VIRTUAL REALITY:
A REVIEW OF ITS IMPLEMENTATION IN THE
VIRTUAL PHYSICS LAB

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ABSTRACT

Virtual Reality (VR), being the third era in Human-Computer Interaction (HCI), has opened up opportunities in education. At the same time, VR supports the theory of constructivism. The mode of learning geared towards a student-centric or self directed learning model, is embedded in the constructivism learning philosophy. The VR system is able to display a virtual environment that entirely exists in the computer. It can display three-dimensional (3D) elements of sight, hearing and the sense of touch (haptic). This paper reviews the existing implementation of this promising technology in Physics throughout the world and proposes a solution to tackle the challenges faced by secondary school Physics teachers in Malaysia. The `Virtual Physics Lab' is developed and applied to assist current teaching practices. It is foreseen that when VR is introduced into the Malaysian educational system, the results from this research will be one of the valuable resources to assist the growth of the government's `Smart School' project. Elementary research methodologies, information gathering, prototype design, development and testing, information analysis and documentation are the steps taken to accomplish the research objectives.

Key words: Education, Smart school, Virtual physics lab, Virtual reality

1.0   INTRODUCTION

A Virtual Reality (VR) system has the capacity to display a virtual environment that wholly exists in the computer. VR can demonstrate 3D elements of sight, hearing and sense of touch (haptic). In the western world countless research coupling the educational system and VR as a teaching tool has been undertaken. Hence VR has created a new window of opportunity towards assisting and enhancing the educational practices and techniques. In essence, the characteristics of VR itself support the theory of *constructivism* i.e., to create a `learning-by-doing' atmosphere.

This paper reviews the existing implementation of VR in Physics and proposes a solution for handling the challenges faced by secondary school Physics teachers in Malaysia. The `Virtual Physics Lab' is developed and applied to assist current teaching practices. In addition, Loftin in Seth (1999) and researchers at the Johnson Space Centre (1999) believe that a new paradigm in science education is needed. Loftin stated,

> *"There are so many people left by the wayside when it comes to traditional science and math education. By the second year of high school, the vast majority of students have lost interest in these subjects, which is a shame."* (Seth, 1999)

A research conducted by the Ministry of Education, Malaysia and UNESCO found that there is a decline in student enrolment in the pure sciences due to the students' perception of "sciences as being difficult and boring subjects" (Md. Shariff *et al.*, 2001).

One of the difficulties in science education experienced by students is when they are faced with abstractions. Computer visualization tools are particularly effective in overcoming this problem (Trindade *et al.*, 2001). Disessa (1986) stated that the trick is not to turn experience into abstractions with a computer, but to turn abstractions, like the laws of physics, into experiences (Trindade *et al.*, 1999).

Recent advancement in computer technologies has created new possibilities. The visualization of 3D objects and data is becoming increasingly important in learning several scientific subjects, in particular the atomic and molecular sciences, fluid dynamics, etc., with VR, visualizing complex data and building more adequate conceptual models is now possible (Trindade *et al.*, 1999).

According to Trindade *et al.* (1999) VR has been touted as a powerful teaching and training tool because VR supports direct experience of the phenomena

concerned; it is 3D, it allows for multiple frames of referencing, it offers multi-sensory communications and it is physically immersive.

A highly regarded article by Stuart and Thomas published in 1991 listed 7 roles of VR in education (Andolsek, 1995). They are:

(a) Exploring places and things students would not otherwise have access to;
(b) Exploring real things that without changes to scale in size and time could not be examined;
(c) Creating places and things with altered qualities, such as Earth during the ice age;
(d) Communicating with people in remote locations;
(e) Interacting with people in non-realistic ways e.g., flying;
(f) Learning abstract concepts in mathematics and science;
(g) Interacting with virtual beings e.g., representations of historical figures.

Pantelidis (1999) said VR should be used to teach subjects, if performance under ordinary lesson sessions might prove dangerous, harmful to the environment, costly or simply just impractical (Seth, 1999).

2.0 THE VIRTUAL PHYSICS LABS

The 'What-Ifs' phenomenon exists numerously in Physics. While trying desperately to comprehend such enticing topics as gravity, moments of inertia, complex interactions between colliding objects and hundreds of other concepts, we know that unless we could visualize what was going on, we would have difficulties to understand them (Austakalnis and Blatner, 1992). Therefore, a visualisation tool is needed to aid understanding (Romli, A.A.Bakar and Shiratuddin, 2001).

The use of VR in physics can be seen in Atom World, Phase World, Science Space project, Virtual Environment Science Laboratory (VESL) and The Virtual Physics which is a multi-user or distributed VR applications .

2.1 Phase World and Atom World

The Human Interface Technology Laboratory (HITL) at the University of Washington had developed two applications, i.e., Phase World and Atom World. Both use the Head Mounted Display (HMD) to project virtual worlds.

Phase World presents 3D graphs (surfaces) showing the relationships between volume, pressure and temperature when changes in state occur at the molecular

level. This world has been used at the Kennedy High School, Seattle since January 1995.

Atom World has been developed as an open area with sources for sub-atomic elements, metered scale for changing electron charges, atom assembly area and notice board identifying atomic element to be constructed. Electron shells are depicted as spheres that change colour when an element is completed. The learning objective of the Atom World is to review the basic atomic and molecular structures. The system was evaluated for its impact of immersion and interactivity at the Garfield High School, Seattle in 1994 and 1995.

2.2   Science Space

The Science Space is being labelled as the most ambitious project using high technology and expertise. It is a collaboration between educators, scientists and computer specialists at the George Mason University in Fairfax, Virginia, the University of Houston and NASA Johnson Space Centre.

The Science Space is considered to be a high-end VR project with a grant from the National Science Foundation (NSF). Donning colour HMD and haptic vests, students navigate through immersive environments that run on robust CPUs and software created at NASA (Seth, 1999).

The Science Space includes Newton World and Maxwell World. The first supports the exploration of Newton's Laws of Motion as well as the conservation of both kinetic energy and linear momentum. Newton World is an open corridor activity area where two balls of various masses move and rebound with moveable cameras recording the events. Signs indicate the presence or absence of gravity and friction, columns and floor markings support judgement of distance and speed, potential energy is portrayed by tactile and visual cues, and velocity through auditory and visual cues. Parameters such as gravity can be changed via the control panel.

Newton World supports guided inquiry into the kinematics and dynamics of one-dimensional motion, with scaffolding to advance the users from basic to complex activities. A user is asked to predict forthcoming events, experience and explain them. It has been evaluated for its usability, effectiveness, multi-sensory interface, content and lesson structure, age group and egocentric vs. exocentric viewpoints to various participants.

Meanwhile, Maxwell World supports the study of electrostatics leading up to the concepts of electric field (force), electric potential (energy), superposition and Gauss's Law. Maxwell World immerses students in the 3D space of

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electrical fields. The menu at left and the virtual hand at right are used for navigation and control. Fig.1 shows the Maxwell World interface.
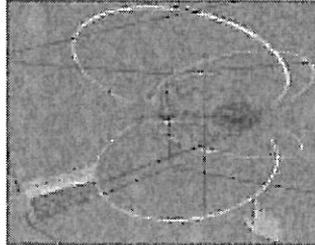
Fig.1: The Maxwell World Interface

The world is a boxed area where a user positions a charge configuration and uses a positive test charge, electric potential meter or electric charge line to query the potential at selected points, and drop test charges into the world. Resultant forces, electric field lines, potentials, equipotential surfaces and lines of electric flux are displayed. Flux of an electric field through Gaussian surfaces can be visually measured.

Maxwell World has been evaluated for its usability, learnability, effectiveness and effect of frame of reference.

2.3   Virtual Environment Science Laboratory (VESL)

VESL allows students to manipulate variables such as mass, velocity and time to learn about linear and orbital mechanics in a setting of the solar system. The interface Technology Corporation developed VESL to provide a virtual physics laboratory that could also be used by disabled students. VESL is a representation of the solar system where students can visit any planet, the sun and then manipulate variables such as mass and velocity. Its game-like experiential paradigm teaches critical concepts. As users learn about the features of the world they will gain virtual tools, e.g., tools that shrink or expand space, slow down or speed up time, that permit further exploration. The games also allow users to conduct experiments where observation of results facilitates learning of linear and orbital mechanics.

2.4   Virtual Physics

The project goal is to investigate how collaborative virtual worlds can be designed to provide improved support for conceptual learning of physics.

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A number of scientific worlds can be entered from a central space. These worlds have been selected to provide motivation for collaboration. They are Cannon World, 3D Pivot World, Friction World and Bowls World. The overriding problem facing the future development of VR technologies at present is associated with cost. Wodaski (1995) said VR investigators can expect to get a range of 8 expenditures, starting at US$100 for a cheap pair of LCD glasses that produce a flickering 3D image on a screen to US$100,000 for a HMD with sophisticated head-tracking and resolution and perhaps a data-glove and a platform (Keppel and Macpherson, 1998).

Even if high-end VR revolution is waiting to happen in education, the question of cost still remains. Will the benefits be worth the financial outlay ? (Moore, 1995). In their conclusion about the state of VR in education, Macpherson and Keppel (1998) suggested that much of the discussion has centred on how VR might be used if the technology were more advanced, rather than focusing on how it could be used on the basis of what actually exists now.

3.0   IMPLEMENTING VIRTUAL PHYSICS IN MALAYSIA

This research has been carried out to evaluate the effectiveness of VR within the Malaysian environment. It is proposed to tackle the challenges faced by Malaysian secondary school Physics teachers.

With the legal framework almost complete, the Malaysian education system is indeed set for a quantum leap which will bring sweeping changes to the learning institution. This will enable a wider range of courses with different options and approaches to learning, better management, new teaching methods and overall increase in productivities and standards. The project is known as the "Smart School".

The project started with 80 existing schools throughout Malaysia. In 2000, 9 more new schools were turned into 'Smart Schools' and served as the 'showcase' schools to the world. The pilot feedback will determine the broad deployment of the project and will have classrooms and science labs equipped with computers in times to come. Suitable teaching and learning materials are necessary so that they can be adapted into the new teaching and learning strategy.

Dr. Sharifah Maimunah Syed Zin, Director of Curriculum Development Center, Ministry of Education said in Utusan Malaysia 16 February 2001, The Ministry of Education has estimated a target ratio of 60:40 for the science & technology (S&T) stream students as compared to the non-S&T students. Unfortunately,

latest statistics show that many students are reluctant to study S&T subjects after entering high schools (Ismail, 2001).

Results indicate that the students' posture and interest towards science is seen to be declining as they move from primary to secondary and higher education level (Suip, 2000). Suip (2000) described the findings by Woolnough (1993) to support earlier research, i.e., the interest of students towards science can be increased through various methods and models of teaching.

As such, this research utilises VR as the techno-teaching tool. This research studies the effectiveness of VR as an alternative teaching means to assist the presently available teaching tools, diversify the methods of teaching and also make experiments and hard to understand concepts, easy and interesting to be learnt (Romli, A.A.Bakar and Shiratuddin, 2001).

With the advancement in visual and interactive technologies such as VR, the process of knowledge construction from a visual and auditory perspective can be further explored (Osberg, 1997).

The present commonly used media will still be used and will be integrated with the high technology media. It will combine teacher centered, network centered methods and courseware.

3.1   Data Collection

Based on the reviews conducted earlier, information regarding the difficulties to visualize physics concepts and experiments were gathered. The concepts and experiments are based on Malaysia's Sijil Pelajaran Malaysia (SPM) syllabus.

The selection process was based upon the schools' academic achievement and performance in the Kedah state (north of Malaysia). A sample consisting of 11 schools with two of them being accredited as 'Smart Schools' were selected. Topics arduous to students and where VR can assist to achieve the research objectives were clearly identified (Romli, A.A.Bakar and Shiratuddin, 2001).

i.   The selected schools were:
ii.   SM Sultan Abdul Halim
iii.   SM Sultanah Asma
iv.   SMK Agama Kedah
        SMK Jitra
vi.   SMK Hosba
vii.   SMK Seri Mahawangsa
viii.   SMK Ayer Hitam

ix.   SM Teknik Jalan Stadium
x.   SMK Kepala Batas
xi.   SMK Changlun
xii. Maktab Mahmud

Schools i, ii and iii are categorised under good achievement, iv, v and vi as moderate achievement and vii, viii and ix are under the category of poor achievement. SMK Changlun and Maktab Mahmud are under a special category. When the survey was conducted, SMK Changlun was having its first science stream class. Maktab Mahmud on the other hand is under state government administration as compared to others which are under a administration of the federal government.

Selection of suitable topics for the respective subjects were based on two main factors, namely the level of difficulties of the experiment and their suitability to be VR implemented.

This research in particular refers to topics that cannot be explained in an actual environment due to the lack of lab equipment and cost, dangerous or harmful to both the students and the environment, and also to increase a high enthusiasm towards certain topics. The topics chosen are force and motion, pressure in fluid, thermionic radiation, radioactivity and nuclear masses.

Some experiments require the use of fume-cupboards. These could cause harm, through use of poisonous chemical substances such as bromine. However the condition of the fume-cupboard has to be taken into consideration. Safety issues regarding the use of expired fume-cupboard is highlighted in Utusan Newspaper on 25 September 2001 (please refer to Fig.2).
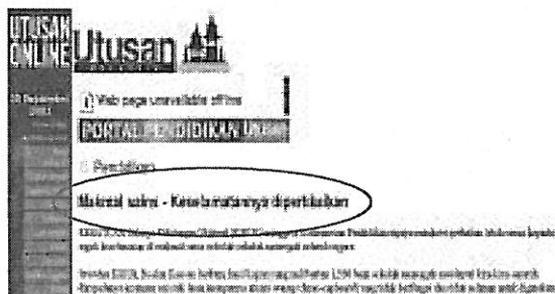
Fig.2: Expired Fume-Cupboards Can Cause Harm or Injury

An analysis was done based on the response acquired from teachers and students about the difficulties faced when explaining and comprehending particular concepts and experiments. An analysis has been done on the topics chosen by students in an earlier survey conducted at 11 schools. Fig.3 shows the graph of analysis.
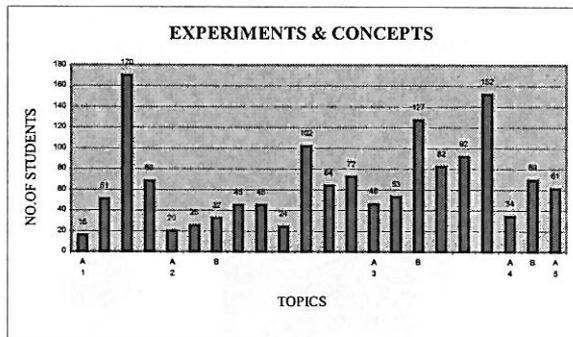
Fig.3: Analysis of the Concepts and Experiments Chosen
Representation of the alphabets is shown in Appendix A (adapted from ICIMU 2001 Proceedings -Romli, A.A.Bakar and Shiratuddin, 2001)

The above topics incorporate a variety of concepts and experiments. The two main concepts chosen to be VR implemented are:

Matter Kinetic Theory that involves the structure of quartz, brownian movement and absorption rate of air.
Archimedes Principle that involves the buoyancy principle, concept and applications in real world.

To facilitate the prototype development process, storyboards were created to display the step-by-step phases to explain the concepts.

3.2   Prototype development

3.2.1 *Type of VR used*
Using desktop PC and by simply incorporating real-time 3D graphics on the monitor, a non-immersive VR system was used for the development. A comprehensive survey to date found that PC-based VR systems are most practical for US schools today. Youngblut (1999), a researcher at the Arlington, Virginia-based Institute for Defense Analyses has reviewed more than sixty VR educational efforts around the world. She explained that while many interesting

experiments are under way, the PC-based VR systems have the best chance of wide-scale espousal. PC-based VR presents many of the positive benefits of more high-end VR applications with little or no additional costs involved for the schools (Seth, 1999).
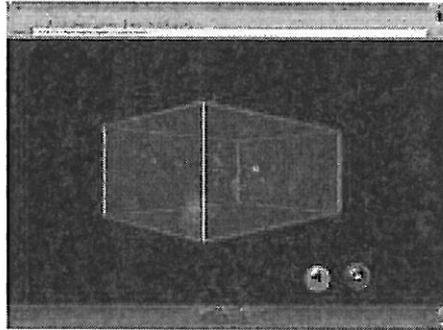
3.2.2 Development tools
Virtual Reality Modelling Language (VRML) was used as the VR development tool, Discreet's 3D Studio Max 3.1 as the 3D modeller and Microsoft Internet Explorer with Cosmo Player 2.1.1 plug-in installed as the delivery system tool. The interfaces were shown in Fig.4, Fig.5, Fig.6 and Fig.7.
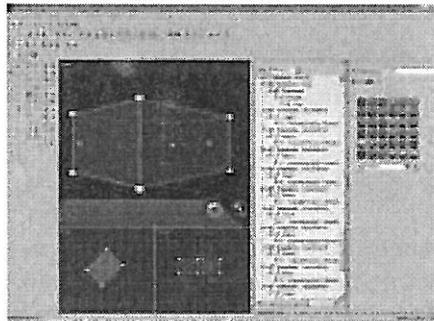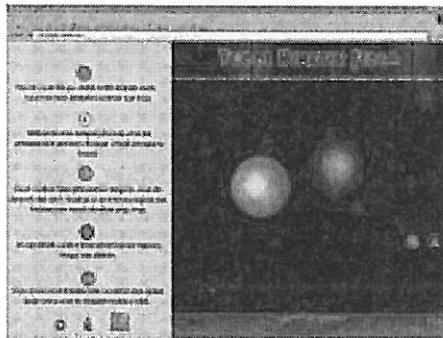

Fig.4: VRML Editor - Cosmo World 2.0
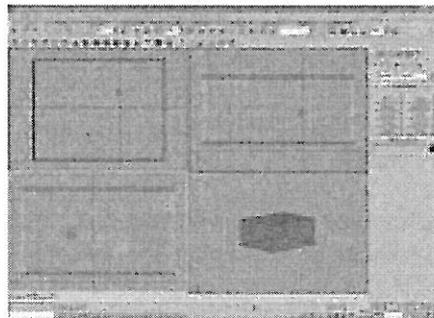
Fig.5: 3D Modeller - 3D Studio Max 3.1

Fig.6: VRML Player-Cosmo Player 2.1.1

**Fig.7: Cosmo Player 2.1.1 Plug-In Integrated With
Microsoft Internet Explorer**

3.2.3 Prototyping

In developing the prototype 5 methods have been followed. The methods are storyboarding, modelling, animating the models, export animated models to VRML editor and lastly preparing the user interface.
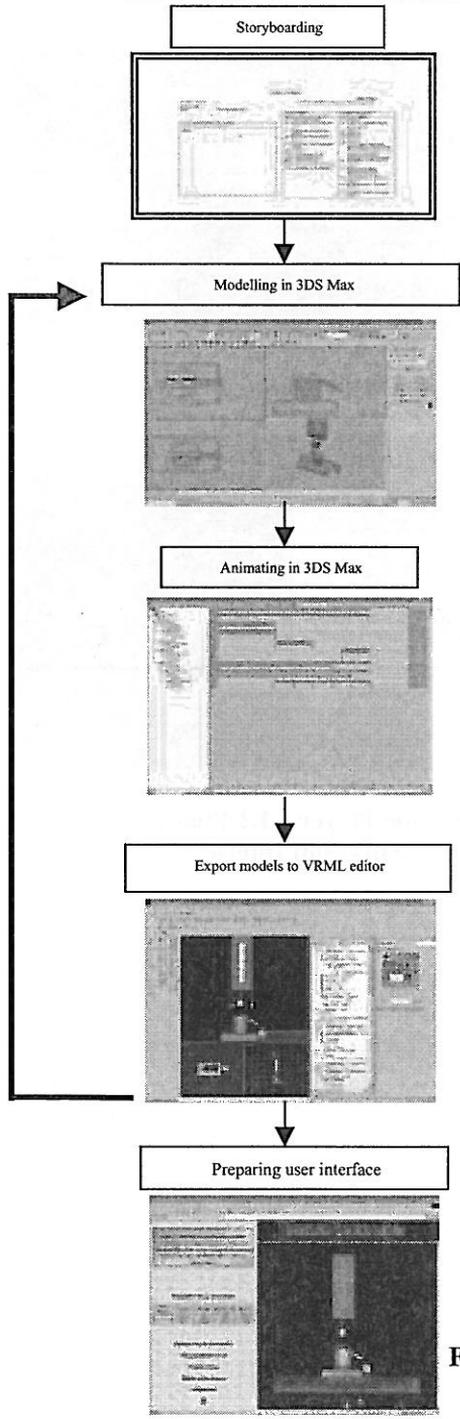
Fig.8: Flowchart of the Methods Use

3.3   Testing and Evaluating Phase

Testing and evaluation phase is conducted to investigate the effectiveness of the virtual environment as a learning tool to assist traditional teaching delivery methods. It is also carried out to get feedbacks on the usability of the learning tool concerned.

The testing and evaluating phase has been successfully completed in January 2002.

3.3.1 Location and Subject
A total of 80 respondents were involved in this evaluation study. The respondents were chosen from 8 schools selected earlier. They were Form-5 students in the science stream from SMK Jitra, SM Sultanah Asma, SMK Agama Kedah, SM Teknik Jalan Stadium, SMK Kepala Batas, SMK Hosba, SMK Changlun and Maktab Mahmud.

3.3.2 Research Instruments
The research instruments used for the evaluation purposes were questionnaires and conceptual understanding tests. The test was divided into two, namely a Pre-test and a Post-test. The Pre-test was conducted to test students' understanding of two particular concepts and the Post-test is to test their understanding after using the system. The hypothesis made here is, if the result from the post-test is higher compared to that of the pre-test, the system has affected student understanding and VR is effective as a learning tool. Sample of the pre-test and post-test questions is attached in Appendix B and C.

T-test was used to measure the difference between the results gathered from the test.

3.3.3 Results
The results obtained from the two tests showed a significant level of increase where the p value is in a range of 0.01 to 0.05. The post-test showed that students yield better results as compared to the pre-test. Fig.9 shows the graph comparing the results from those tests for Maktab Mahmud.
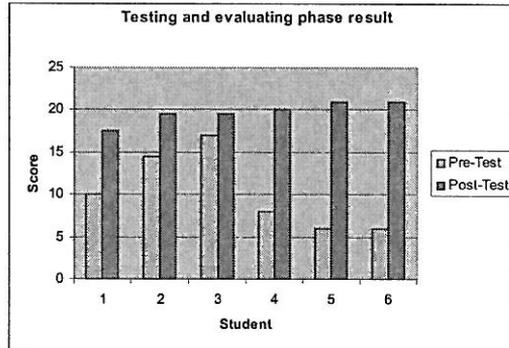
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Fig.9: Maktab Mahmud Testing and Evaluating Result from 6 Students

Results obtained from the questionnaires show that the respondents are able to navigate and understand the learning tool. Most of the students agreed that this method of learning can give positive impact to them. 58% strongly agreed and 33% agreed. Fig.10 describes responds from students on the effect of the system to them.
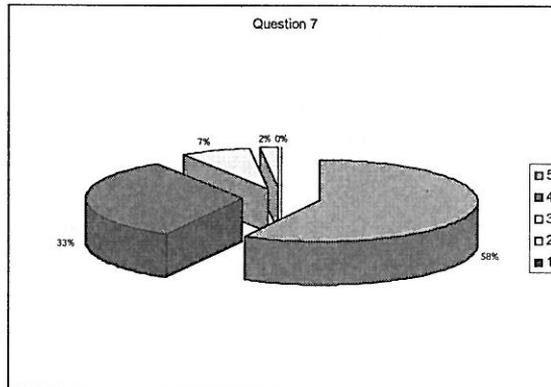

Fig.10: Overall Results for Question Number Seven in the Questionnaire (Appendix D)

4.0   CONCLUSION

Hewitt (1991) stated that education using VR as a teaching tool involves creating, experiencing and sharing a computer-generated world as realistic or as fanciful as the user can imagine. To understand how to help the students master

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complex scientific concepts and to examine the general nature of learning is vital. Firstly, the prerequisite of learning is attention. Students must focus on or be engaged in an experience in order for learning to occur. Secondly, meaningful representations are necessary to communicate information (Kozma *et al.*, 1997). Finally multiple mappings of information can help to enhance learning (Dede *et al.*, 1999).

The existence of virtual labs utilizing VR technology as a teaching tool is hoped will spark a new dimension in the method of teaching science subjects. With the positive growth of a low-cost high performance computer system, VR is expected to be the next step in the computer user interface evolution.

The Virtual Physics Lab is no other than an alternative of a meaningful representation to communicate information and is one of the methods of the multiple mappings of information. It is foreseen that when VR is introduced into the Malaysian educational system, the results from this research will be one of the valuable resources to assist the growth of the government's 'Smart School' project.

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