned with methods in support of reducing working memory load with the purpose of ease the changes in long term memory correlated with schema acquirement (Sweller, 1994). Figure 1.2 showed sensory memory, working memory and long-term memory in human cognitive architecture.

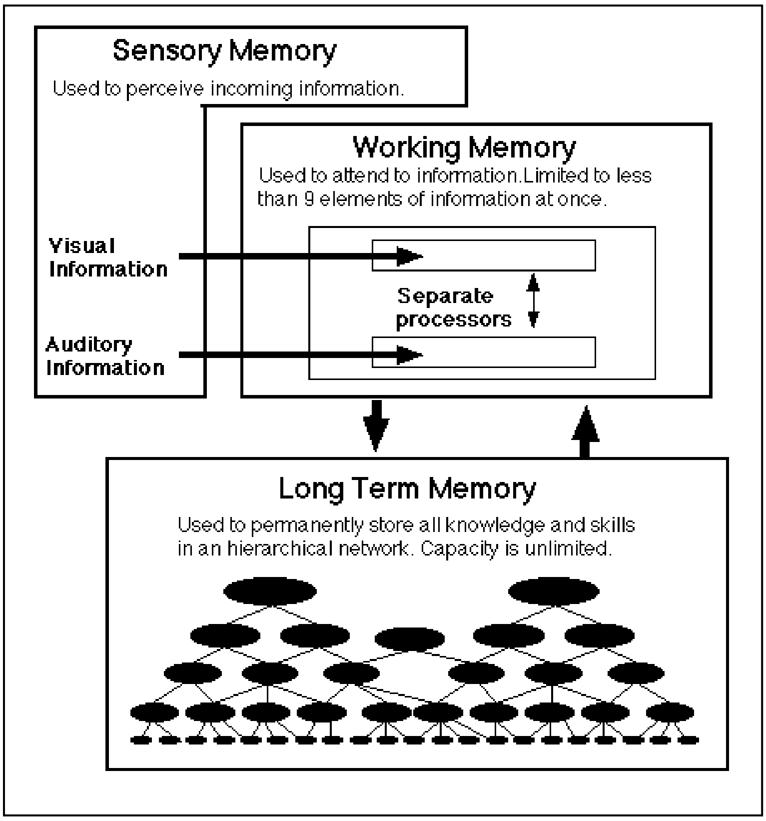

Figure 1.2: Human Cognitive Architecture (Cooper, 1998)

1.8.2 Cognitive Theory of Multimedia Learning

The information processing system in human beings uses both words (printed text, spoken text) and pictures (graphics, maps, photos, dynamic representation, drawing, charts, and video) together rather than words single-handedly when watching a multimedia presentation (Mayer, 2001). The design of multimedia environments should be compatible with how people learn. Mayer (2001) presented a cognitive model of multimedia learning to present the human information processing system as shown in Figure 1.3. Information processing occurs in three stages, which is the sensory memory, working memory and long-term memory.

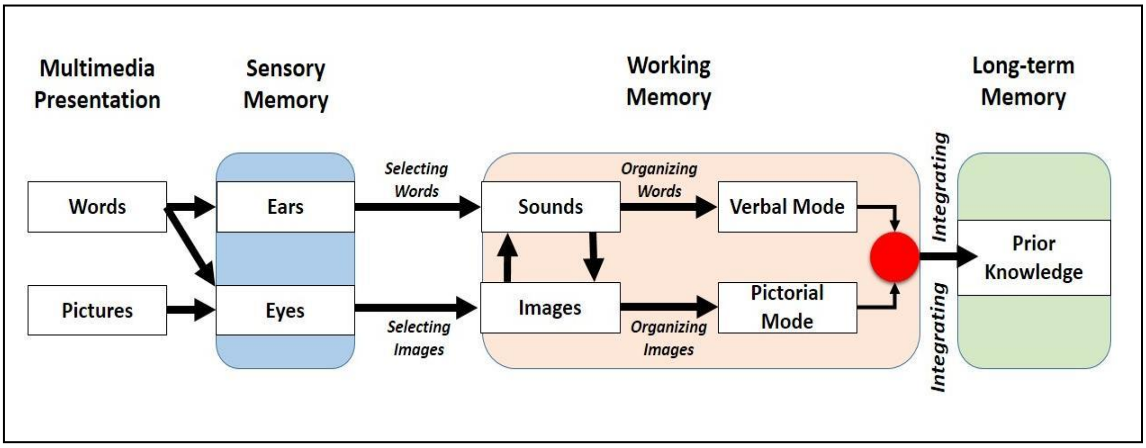

Figure 1.3: Cognitive Theory of Multimedia Learning (Mayer, 2001)

1.8.3 The Cognitive Affective Theory of Learning with Media

The cognitive-affective theory of learning with media (CATLM) (Moreno, 2005) was expanded from cognitive theory of multimedia learning (Mayer, 2001, 2005a) to media for instance VR, cased-based learning environments, and agent-based which the learner will be presented with instructional materials other than words and pictures. Figures 1.4 showed the cognitive-affective theory of learning with media (CATLM) (Moreno, 2005).

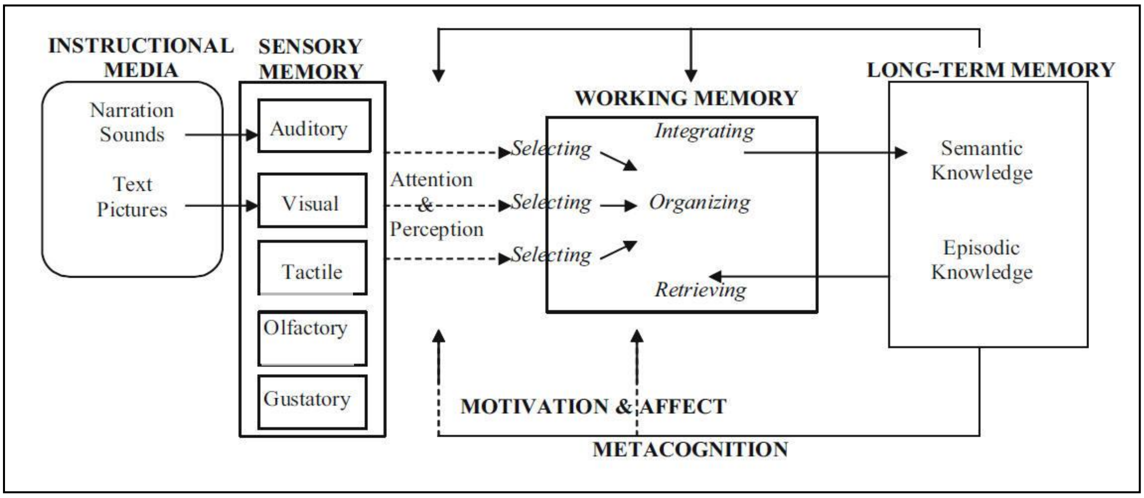

Figure 1.4: Cognitive Affective Model of Learning with Media (Moreno, 2005)

1.8.4 ARCS Motivation Model

In order to stimulate and sustain students' perceived motivation in learning environments, the ARCS model was designed by Keller (1983). Main (1993) stated that the teacher should spend as much effort in motivating the student to learn as well as with the cognitive and psychomotor needs since it has such a powerful impact on performance. The ARCS model is based upon the macro theory of motivation and instructional design developed by Keller (1979, 1983, 1987a: Keller & Kopp, 1987). The ARCS model of motivation design presents a systematic approach to design motivational approaches into instruction (Song & Keller, 2001). Motivational design and approaches are based on four dimensions: attention (A), relevance (R), confidence (C), and satisfaction (S). The principles pertaining to the dimensions of the ARCS model is shown in Table 1.1.

Table 1.1

Details of ARCS Model (Keller, 2008)

Dimensions	Principles
Attention	Motivation to learn is promoted when a learner's curiosity is aroused due to a perceived gap in current knowledge.
Relevance	Motivation to learn is promoted when the knowledge to be learned is perceived to be meaningfully related to a learner's goals.
Confidence	Motivation to learn is promoted when learners believe they can succeed in mastering the learning task.
Satisfaction	Motivation to learn is promoted when learners anticipate and experience satisfying outcomes to a learning task.

1.9 Research Framework

There were three types of variables in this study, the independent variables, the dependent variables and the moderator variables. The independent variables were the multimedia instruction employed to teach Science Laboratory Safety. The two instruction methods employed were the VRS and VRNS. The dependent variables were the students' performance score, cognitive load and students' perceived motivation score. The moderator variables were Spatial Ability. Figure 1.5 showed the research framework of this study.

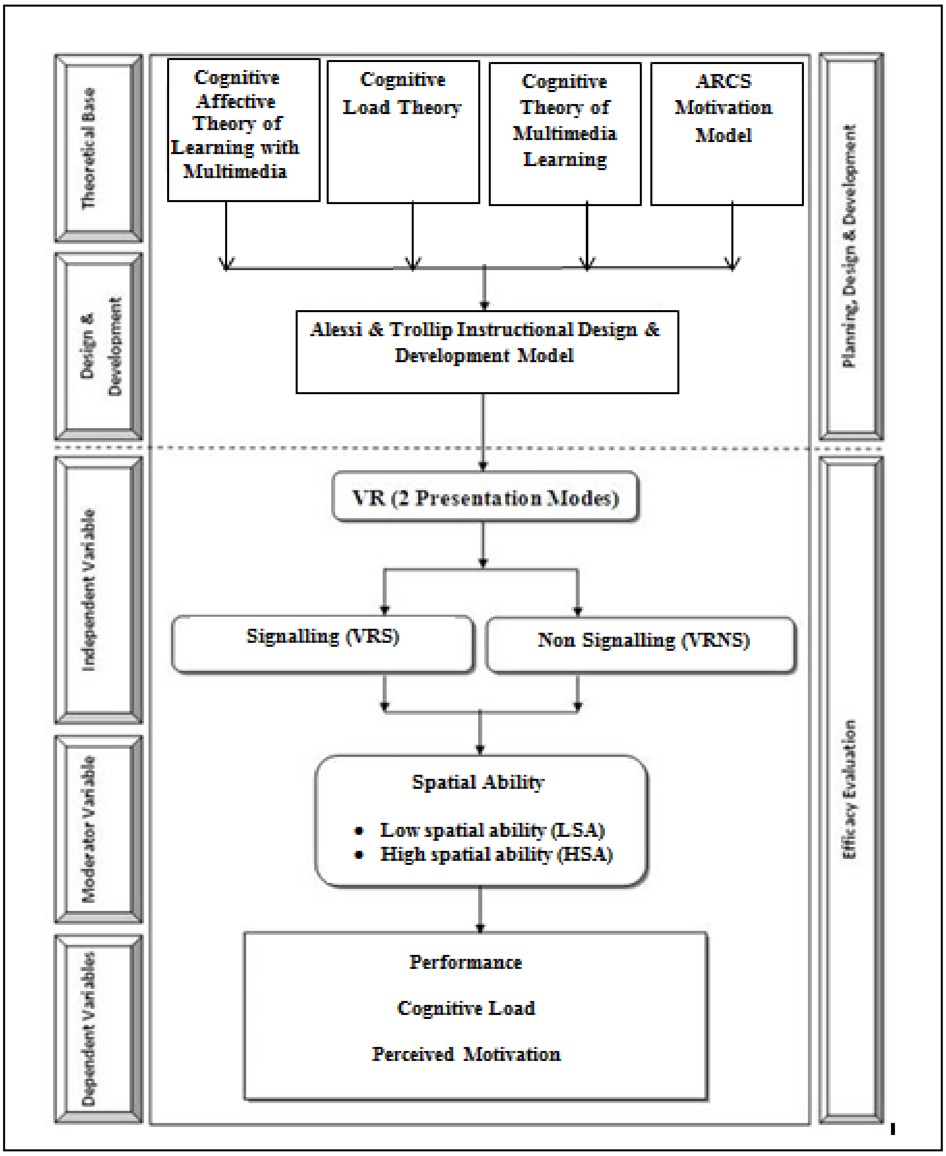

Figure 1.5: Research Frameworks

1.10 Limitations of Study

There are some limitations in conducting the research that should be taken into consideration. The main limitation for the project is the limited resources and time available for the development of animated materials by using Unity 3D for the production of Virtual Science Laboratory. It is time-consuming to prepare the materials. Laboratory safety needed a great deal of thought as well as the VR development and design. So it is even more time-consuming to prepare the materials. It is, however, a very worthwhile project because the results are very encouraging.

Another limitation of the project was the accessible population in this research would be year-one science stream students in one of the colleges in Penang. Therefore, the result of this research cannot be generalized for the whole population of this age group in Malaysia or other parts of the world. Furthermore, the students only have one hour to attend tutorial classes in the computer lab. Hence, the result may be more accurate if the learning process is extended for a longer period so that the students are able to learn more to achieve a better result.

It is important to note that the experimental design would be too narrow. At the same time, a research design using a questionnaire would be logistically impossible and might not yield the type of data required in this study. Despite advances in immersive VR technology, it is still inaccessible to teachers in the classroom because of complex equipment and high cost. Not every school can afford HMD, trackers and other VR-related utilities (Chen, Yang, Shen & Jeng, 2007). Teachers need to spend much time learning and configuring the equipment.

Therefore, in this study, the researcher decided on a non-immersive desktop VR because it is less costly, more accessible, does not induce motion sickness, yet still provides a good sense of immersion in the virtual world.

1.11 Operational Definitions

The following is a list of terms or phrases used in this study and their respective operation definitions.

Desktop VR

- Desktop VR creates full use of a desktop computer to present images in common monitor. Besides, Desktop VR allows learners interaction with the computer-generated images via generic input devices such as a computer mouse and keyboard (Fisher & Unwin, 2002). Desktop VR if compared to the immersive VR will be more cost-effective, since it does not involve any expensive hardware and software. Moreover, it is also relatively effortless to develop. Therefore, the most familiar with least expensive form of desktop VR is used in this study.

VR Signalling

- Signalling is a technique that inserts cues to direct the leaner's concentration toward the vital objects (Mayer, 2009). There are two types of signalling principles which is verbal signalling and visual signalling. In order to avoid students' cognitive overload, researcher only used two features of visual signalling: flashing and distinctive colour in ViSLab courseware. A particular component of the system will flash and the colour of the particular component will use to show the hints in the completion of the ten missions.

VR Non-Signalling

- In ViSLab courseware, VR Non-Signalling (VRNS) mode will not be given any guidance to the learners. Learner need to try their best by their own in the completion of the ten missions.

Performance Score

- An assessment that test what students have been taught in school. It is designed to provide information about how well students have learned, and are usually practice in school settings (Gay & Airasian, 2009). The pretest and posttest were the tests to measure the criterion variable of students' performance. In this study, the two sets of Science Laboratory Safety Test (SLST) of pretest and posttest were identical except for the order of the questions. The pretest and the posttest were administered before and after the treatment respectively.

Perceived Motivation

- According to Keller (1983), motivation shows the magnitude and direction of behaviour of certain person in the learning process. It refers to the learners' preferences to what practices or objectives they will move towards or stay away from, as well as the level of attempt they will put forth in that respect. In this study, researcher used Keller's Instructional Materials Motivation Scale (IMMS) to verify students' perceived motivation towards the instructional materials. IMMS in this study was used to assess the motivational characteristics of the ViSLab courseware based on the

Attention, Relevance, Confidence, and Satisfaction (ARCS) model of motivation.

Spatial Ability

- Spatial ability can be grouped into three types of ability based on cognitive functions: spatial visualization, spatial perception, and mental rotation (Linn and Petersen, 1985). In this study, researcher used Newton and Bristol Spatial Ability Tests by Newton and Bristol (2009) to measure students' spatial ability level. The reason used this instrument is because this instrument tested all three types of spatial ability and more up to date as compare to others. This Spatial Ability Test questions cover: combining shapes, cube views in 3-dimensions, shape matching, shape rotation and the manipulation of other solid shapes in 2D and 3D and use maps and plans. There are two levels of spatial ability: High Spatial Ability (HSA) and Low Spatial Ability (LSA).

High Spatial Ability Students

- Students who achieved above the median or above in the Spatial Ability Tests. The median is described as the numeric value separating the higher half of a sample, a population, or a probability distribution, from the lower half.

Low Spatial Ability Students

- Students who scored at the median or below in the Spatial Ability Tests.