VIRTUAL FIELD TRIPS IN SCIENCE: WHY STUDENTS WOULD RATHER TAKE THEM THAN LEAVE THEM

Anne Jelfs, Denise Whitelock

ABSTRACT
Virtual Field trips open new possibilities for instructional designers to create more interactive worlds for learners. However is the interactivity afforded by such desktop systems for users sufficient for learners to feel they were worthwhile study experiences? Three virtual field trips are examined in this paper. They have all been developed for the Open University undergraduate science courses and make clever and innovative use of QuickTime VR to allow students to enter three contrasting worlds. Two of the programs are from the Biological Sciences and illustrate the complex sets of relationships that exist within natural habitats. One of the Biological science virtual trips introduces the student to an idealised world found at the bottom of the Ocean in the North Atlantic Ridge. While the other represents all the flora and fauna found in a British Oakwood. The third virtual excursion consists of a visit to the county of Devon, in England, on a Geology field trip, where students examine three contrasting sites of geological interest. The principal notion to be understood here is how the structure of the underlying rocks contributes to the larger landscape. Learning gains have been ascertained from pre and post test cognitive scores obtained from questionnaires. Perceived learning was also measured with a post experience questionnaire, together with observational data taken from video recordings. The findings are very interesting in that students felt they learnt more from the virtual environment than standing out in the cold waiting to sight a deer in the Oakwood or from sketching a geological terrain. However, when it came to dealing with rock samples students wanted the real thing. This paper describes the advantages and disadvantages of using virtual science field trips. These factors are discussed with respect to interface design and task structure in order to make recommendations about how the interface can be constructed to assist navigation and to provide tools for exploration. More importantly, if Virtual Environments are to be used to promote conceptual learning, then the nature of the feedback given to the students about their actions in such environments needs careful consideration.

KEY WORDS
Virtual environments, presence, fidelity

INTRODUCTION

Virtual Environments open new possibilities for instructional designers to create more interactive worlds for learners. In fact a great emphasis is placed upon interactivity by a number of educational theorists. For example, Piaget (1930) stresses the role of action upon objects, whereas Bruner (1966) takes a more conceptual view and emphasises the importance of the categorisation of actions in learning environments. While Vygotsky (1962) recognises the social aspects of learning, particularly highlighting action upon others. As with all these theoretical positions, it is often difficult to translate these theoretical notions into real classroom experiences and raises the question of whether the ability to interact and manipulate objects in a new software environment is going to be enough to promote conceptual learning.

Hence, what are the parameters of a Virtual Environment that will afford interaction for conceptual learning? (In this instance conceptual learning is defined as a conceptually-orientated method of learning, where specific scientific content is understood and later manipulated by the subject: as opposed to the subject gaining procedural skills from working with a training environment). These parameters could well be different from those needed to produce a training environment which could have merited commercial success, such as pilot training (Krueger 1982).

The parameters which Whitelock et al (1996) selected to create a model that compares salient properties of virtual systems are: representational fidelity; immediacy of control and presence. These parameters build upon Zeltzer's (1992) notions of autonomy, interaction and presence. The term Presence is adapted from 'telepresence' which Marvin Minsky (1980) used to refer to technology that provided the user with a remote presence. Presence does not refer to one's surroundings as they exist in the physical world, but to the perception of those surroundings (Steuer 1992). Steuer refers to telepresence as the extent to which one feels present in the mediated environment, rather than the immediate physical environment. This means that the dependent measures of virtual reality must all be measures of individual experience providing an obvious means of applying knowledge about perceptual processes and individual differences in determining the nature of virtual reality (Steuer 1992). The more an individual is aware of the interface then the harder it will be to achieve a high level of telepresence. To lessen the awareness of the interface, there needs to be increased level of presence. In 1991, the term was adapted and shortened when the journal Presence was founded and by 1997 a review by Lombard and Ditton identified six conceptualizations of presence: social richness; realism; transportation; immersion; social actor within medium and medium as social actor (Lombard, Ditton et al 2000). The view on presence we are adopting is that of Steuer, i.e. the extent to which one feels present in the mediated environment.

Building upon the earlier theoretical work, Whitelock (1999) found that when students used two desktop virtual environments, the students learnt more in one environment than the other. The two environments were called Oak Wood and The North Atlantic Ridge. Oak Wood required the student to investigate an English wooded habitat with a complex eco-system. The ground layer of the wood was occupied by a large number of diverse organisms, where the oaks supported a variety of species and the dead wood contained other organisms. The North Atlantic Ridge environment required the student to explore, via a submarine, the bottom of the ocean. Students could explore the terrain for geological structures and biological life in seven major locations along the Ridge. The expert designers rated the Oak Wood system with higher representational fidelity than the North Atlantic Ridge. The Ridge would be unfamiliar terrain to students and therefore on the scale of representational fidelity it received a low rating. However, Oak Wood had a lower rating for immediacy of control than North Atlantic Ridge.

This study found that students learnt more in the Oak wood environment than with the North Atlantic Ridge. This might be attributed to the tighter task structure and more elaborate feedback, but students' perceptions of engagement and learning were higher in the North Atlantic Ridge environment, yet, experts rated them the same. However, the difference was the students' perceptions of the degree of presence afforded by these two environments. There was a higher notion of presence in the North Atlantic Ridge experience rather than in the Oak Wood software. Why should this occur? One suggestion is that higher immediacy of control is a confounded variable within a cluster of attributes that define presence in virtual environments. In order to probe this latter hypothesis we have developed a further study with a third desktop virtual environment 'Earth Science Field trip to Devon' to probe what features of this virtual environment contribute to the notion of presence and how this complex parameter interacts with students conceptual learning. Hedley et al (2002) used a similar model to our study where they had users who could look at a real map and also view a three-dimensional virtual terrain. In our study we have used our findings from our earlier studies and are compared with the same student users working through some other multimedia materials on this science course.

SYNOPSIS OF SOFTWARE CONTENT

North Atlantic Ridge

The North Atlantic Ridge software was a desktop virtual environment, developed in *MTropolis.* The submarine could move in all four major directions of the compass, North, South, East and West. Speed of travel varied on how quickly one moved the mouse across the screen and there were two views of the proceedings. One was the view from the submarine which filled most of the screen, while the other comprised a plan view of the submarine itself and where it was located presently in the Ridge. Students were asked to navigate around the Ridge investigating the geological structures together with the flora and fauna. Tasks were then associated with these different features.

Oakwood

The Oak Wood program presented the students with a complex habitat which would take many days out on a field trip to study and even then not all the species would necessarily be observed. The program presented the user with a large number of species to investigate and, from their inter-relationships, concepts such as ecosystems, food chains and energy transfer levels could be appreciated. The first part of the program introduced the students to a number of species in the wood and provided them with a field guide which was used as a resource for further study. The second part asks them to create a mini food web with respect to the life cycle of the sparrow hawk.

Geology Field Trip to Devon

This program provided students with a Virtual Geology Field Trip. It introduced them to the methodological approach adopted by researchers in the field when they visit a new location and, in fact, gives students a three point plan to follow when taking field notes.

1. Stand back and make a note of geological features you can see from a distance i.e. colour of rock and layering of cliff etc.
2. Take a closer look at the panorama.
3. Finally observe the rock sample.

The students are given the opportunity to apply this methodological approach at three different sites, namely Dawlish, Budleigh Salterton and finally Aust Cliff on the Severn Estuary. They are advised to visit Dawlish first and Aust Cliff last. In that way they will study the rocks in their correct age sequences. Dawlish has the oldest rocks while Aust Cliff the youngest.

After working through these three locations, students were given two examples of a site sketch and then asked to try to sketch one of the sites in the light of the tutorial they have received.

METHODOLOGY

The virtual environments were developed together with a suite of multimedia programs to support undergraduate science students, studying a distance learning course with the Open University. All the programs were subjected to a formative evaluation and the same methodology was adopted for the whole testing series. A core group of subjects became expert testers as described below; there were real advantages to using experienced subjects in this way. This is because the subjects became familiar with the experimental set-up, were used to being video-taped and felt they were not being examined personally but were testing the various learning environments' usability to their limits. Since both the methodology approach and cohort of subjects were similar in the testing of all three virtual environments, these procedures are not described separately, but are detailed below in one Methodology section.

Procedure

The subjects were pre-tested with a written questionnaire for each virtual environment studied. This test instrument, which was also used as the post test, was constructed in collaboration with the academics and designers of the software in order to understand what the students knew before they interacted with the VE and secondly, whether they had attained the main learning objectives that the software had been built to achieve.

After completing the questionnaire, the subjects worked with the virtual environment and they were all video-recorded throughout the experiment sessions. After working through the activities, they were asked to comment on what they enjoyed and disliked in the environment, and to comment upon their sense of presence in the virtual environment and to offer recommendations for suitable changes with respect to ease of use and understanding of the subject material. All then completed a post test in which all the pre-test questions were repeated. They then completed another questionnaire where extra information about their perceptions of the whole experience was recorded, including what they thought they had learned from interacting in the virtual environment.

Participants

All the participants in this study, eight in total, had the required scientific background to understand these programs. In fact they had followed and passed the Open University's Science Foundation Course the previous year. They worked with two other programs before embarking on this test regime which required them to work with these seven different programs. The testers were therefore, familiar with the testing regime and consider themselves as 'expert testers' and freely criticised features that they felt were unhelpful in learning with these multimedia materials.

One tester considered him/herself as an expert computer user while another was a complete novice who had only used computers in these testing sessions. The six others rated themselves as competent users who used computers on a daily basis through the course of their employment, and their self-assessment revealed an accurate measure of their experience with respect to later task performance measures.

RESULTS

All three desktop computer programs illustrated a difference in the Presence ratings. The North Atlantic Ridge was considered by the students to be extremely engaging. They felt they were moving around in this strange world on the ocean floor. (See also findings from Jelfs & Whitelock (2000) and Jelfs & Whitelock (2001)). The sense of Presence was reduced for the Geology field trip to Devon and paralleled the rating given for Immediacy of control. This is an important finding because the students' explanations of that latter rating were that they could not focus sharply enough on the rock samples to make accurate enough deductions about their crystalline structures. This data suggests that the variables of presence and immediacy of control, i.e. focusing, are not orthogonal and that maybe as designers of virtual reality systems for conceptual learning it would be better to investigate differences in feedback as the third variable and collapse the notion of presence with immediacy of control.

The findings illustrate a difference in presence and the other parameters.

Table 1. Ratings attributed to the dimensions of presence, representational fidelity and immediacy of control for three different desktop Virtual Reality environments

Variable of Science Multimedia	North Atlantic Ridge	Oakwood	Earth Science Field trip to Devon
Presence	9	7	6
Representational Fidelity	8	9	7
Immediacy of control	9	6	6

How did they learn with these programs?

The Geology field trip software had more structured tasks with lots of feedback. However, the main difficulties were the users' inability to zoom in and out enough to see the fine detail in the rocks as accurately as students' wished. They did however feel they had learnt about the subject matter more quickly with the CDrom than actually being on site. This was because it would be more uncomfortable in real life to collect the data (particularly for disabled and older students) and they were also more likely to be blown over and soaking wet, this is England after all, if they were attending the real field trip!!

Table 2. The Cognitive Change Scores and On Task Performance Measures for Science Multimedia Programs (VR)

Name of C.D. Rom	Cognitive Change Score	On Task Performance Measure
Oakwood	4.4	5.8
North Atlantic Ridge	2.6	4.0
Earth Science Field Trip to Devon	5.4	7.1

With respect to cognitive performance the Geology field trip out performed the other two programs (see Table 2). A reduced sense of presence with good representational fidelity appeared to afford better learning gains. This points towards a sense of 'being there' (Jelfs & Whitelock 2000) as not enough if it distracts you from the learning activities.

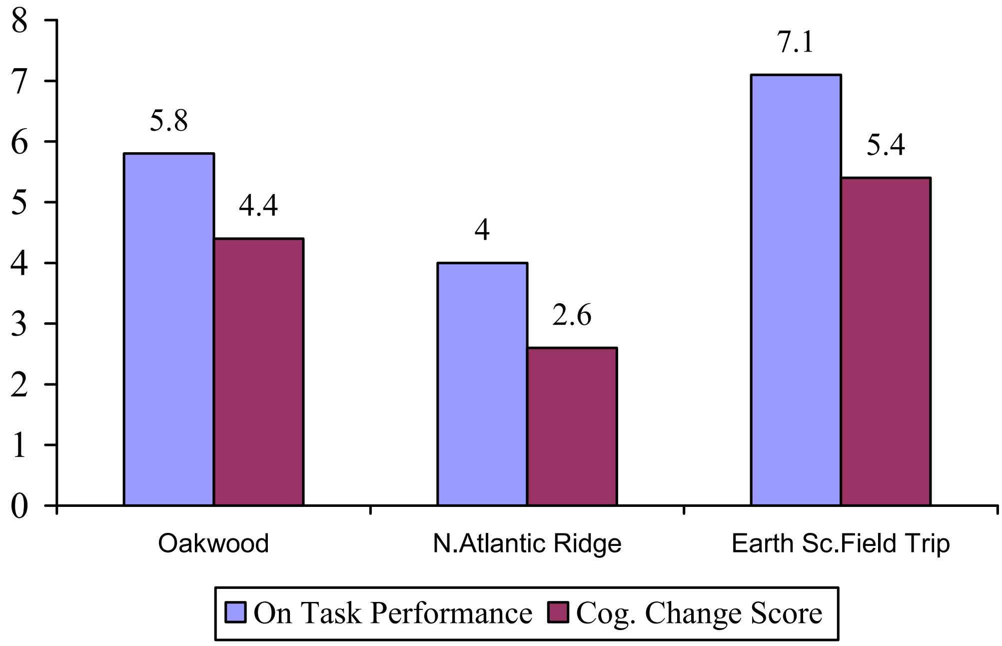

Figure 1. Graph to illustrate the Cognitive Change Scores and On Task Performance Measure for Science Multimedia Programs (VR)

In order to check the above hypothesis, that high presence can confuse or add to students' difficulties. Another set of science programs were tested by the same group of students. These multimedia programs were taken from the following science disciplines; Biology, Chemistry and the Earth Sciences. It appears here that a lower presence value (see table 4), can lead to higher cognitive change scores. For example the manipulation of organic chemistry models which students rated as having the lowest presence score resulted in the highest cognitive change score and on task performance measures. The presence rating in itself should not be ignored as we have found that students find working with virtual systems with a high presence value to be the most engaging and motivating (Jelfs & Whitelock 2001). They also feel that they have learnt more with these programs. So how can we compensate for students not performing so well with the high presence virtual reality programs?

The introduction of conceptual compasses as well as navigational compasses suggests itself as a possible solution. This means constraining the virtual reality tour more at key spots. Introducing tasks that make more explicit that the student is now entering the 'theory world' of science and providing graduated feedback to a number of critical exercises that should be given to the student in these VR programs

The following table (table 3) indicates that when using interactive multimedia, the values of high presence, representational fidelity and immediacy of control are related. It appears that high presence ratings affect the perceived levels of immediacy of control. For example in table 4 it can be seen that seismic waves which was a very visual program making full use of animation to illustrate the different types and properties of seismic waves. Had a large number of interactive tasks that were designed to check student understanding. In this case the presence value was only 1.1, but the cognitive change score was 7.3.

In the case of 'Organic molecules', this program allowed students to build 2 and 3 dimensional models of the products of organic chemistry reactions. The advantages were that they could not build the wrong model and could see more clearly the active sites for the reactions.

Whereas for the Galapagos Islands it included viewing and completing tasks with different species found on the islands to understand the development of Darwin's theory of evolution.

Mitosis and Meiosis was an animation driven program which taught cell division together with gamete formation.

Table 3. Presence, Representational Fidelity and Immediacy of control measures for Science Multimedia Programs (Non VR)

Variable of Science Multimedia	**Galapagos**	**Organic Molecules**	**Mitosis and Meiosis**	**Seismic Waves**
Presence	6.8	2.7	2.1	1.1
Representational Fidelity	7.3	6.4	6.2	5.5
Immediacy of control	1.8	7.1	5.2	3.6

Table 4. The Cognitive Change Scores and On Task Performance Measures for Science Multimedia Programs (Non VR)

Name of C.D. Rom	**Cognitive Change Score**	**On Task Performance Measure**
Galapagos	5.8	7.8
Organic Molecules	6.2	9.1
Mitosis and Meiosis	4.4	5.6
Seismic Waves	7.3	8.9

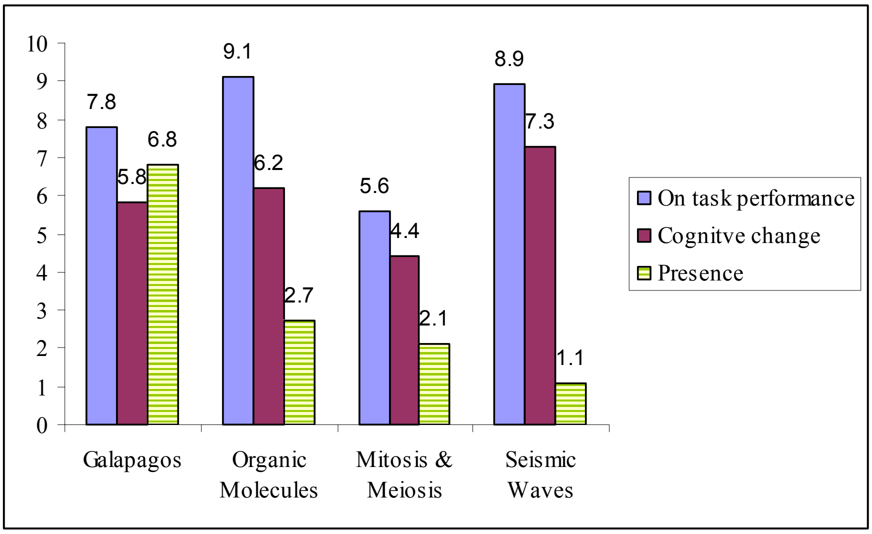

Figure 2. Graph to illustrate the Cognitive Change Scores and On Task Performance Measures for Science Multimedia Programs (Non VR)

CONCLUSIONS

In conclusion, we found that students enjoyed working with these programs. Virtual reality provided them with opportunities that they had previously been excluded from due to dangerous situations etc. The immediacy of control and feedback enabled the students to feel 'there' and to some extent the increased levels of Presence impacted on understanding and cognitive change. We also recognised the need to provide signs and pathways to students, as navigational compasses, and to restrict their movements to essential learning areas. There is less constructivist learning, but it does provide the type of support and guidance recommended by other researchers such as Corbit (2002).

From our findings we think there are a number of metrics that need to be considered and discussed further in the design and pedagogical reasons for using virtual reality programs for teaching. We have found that the theoretical model provided some benchmark data, but what we need to do now is to untangle the salient parameters. One of our most important suggestions to program designers and to instructors is to provide navigational and conceptual compasses to enable students to understand where they are and where to go next. We need to gain further understanding of what these compasses involve. Questionnaires to students have the potential to assist in the development, but as Usoh, Cateno, Arman and Slater (2000) found questionnaires, although valid in specific environments, are doubtful when used as comparison tools across environments. For example when used to compare desktop environments and immersive environments. We are now considering a number of questionnaires for our future work.

Our future work is based on trying to understand if the need for conceptual presence is more important than physical presence. If this is true, then the use of interactive programs can enhance and provide good pedagogical reasons for including virtual field trips in teaching and learning. However, it is task structure and feedback which is essential for student understanding, as it provides 'handles on the theory world'.

REFERENCES

Bruner, J.S. (1966) Towards a Theory of Instruction. Cambridge, Harvard University Press.

Corbit, M. (2002) Building Virtual Worlds for Informal Science Learning (SciCentr and SciFair) in the Active Worlds Educational Universe (AWEDU). Presence Vol.11, No1, pp55-67

Hedley, N.R., Billinghurst, M., Postner, L., May, R. & Kato, H. (2002) Explorations in the Use of Augmented Reality for Geographic Visualization. Presence Vol.11, No2 pp119-133.

Jelfs, A. and Whitelock D. (2000) The notion of presence in virtual learning environments: what makes the environment "real". British Journal of Educational Technology Vol31 No2 pp145-152

Jelfs A. and Whitelock D. (2001) Presence and the Role of Activity Theory in Understanding: How student Learn in Virtual Learning Environments. In M. Beynon, C. Nehaniv and K. Dautenhahn (eds) Proceedings of Cognitive Technology: Instruments of Mind. 4th International Conference, CT 2001, Coventry UK pp123-129

Lombard, M. Ditton, T.B., Crane, D., Davis, B., Gil-Egui, G. Horvath, K., Rossman, J., & Park, S. (2000) Measuring presence: A literature-based approach to the development of a standardized paper-and-pencil instrument. Paper presented at the Third International Workshop on Presence, Delft, The Netherlands, http://nimbus.temple.edu/~mlombard/P2000.htm

Minsky, M. (1980) Telepresence. How the development of teleoperators would have immense benefits in the areas of Energy, Productivity, and Space Exploration. (May 1980) OMNI magazine.

Piaget, J. (1930) The Child's conception of Physical Causality. London, Kegan.

Steuer, J. (1992). "Defining Virtual Reality: Dimensions Determining Telepresence." Journal of Communication Vol. 42 No.4 pp73-93.

Usoh, M., Catena, E., Arman, S., Slater, M. (2000) Using Presence Questionnaires in Reality. Presence Vol. 9 No.5 pp497-503

Vygotsky, L. (1962) Thought and Language. Translated from the Russian and edited by E. Hamsman and G. Vankan, Cambridge, Mass. MIT Press.

Whitelock, D. (1999) Investigating the role of Task Structure and Interface support in two Virtual Learning environments. IJCEEL Vol. 8 No. 2.

Whitelock, D., Brna, P. & Holland, S. (1996) What is the value of Virtual Reality for Conceptual Learning? Towards a theoretical framework. In. P. Brna, A. Paiva and J.A. Self (eds.) Proceedings of the European Conference on Artificial Intelligence in Education, Lisbon pp.136-141.

Zeltzer, D. (1992) Autonomy, Interaction and Presence. Presence Vol.1 No1: pp.127-132

Anne Jelfs, Evaluator: Online Materials,
I.E.T.,
Open University,
Walton Hall,
Milton Keynes, UK, MK7 6AA
E-mail : a.e.jelfs@open.ac.uk

Dr. Denise Whitelock, Lecturer,
I.E.T.,
Open University,
Walton Hall,
Milton Keynes, UK, MK7 6AA
E-mail : d.m.whitleock@open.ac.uk