SCENARIO-BASED MUVE FOR SCIENCE INQUIRY

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ABSTRACT
The development of scientific inquiry skills is a core element of the draft national science curriculum for Australian secondary school students. Yet, despite the prominence of inquiry learning in the curriculum, the use of integrated classroom technology to facilitate inquiry learning is difficult for teachers to implement successfully without support in Australian secondary schools. The purpose of the Virtual Worlds project, which commenced this year, is to conduct learning and cognitive sciences-based research into the potential of scenario-based Multi-User Virtual Environment systems to promote, and perhaps enhance, secondary school learning experiences. In this paper we consider a number of existing science education-based multi-user virtual environments and introduce our project including our goals, approach and scenario underpinning the virtual world.

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INTRODUCTION
The difficulties that students experience learning science, as well as the low overall interest in science that many students have, are well-documented (Barnett, Barab, & Hay, 2001; Bransford, Brown, & Cocking, 2000; de Jong & van Joolingen, 1998). There have been many arguments advanced about the potential serious consequences of a pervasive lack of understanding of important scientific perspectives both for individuals and for an informed citizenry that must increasingly deal with a variety of local and global challenges concerning interconnected social and physical systems (Jacobson & Wilensky, 2006; Rutherford & Ahlgren, 1990). Of course, no single panacea can possibly address the multitude of cognitive, pedagogical, and social factors that contribute to the decline of students' interest in, and the poor overall level of understanding of science.

However, several research studies suggest that great potential exists to help address issues, such as a general lassitude towards science, through the educational use of appropriately designed digital media sometimes referred to as a "3D" game or multi-user virtual environment (MUVE) that can run on currently available multimedia and Internet capable computers in schools and homes (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Barab, Warren & Ingram-Goble, 2006; Dede, Clarke, Ketelhut, Nelson & Bowman, 2005a). In fact, the 2009 Australia – New Zealand Horizon report (2009) indicates that virtual and alternate realities are one of the technologies to watch over the next five years in classroom education as they are proving to be an effective means of attracting and gaining students' attention and interest. To ensure engagement, we are particularly interested in scenario-based MUVEs, such as Quest Atlantis (Barab, Warren & Ingram-Goble, 2006), River City (Dede, Clarke, Ketelhut, Nelson & Bowman, 2005a), and Virtual Singapura (Jacobson, June Lee, Hong Lim & Hua Low, 2008), that are underpinned by a scenario and are more akin to a role-playing game than a virtual lecture or meeting room. In this paper, after providing an overview of research on science learning in MUVEs, we introduce our project that is aimed at the investigation of centrally important issues related to learning in MUVEs, and to provide practical approaches for their integration into Australian science education classrooms.

OVERVIEW OF RESEARCH INTO LEARNING IN MUVES
Educational researchers have recently argued that the affordances of highly interactive game-like systems are well suited to support many of the recommendations emerging from learning sciences and educational research related to how students learn (Barab, Thomas, Dodge, Carteaux, & Tuzun,

2005; Jacobson, June Lee, Hong Lim, & Hua Low, 2008; Jacobson, Kim, Miao, Shen, & Chavez, 2009; Ketelhut, Nelson, Clarke, & Dede, 2010; Squire, 2005; 2004). Indeed, the question seems to be not whether or not to use the technology in education, but rather what is the best way to use the technology in terms of effectiveness (Squire, 2005).

Given the motivational and active learning potential of MUVEs or interactive game systems, researchers have begun to develop highly interactive 3D environments that are aligned with specific content in school curricula, rather than attempting to repurpose existing commercially available games. For example, Squire, Barnett, Grant and Higginbotham (2004) conducted a study in which 61 students used a game, *Electromagnetism Supercharged!,* to learn science content related to electrostatics, while 35 students in the comparison condition did not use the game. Students in the experimental condition scored significantly higher on conceptual items related to electrostatics on the posttest compared to the comparison condition. No significant gender differences were found. Other qualitative findings were that both boys and girls were initially eager to play the game, but that many boys lost interest by the second day once they felt they had “beat” the game. Interestingly, girls were less interested in “playing-the-game-for-points” mode and instead explored the game as a simulation in which they collaboratively worked to record their actions and to share their results with student peers.

Quest Atlantis (*QA*), employs a scenario-based educational MUVE environment that allows students to travel in a virtual space to perform in-class or after school educational activities, talk with other students and mentors, and build virtual identities (Barab et al., 2005). Students have been found to be motivated when engaged in *QA* “quests” and to respond to the narrative aspects of the immersive experience more so than the “game-like” features (Barab et al., 2005). Also, a study of sixth grade students in the U.S. who used *QA* found statistically significant increases in the students’ conceptual knowledge of cells, while another study found students constructed solid understandings of ecological concepts such as erosion and eutrophication after using the *QA* Anytown unit (Barab et al., 2005).

In a study of the *River City* MUVE involving the participation of approximately 700 students in grades five to eight in two different U.S. cities it was found that the experimental group students who used *River City* over a two-week period had significantly higher science content knowledge and science inquiry skills gains compared to the comparison condition students who used a paper-based version of the science inquiry curriculum. A large proportion of the students came from low SES communities, so another important finding in this study was that compared to the control group, students in the experimental group were highly engaged in their learning activities with the system, had improved attendance and less disruptive behaviour, and made significant learning gains. Overall, these findings, which have been substantiated by recent research (Ketelhut, 2010), suggest that the use of an engaging scenario via a multi-user virtual environment offers a learner-centred pedagogical approach that can enhance student academic achievement and may particularly help teachers to reach students struggling with motivation, self-worth, and lack of content knowledge. However, Dede et al. (2005a) also stress that important research is still needed in order to explore how students might better transfer or apply subject specific knowledge and skills learned in immersive virtual environments to new situations and contexts outside of the virtual.

RESEARCH FRAMEWORK, AIMS, QUESTIONS AND APPROACH

Science is often presented to learners as a body of information and facts to be remembered; a strategy that provides learners with little opportunity to engage and process the information (Siorenta & Jimoyiannis, 2008). Science teachers acknowledge that there is a difference between ‘doing’ science and science education (la Velle, Wishart, McFarlane, Brawn, & John, 2007). The challenge, of course, is how to implement research-validated and authentic pedagogies for learning core subject knowledge and skills in ways that are logistically viable in formal and even informal learning environments. The use of technologies, such as MUVEs, in a science classroom may better foster scientific habits than traditional pen and paper activities as students have the opportunity to simulate science processes, such as data collection, without the real world messiness or risk of harm (Bainbridge, 2007; la Velle et al., 2007).

The research methodological framework underlying this project is design research involving the use of two different educational MUVEs (described below) in secondary school classrooms and in teacher education courses. Design research involves conducting formative studies in real world contexts such as classroom environments that test an innovative theory or research based educational design, and that in turn iteratively refines the design of the learning environment over time (Brown, 1992; Collins, Joseph & Bielaczyc, 2004). In terms of learning theory, the design of the technology and the curriculum are informed by general learning sciences theories such as situated cognition (Brown, Collins & Duguid, 1989) and distributed cognition (Salomon, 1993) as well as what might be called “focused” cognitive theories of conceptual change (Salomon, 1993), and knowledge transfer (Bransford & Schwartz, 1999; Gick & Holyoak, 1987). More recent cognitive and learning sciences theoretical perspectives that have important pedagogical implications, such as analogical encoding theory (Gentner, Loewenstein & Thompson, 2003) which suggests that analogies promote attention to commonalities between objects, activities and concepts and productive failure (Kapur, 2008) which suggests that using low structure in the initial phase of a problem can result in deeper learning, will also ground some of the specific experiments to be conducted and be directly relevant to the first two research questions given below.

This project aims to conduct learning and cognitive sciences-based research into the potential of MUVE systems to promote and perhaps enhance secondary school learning experiences. To achieve these aims and based on issues identified in the literature, three central research questions related to the integration of immersive virtual environments in Australian classrooms are being investigated in this project:

- *First, how might learners construct deep and transferable understandings of important and challenging scientific knowledge and skills through specifically designed pedagogical experiences involving immersive virtual learning environments?*
- *Second, how might science learning activities involving MUVEs motivate students both to learn science knowledge and skills as well as to develop positive attitudes and predispositions towards science?*
- *Third, what roles will teachers assume when teaching with MUVEs and what types of professional development and support will they need in order to effectively integrate and use MUVE systems in their classrooms?*

The approach to be used in this program of research is to conduct classroom-based, quasi-experimental research studies into the efficacy of multi-user virtual environments to help students learn content knowledge and skills in ways that are deep, adaptable, and transferable. The main research contexts for the project consist of Australian secondary school classrooms.

The role of teachers is pivotal in the successful integration of technology into a classroom setting (Becta, 2004; Urhahne, Schanze, Bell, Mansfield, & Holmes, 2010; M. Webb & Cox, 2004; M. E. Webb, 2005). In this project science teachers from government and private secondary schools in New South Wales are currently collaborating with the research team on the design of the scenario, activities and assessments. Regular meetings with the science teachers have involved the training of staff in the use of *Virtual Singapura (VS)*, the scenario-based MUVE we are utilizing in the first year of our project as discussed below, so that teachers are familiar with the type of technology that can be used in science learning and can provide input on how to design the materials that meet the needs of the students and address the outcomes of the curriculum. This project has also involved several trials with pre-service teachers both to pilot the materials as part of the ongoing cycle of iteration and to gain an understanding of user processes.

We hypothesise that as a result of this level of teacher and state education level feedback and interactions that the participating teachers and schools will feel more “ownership” and long-term positive interest in the project’s virtual learning environments and innovative pedagogical approaches, and thus be more receptive to the professional development experiences that will be provided before the research implementations, in contrast to other research that has shown technological innovations in schools are often perceived as a distraction or imposition on the teachers who consequently resist initial and/or subsequent uses of these approaches (Henriques, 2002; Lee, 1997). We also hope that having an experienced cohort of teachers from the first year of the project will help with recruiting and training teachers to be brought into the project in other schools in the second and third years of the project.

MUVES AND LEARNING IN AUSTRALIAN SCHOOLS

Currently available commercial 3D virtual environments are almost exclusively oriented to "gaming" experiences that students (and many adults) find exciting and challenging, but which unfortunately are not aligned with subject specific knowledge and skills that students must learn in formal school settings (Dede et al., 2005a; Kirriemuir & McFarlane, 2004; McFarlane, Sparrowhawk, & Heald, 2002). Consequently, in order to conduct research into learning with MUVEs in Australian schools, it is necessary at this time to utilise non-commercial educational MUVEs that have been developed as part of prior research as well as to develop a new Australian-oriented MUVE. This project is employing both approaches.

The project is initially utilising *VS*, a scenario-based MUVE prototype built in ActiveWorlds[1] which has already been successfully deployed in classroom settings in Singapore. *VS* provides an environment in which secondary students learn science inquiry skills such as proposing research questions, hypothesis formation, identification of dependent and independent variables, analysis of data, and interpretation of findings in relationship to hypothesised outcomes as well as learn about communicable diseases and the impact of humans on the environment. The scenario for *VS* is based on historical information about disease epidemics in 19th century Singapore, which are similar to those in Sydney during the same period. In this virtual world, 21st century students go back in time to help the 19th century Governor of Singapore, Sir Andrew Clarke, and the citizens of the city figure out what is causing various illnesses and to propose viable 19th century solutions to stop the epidemics. When students teleport back to 19th century Singapore, they arrive at the Boat Quay in 1874 and then use their avatars, which are computer generated characters on the screen that they control and communicate through, to explore portions of the historical city that include the Tan Tock Seng Hospital (Chinese Pauper Hospital), rickshaw tenement houses in Chinatown, houses in the wealthy European neighbourhood, and so on.

As the 21st century student scientists investigate the causes of diseases that manifest during different seasons of the year, they meet computer-generated *VS* citizens (i.e., programmed to be adaptive with intelligent agent technology) and visit various locations in the city to view pictures (that include written descriptions and information relevant to the inquiry activities), inspect various digital objects to gather information, and obtain air, water, and bug samples at virtual data collection stations (see Figure 1). The students communicate with their team members (usually in groups of four) using a group-chat function and can also chat with the various 19th century agents they meet, such as the doctor and nurse in the hospital, coolies on the street, a scholar at the medical school, the poor mother of a sick child, and so on. There is also a *VS* Lab Book that currently introduces students to aspects of inquiry learning such as data collection, making observations, evaluating data and making recommendations.

The *VS* MUVE was developed so that students in secondary classroom settings could easily use it, and it also has a number of research design features to collect specific types of data to investigate both the learning outcomes as well as learning processes or trajectories associated with the experiences that students have in the virtual environment. For example, log files are automatically collected as the students communicate with their team members using the group-chat function or when they interact with the various 19th century characters. Also, log files of all location information are collected for each of the students' avatars and screen capture software with webcams and microphones are used to record exactly what is on the screens as students use *VS* as well as video and audio of any conversations they may have with fellow students, teachers, or members of the research team. This process data, in turn, is used to complement the analysis of pretest and posttest summative assessments related to the research questions regarding learning for deep understanding of scientific knowledge and skills and knowledge transfer in virtual environments. Results involving the use of *VS* by grade seven students in Singapore found that all of the students were highly motivated by the experience in the virtual environment (Jacobson et al., 2008).

[1] http://www.activeworlds.com/

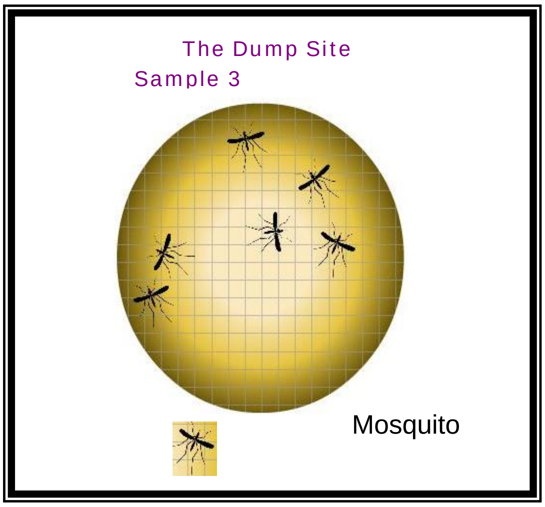

Figure 1: Virtual Singapura bug catcher

Figure 2: Predator Model created in Unity3D

We are currently developing a new virtual world with Australian-themed scenarios using the game development tool Unity3D[2]. The topics being considered include: Year 8) ecosystems; Year 9) diseases; and Year 10) evolution. These topics have been identified and suggested by the science teachers in our focus groups. While these scenarios are currently more focused in the biological sciences, we intend to develop modules for physics and chemistry content. To this end, as part of this Discovery project and specifically as the focus of a concurrently running Linkage Project with the Centre of Learning Innovation in the New South Wales Department of Education we are currently developing a number of simulation models that will be incorporated into the Australian MUVE. All three school years have common skills concerned with scientific inquiry: hypothesis, investigations, experimental design, the use of secondary resources and data, using equipment, managing risk, collecting data including ICT, analysis, conclusions and communications. The initial in-world activity is being developed for Year 8 science with additional activities being developed in years two and three of the project. The new virtual world is based on the national science curriculum that will be implemented into Australian schools in 2011.

As in *VS, RiverCity* and *QA*, we have an overarching scenario, the students will work for the Intergalactic Environmental Preservation Association (IEPA). The students will be part of a team of interstellar scientific detectives working for the IEPA. As the team travels around the galaxy they are given certain problems to solve. For example, the team is asked to visit a small terrestrial planet where several species of mega-fauna, that once thrived, are disappearing. The team's job is to discover what the possible reasons are for these disappearances. The students will be able to interact with a hunter, ecologist and climatologist that live on the planet. They will also be able to observe animals hunting, interact with virtual timelines and biological records and run population models. As an example, in Figure 2 we show a predator model involving grass, sheep and wolves which we have developed in Unity3D as a prototype to allow students to model the behaviours and relationships between these populations. There is a progression in concept development as students move from one problem to another. The initial problem will investigate the impact of humans on an environment, the second and third problems will investigate the impact of disease and climate change on animal populations.

CONCLUSIONS

Through focusing in particular on how students might better and more deeply learn knowledge and skills for transfer to new problems and settings as part of theoretically grounded virtual pedagogical experiences, the project seeks to understand how people learn in general and in these specific types of innovative digital media learning environments. The practical significance of the project lies in the fact that there has been little research into how Australian students might learn in these newly

[2] http://unity3d.com/

available and innovative multi-user virtual environments and the sustainability of MUVEs in the longer term. In addition, there has been little work into opportunities and challenges that in-service Australian teachers might face as they begin to learn about and to integrate technological and pedagogical innovations such as MUVEs into their current and future classes.

At the conclusion of the project, there will be sets of pedagogical modules with virtual learning environments for subject topics in science that will have been designed in conjunction with the collaborating teachers and with the Centre of Learning Innovation in the New South Wales Department of Education, which we expect should then be adaptable for more general dissemination to other schools in NSW and in the other Australian states that are linked to the national science curriculum. We also hope the design research approach used in this project might serve as a model for how innovative learning technology and teaching approaches might be iteratively researched in real classroom situations in ways that can, if warranted based on research findings, be implemented more widely in practice longer term.

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