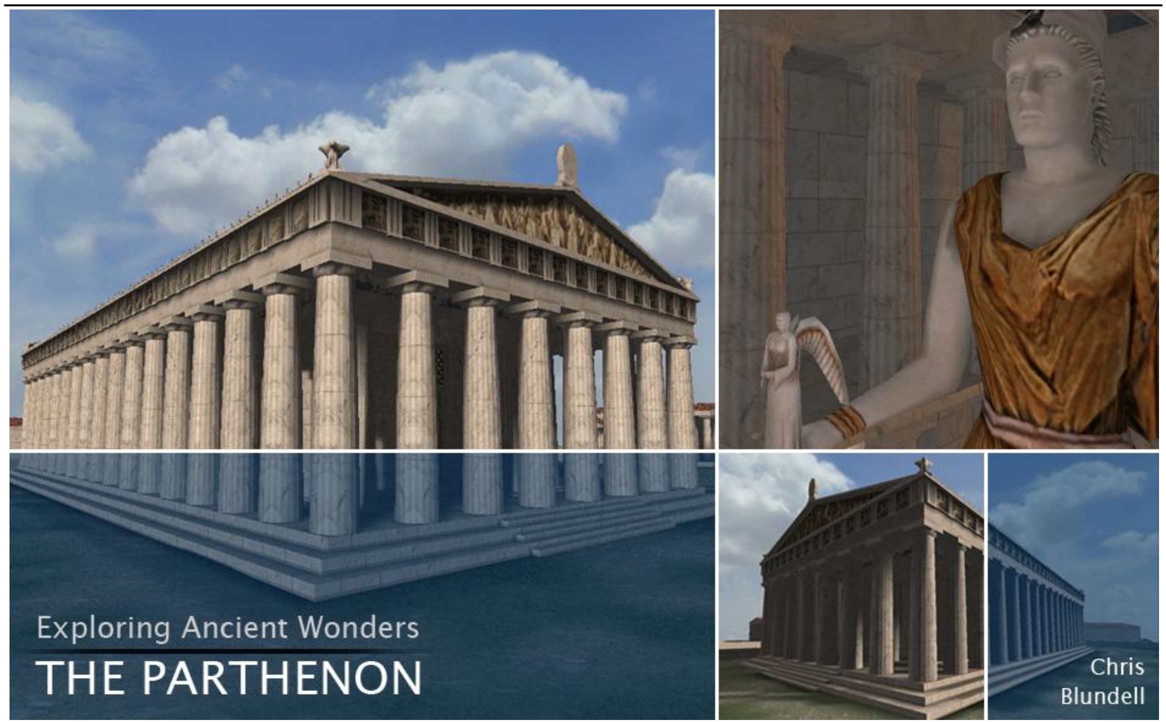

Investigation of the effectiveness of computer game-based virtual learning environments to facilitate students' understanding of the features and history of ancient architectural wonders

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Support Files

Information about the "Exploring Ancient Wonders: The Parthenon" virtual learning environment, download links, and instructions for installation and use are available at: http://www.plutonicdesign.com/eaw/.

The control WWW site can be found at: http://www.plutonicdesign.com/eaw/control/.

1 Abstract

This project investigated the use of computer game-based virtual learning environments to facilitate students' understanding of the features and history of ancient architectural wonders. A group of twenty-nine students participated in a treatment-control group methodology that utilised pre- and post-tests to determine the relative educational effectiveness of a virtual learning environment in comparison with a WWW-based learning experience that utilised the same constructivist pedagogy. The results indicate that virtual learning environments are beneficial and effective pedagogical tools, demonstrating a significant influence on male participants' knowledge and confidence. Based on a limited sample, learning style did not influence the results. The students responded positively to the self-guided, non-sequential learning experience offered by the virtual learning environment.

2 Rationale

Students learning about ancient civilisations in subjects like History and Art are often taught about ancient architectural wonders. These provide valuable insight into the complexity and social, scientific, mathematical and artistic sophistication of ancient societies. In the absence of first-hand experience, it is usually quite difficult for students to genuinely appreciate the significance of these structures. Anecdotal observations suggest that traditional forms of representation – descriptive text, images and diagrams – fail to effectively support students' appreciation of the scale, design integrity and grandeur of the architecture and therefore, the cultural, historic and social significance of ancient buildings. The purpose of this project was to investigate the effectiveness of computer game-based virtual learning environments (VLE) to enhance students' understanding of the features and history of ancient architectural wonders.

3 Literature Review

Immersive virtual reality – specialist hardware and software technologies designed to create artificial, three-dimensional environments – have been utilised in education since the 1950s (Beier, 2004; Brooks, 1999; Jeffs & Whitelock, 2000). More recently, personal computer-based virtual reality technologies – such as VRML (Virtual Reality Modelling Language), QuickTime VR and computer game-based representation - have become available; these are described as *non-immersive* virtual reality (Beier, 2004; Dickey, 2005). The educational rationale for non-immersive virtual reality seems to be made relative to research that demonstrates the positive value of immersive virtual reality in education (Dickey, 2005; Foreman, 2004; Moreno, 2002; Winn, 2002). Qualitative studies of non-immersive virtual reality suggest increased student engagement and positive perceptions that lead to conceptual change (Mackenzie, Baily, Nitsche & Rashbass, 2003; Winn, 2003). Moreno (2002) argues that the retention of knowledge is not affected by whether immersive or non-immersive virtual reality is used.

Constructivist cognitive theory states that learning is promoted through engagement and experiential participation (Bruner, 1966; Huitt, 2003; Jonassen & Rohrer-Murphy, 1999) and it is argued that this process can be facilitated by virtual learning environments (Dickey, 2005; Foreman, 2004; Winn, 2003). Both immersive and non-immersive virtual reality engage the user in a multi-sensory fashion – visual, auditory and kinaesthetic engagement – that leads to the development of experiential intuitions which are retained by the user (Dede, Salzman, Loftin & Sprague, 1999). It is argued the presentation of information in a first-person, non symbolic manner can provide a conduit between experiential learning and information representation (Dickey, 2005). The transfer of learning is better, according to Moreno (2002), when the virtual environment is closer to the real world due to stronger, more logical perceptual cues and feedback.

The highly visual nature of virtual reality would seem to suggest it would be more beneficial to students with well-developed visual processing skills, but Chen, Toh, & Ismail (2005, pp. 126) argue that learning in virtual environments is dependent on transformation of multi-sensory experience and hence of "great benefit to all learning styles. Transformation of the multi-sensory experience may explain the perceived value of virtual learning environments in constructivist learning experiences.

Successful use of virtual learning environments is dependent on effective pedagogy, rather than the type of virtual reality technology utilised; conversely, ineffective pedagogy can impede successful learning in an otherwise well-realised virtual environment (Chen et al. 2005; Moreno, 2002). The degree of conceptual change is dependent, however, on the user's engagement with the learning environment (Winn, 2002) because effective learning in a constructivist environment is contingent on learner activity (Jonassen & Rohrer-Murphy, 1999). The inclusion of mechanisms that promote intellectual engagement, such as goals that utilise a game-style progression, can be used to promote engagement and therefore meaningful learning (Champion, 2006).

The ubiquity of computer games has been used to rationalise implementation of game-based virtual learning environments in education (Wellings, nd). Computer game technologies provide the core functionalities and tools required to create virtual reality with the added advantage that most students understand their operational paradigms and are comfortable using them (Calef, Vilbrandt, Goodwin & Goodwin, 2002; Foreman, 2004; Jacobson & Holden, 2005;). Prensky (2005) argues that students in the modern education context are efficient multi-tasking, multi-sensory learners largely due to engagement in their own information communication technology-based pursuits; and they are coming to expect but are typically not achieving similar levels and forms of engagement at school.

4 Solution Design

For the purpose of this project, a virtual learning environment representation of the Parthenon – called 'Exploring Ancient Wonders: The Parthenon' - was developed using UnrealEngine2 Runtime (Epic Games, 2004), a free version of a popular computer game technology. The representation depicted the Parthenon in its original form and to scale with the user's in-game perspective. Two experiential modes were available - fly-by cinematic and free exploration. Both identified and explained the same historic information and architectural features; users were able use either or both. The fly-by mode presented this information as a sequential cinematic experience. The free exploration mode allowed users to engage in a self-guided tour of the Parthenon and the immediately surrounding area of the Acropolis. Users were able to activate a feature allowing them to float off the ground to explore the significant features, high on the Parthenon. In free-exploration mode, information markers (Figure 4-1) identified significant locations. Both modes utilised audio voice-overs with specific terms displayed as on-screen text, often as location-specific labels (Figure 4-2). Illustrative diagrams, photographic images (Figure 4-2) and feature markers (Figure 4-3) were included to provide additional clarity.

Figure 4-1: Information marker

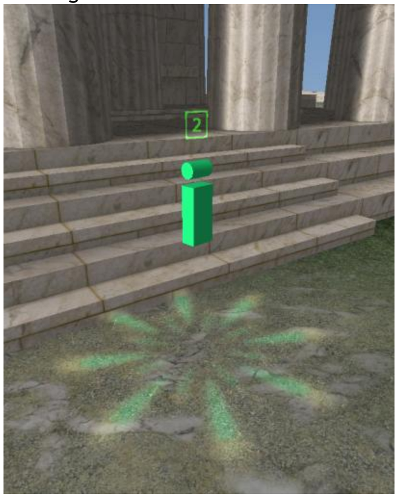


Figure 4-2: Example of labels and illustrative diagrams to draw attention to significant terminology and features

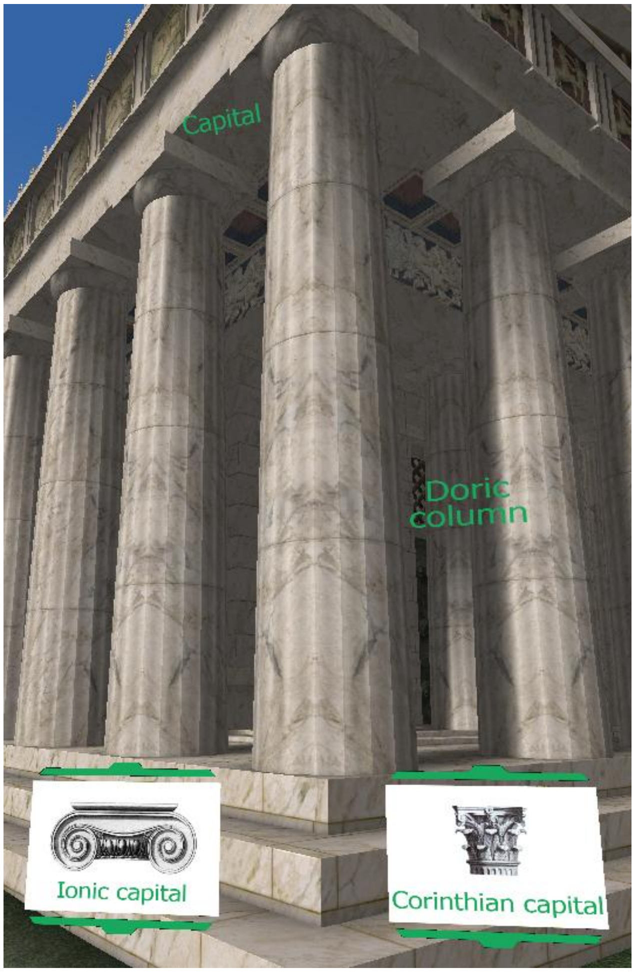
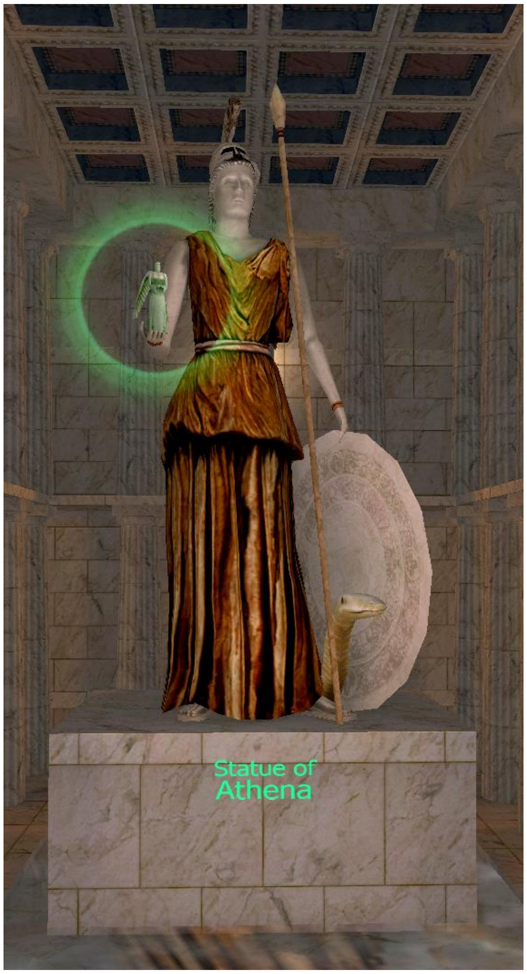


Figure 4-3: Example of marker effects to draw attention to significant features (green highlight and halo effect)



The constructivist learning experience was contextualised by a scenario regarding six artefacts from the Parthenon that would be used in a museum display. The participants were given images of the artefacts; their goal was to find each in the virtual space, then gather and record information about each artefact on a work sheet. A map of the Parthenon, including the location of all information markers was provided to reduce the probability of becoming lost. The artefact activity was designed to facilitate engagement in the virtual learning environment for one hour.

5 Implementation Process

The research methodology was based on the pretest - posttest control group design (Gay, 1992 pp. 322), summarised as follows:

			Intervention	
Treatment group	R	O_1	X_t	O_2
Control group	R	O_1	X_c	O_2

R = Random assignment with constraint that both groups needed to be gender balanced
O_1 = Pre-test questionnaire
X_t = Treatment – utilisation of the virtual learning environment for one hour
X_c = Control – utilisation of a World Wide Web (WWW) site that included all information, photographs and images from the virtual learning environment for one hour
O_2 = Post-test questionnaire

For the purposes of determining the educational value of virtual learning environments, the artefact activity was utilised for both treatment and control groups. The control WWW site was developed to promote non-sequential exploration and hence a learning experience that was pedagogically consistent with the treatment. Both groups were given to access to the same information and the opportunity to explore their respective information sources in a self-guided and self-paced manner. The variable was the environment in which the learning took place.

The pre-test questionnaire gathered demographic data, including learning style, and assessed the level of each participant's knowledge of the historic and architectural information presented during the implementation phase. The post-test questionnaire reassessed the level of each participant's knowledge using the same questions as the pre-test questionnaire. It also included five-point Likert-scales to gather data about the participant's impressions of the treatment and control learning experiences.

The participants were twenty-nine Year 8 History students with an average age of 13 years. The students were from a History class that represented a segment from the higher academic range of a larger cohort. Females and males were evenly distributed between the two groups. All participants reported having a computer at home and rated themselves as confident or better computer users with an average of 8 hours of use per week, though males averaged almost 1.5 hours more per week than females. 72% percent of the students indicated they played computer/video games – 46% females and 100% males – devoting an average of 3.93 hours per week. The girls, with an average of 1.67 hours per week, spent less time than the boys, who spent on average of 5.69 hours per week playing computer/video games.

On the basis of the data generated by the 'learning style identifier' (Thinkwell Corporation, 2003), just over half the students were multi-sensory learners and another third were visual learners with the balance comprised of kinaesthetic/tactile learners and one auditory learner. Refer to Table 5-1 for the specific learning styles of the groups. It is worth noting that 60% of all participants demonstrated a multi-sensory learning style with a slight preference to visual learning. To some extent, this reflects Prensky's (2005) contention that students in the modern education environment are multi-sensory learners.

Table 5-1: Learning style of the participants by group and gender

	Control		Treatment		Total by Gender		Total
Learning Style	Female	Male	Female	Male	Female	Male	
Visual	2	1	3	4	5	5	10 (34.5%)
Auditory	0	1	0	0	0	1	1 (3.4%)
Kinaesthetic	1	0	1	1	2	1	4 (10.3%)
Multi-Sensory	3	6	3	3	6	9	15 (51.7%)

6 Analysis and Evaluation

6.1 Understanding of Features and History

Both the control and treatment resulted in a significant improvement in the students' ability to accurately answer factual questions about the Parthenon, with a tightening of both the standard deviation and the range. The improvement in the average result for the treatment group was greater than the control group; reductions in the standard deviation and range were more pronounced. According to the effect size test (Cohen in Becker, 2002) the post-treatment difference between the control and treatment groups demonstrates strong effect, however, with a t-test of .052, the difference is not significant.

Table 6-1: Percentage correct on knowledge test

	Pre-test			Post-test				
Group	Average Percentage	Standard Deviation	Range	Average Percentage	Standard Deviation	Range	Change	t-test
Control	38%	19%	6-68%	77%	11%	59-94%	+ 39%	0.052
Treatment	32%	22%	6-53%	82%	7%	71-94%	+ 54%	

Analysis of the results on the basis of gender (Table 6-2) indicates that the post-test results for males in the treatment group improved significantly more than those in the control group. This is also evident for females, though the difference between the control and treatment results is not significant.

Table 6-2: Percentage correct on knowledge test by gender

	Pre-test		Post-test			
Group	Average Percentage	Standard Deviation	Average Percentage	Standard Deviation	Change	t-test
Control – Female	36%	23%	81%	15%	44%	0.533
Treatment – Female	34%	16%	83%	6%	49%	
Control – Male	40%	19%	75%	7%	35%	0.030
Treatment – Male	34%	14%	90%	5%	59%	

There was a notable difference between males in the control and treatment groups regrading their self-assessed confidence to name the major features of the Parthenon (Table 6-3). Males in the treatment group felt more confident to name the features of the Parthenon. By comparison, females in both groups indicated the same level of confidence in naming the features of the Parthenon (average of 4.0 and a standard deviation of 0.6). The greater confidence of males in the treatment group seems consistent with their stronger knowledge results, when compared to the males in the control group (Table 6-2).

Table 6-3: Males' confidence naming features of the Parthenon

Likert statement	Control - male		Treatment - male	
	Average*	Standard Deviation*	Average*	Standard Deviation*
I can confidently name the major features of the Parthenon.	3.38	0.52	4.13	0.6

*1 = strongly disagree and 5 = strongly agree

Due to the nature of the available sample of learning styles (refer to Table 5-1), it was only feasible to examine the impact of the control and treatment relative to visual and multi-sensory learning styles. While the difference can not be solely attributed to the intervention, the data (Table 6-4) suggest the treatment resulted in stronger knowledge development, irrespective of visual or multi-sensory learning style. This suggests that the constructivist pedagogy was similarly effective for both learning styles. A wider standard deviation for the multi-sensory learners is evident, possibly due to the population size.

Table 6-3: Pre- and post-test performance by learning style

	Pre-test		Post-test			
Group	Average Percentage	Standard Deviation	Average Percentage	Standard Deviation	Change	t-test
Control - Visual	39%	22%	77%	15%	39%	0.095
Treatment - Visual	33%	12%	89%	5%	55%	
Control – Multi-sensory	40%	20%	78%	8%	38%	0.319
Treatment-Multi-sensory	32%	18%	85%	5%	53%	

Where there were positive differences in the accuracy of answers provided by the treatment group in comparison to the control group, the questions related to architectural features of the Parthenon. In instances where the treatment group's answers were, on average, less accurate than the control group's, the questions related to factual information that was only presented in audio format.

Written anecdotal feedback from the treatment group generally focussed on the nature of the learning experience and enjoyment levels, as discussed in section 6.2. Four treatment participants made direct comment about knowledge development.

> *"It was a great way to learn because I was having a lot of fun while I was learning. I found it a bit easier to remember the information."*
>
> *"It was a good experience and creates a different, easy way to learn."*
>
> *"The program improved my knowledge of many aspects of the Parthenon."*
>
> *"I thought that having a virtual tour of the Parthenon was a good idea and helped me understand more about it."*

6.2 Impressions of the Project

6.2.1 Ease of Use

Based on Likert-scale data, both groups agreed they found the respective technologies easy to use and they were comfortable using them. Four respondents, two from each group, indicated they would have liked more time to become comfortable with the technologies. The data indicated students in the treatment group were comfortable using the keyboard and mouse to interact with the virtual learning environment; there was no significant difference between female and male participants.

Two participants indicated they became lost when using the virtual learning environment, but the remainder of the students in the treatment and control groups indicated they did not become lost. 83% of the participants agreed or strongly agreed that the worksheet helped them to explore the site more carefully; the control group had a slightly stronger impression of the value of the worksheet. In their anecdotal comments, three students from the treatment group identified getting lost or not being able to find a specific location or marker as a source of frustration though this didn't impact on their high levels of comfort using the virtual learning environment. Only one student in the control group indicated becoming lost as a source of frustration.

6.2.2 Enjoyment of Learning Experience

All students agreed or strongly agreed that they enjoyed using their respective versions of 'Exploring Ancient Wonders: The Parthenon'. Generally the data about levels of enjoyment were similar between the control and treatment groups – positive, with very limited uncertainty or dissatisfaction. 87% of the treatment group, compared to 79% for the control group, indicated a preference to learn more about historic places using the respective technologies.

Written anecdotal feedback indicated the treatment was a departure from typical classroom learning practices and, as a result, heightened enjoyment and interest levels.

> *"It is not something that you would normally do at school. It makes it more fun and interesting to learn."*
>
> *"Being on the computer is more fun than listening to a teacher or taking notes. The whole experience was new and interesting in a good way."*

Two students specifically identified the treatment's use of computer game technology as a motivating factor. Many others indicated the presentation of the Parthenon *"in a realistic form"*; the ability to freely explore the site; and the opportunity to examine the important features carefully and in a self-directed manner, as factors that increased their enjoyment.

6.2.3 Engagement

The data suggest a high level of engagement for both the treatment and control groups. All students, except one, indicated they liked the ability to decide the sequence in which they explored the "site". The Likert data, however, indicated that 30% of the control group were uncertain about whether they would have preferred the information on the WWW site to be presented sequentially. Conversely, 90% students in the treatment group expressed a very strong preference for the information to be presented in a non-sequential form. Written anecdotal data supported this, indicating considerable recognition by the treatment group of the value of and a preference for non-sequential site exploration. While the control group regularly mentioned exploration as an important part of the learning experience, the treatment group's comments included regular, more overtly identified and positively framed references to the nature of the exploration, suggesting a higher level of immersion. Three students commented: *"I felt like I was really there"*.

Student self-assessment of their level of involvement in the respective learning experiences demonstrated consistently strong involvement by females irrespective of their group. Males in the treatment reported a significantly stronger involvement than males in the control group (Table 6-5).

Table 6-5: Involvement of males in the learning experience

Likert statement	Control - male		Treatment - male	
	Average*	Standard Deviation*	Average*	Standard Deviation*
I left involved in the learning experience.	3.75	0.46	4.5	0.5

*1 = strongly disagree and 5 = strongly agree

The treatment group were also asked to identify any frustrations encountered while using the virtual learning environment. Two students identified that they were frustrated by being blocked from exploring the rest of the Acropolis, suggesting a genuine interest in engaging further in the exploration experience.

7 Conclusions

This project demonstrates that a virtual learning environment can be a beneficial educational tool, thereby confirming the literature (Dickey, 2005; Foreman, 2004; Mackenzie et al., 2003; Moreno, 2002; Winn, 2002; Winn, 2003). The data suggests that, within the constructivist pedagogical context, the virtual learning environment and the WWW site facilitated a similar level of development and short-term retention of knowledge, but the virtual learning environment demonstrated stronger level of effect (Table 6-1). The reduced standard deviation for the treatment group's results (Tables 6-1, 6-2 and 6-4) suggests that the effect of the virtual learning environment was more consistent.

In relation to the participants' understanding of features and history of ancient architecture, it would seem that the virtual learning environment was effective. Two specific conclusions can be drawn in this regard. Firstly, the data indicates that, unlike female participants, males in the treatment group demonstrated a significantly better knowledge than those the control group (Table 6-2), and greater confidence in their knowledge (Table 6-3). This suggests the benefits of learning in a virtual learning environment are more effectively realised by males, though the male participants' greater exposure to and experience of computer games may have influenced this result. Secondly, although the data generated is limited in range, it does support Chen et al. (2005) - learning styles did not influence the effectiveness of virtual learning environments (Table 6-4). A larger study with a wider sample of learning styles would be required in order to confirm this conclusion.

In terms of pedagogical effectiveness, both the treatment and the control activities resulted in high levels of engagement and hence effective learning (Champion, 2006; Jonassen & Rohrer-Murphy, 1999; Winn 2002). This may be due to the fact that both activities required self-guided, non-sequential engagement supported by a constructivist exploration activity. Many of the participants directly commented that they liked this aspect of their respective learning experiences, though the treatment groups' comments demonstrated a greater level of appreciation. This would seem to be consistent with Prensky (2005) – students are looking for and are comfortable with dynamic, multi-tasking learning experiences. It is worth noting that the virtual learning environment seemed to promote a higher level of immersion and involvement than the WWW site, particularly for male participants.

One notable conclusion about the design of virtual learning environments can be drawn. Merono (2002) indicates that audio-only information is retained by users as effectively as simultaneous presentation of audio and text information. Data generated by this project contradicts this. The standard of participants' knowledge was higher when the factual information was presented simultaneously in audio and text formats.

This project was designed and implemented as a small-scale pilot study with the intention of determining the pedagogical viability and value of a computer game-based virtual learning environment. In this regard, the data generated suggests that the virtual learning environment was viable, with similar level of effectiveness as the WWW-based resource and hence, represented a valuable pedagogical tool.

8 Suggestions for Further Research

Due to small sample size, the restricted range of their academic ability, and predominance of visual and multi-sensory learning styles, the conclusions of this project may not translate to a broader context. As a result, further research is required. A similar methodology should be used with a larger, more academically diverse sample to verify these results. The utilisation of a second post-test questionnaire completed four to eight weeks later to assess the impact of the intervention on long-term memory, would be beneficial. Improved mechanisms – such as interviews - for determining the extent of the students' appreciation of scale are required as the techniques used in this pilot study were ineffective; the results were inconclusive and hence not included in this report.

Several significant research questions about the use of virtual learning environments have been have been identified by this project. The impact of sequential versus non-sequential information presentation on knowledge development needs investigation. The effectiveness of various models of learning – behaviourism, cognitivism and constructivism - in virtual learning environments needs to be explored in detail. Investigation of more dynamic, game-style goals delivered in the virtual learning environment would be beneficial, particularly in relation to constructivist learning. Anecdotal comments by a number of participants suggested they wanted an opportunity to meet classmates in the virtual space and to explore the site together. The educational benefits of this suggestion need to be explored. Further investigation of the influence of gender and prior computer game experience on learning in virtual learning environments would also be beneficial.

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