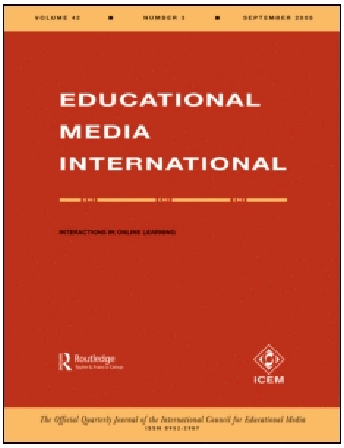

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3-Dimensional online learning environments: examining attitudes toward information technology between students in Internet-based 3-dimensional and face-to-face classroom instruction

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3-Dimensional online learning environments: examining attitudes toward information technology between students in Internet-based 3-dimensional and face-to-face classroom instruction

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3-dimensional online learning environments can provide a means for users with limited connectivity to the Internet to participate as fully as their broadband-enabled peers in collaborative experiences, information sharing and feedback. Nearly 90% of the universities in the USA that support distributed learning programmes use web-based course delivery methods. Directors of these programmes state that web-based delivery allows them to handle the wide range of connectivity among student populations. 3-Dimensional online learning environments can increase online course interaction and feedback beyond current web-based document delivery in a cost effective and scaleable manner. This article examines attitudes to information technology of students in a 3-dimensional online learning environment versus those involved in face-to-face classroom instruction at the University of North Texas. We were interested in looking to see how the benefits of immersion, interaction and feedback provided by the 3-dimensional online learning environment would impact on the students' attitudes to information technology for an established traditional course.

Les environnements d'apprentissage en ligne à trois dimensions: un examen des attitudes respectives des étudiants travaillant en 3D basé sur Internet et de ceux qui travaillent dans des classes présentielles par rapport aux TIC
Les environnements d'apprentissage en ligne en 3D peuvent offrir aux usagers ne disposant que d'un accès limité à Internet, le moyen de participer aussi pleinement que leurs collègues bénéficiant de la bande large, aux expériences collaboratives, au partage de l'information et à la rétroalimentation. Près de 90% des universités des Etats-Unis qui offrent des programmes d'apprentissage distribué, utilisent des méthodes de transmission des cours reposant sur le Web. Les directeurs de ces programmes affirment que la transmission par le Web leur permet de faire face aux grandes différences de capacité d'accès aux réseaux, d'un groupe d'étudiants à l'autre. Les environnements d'apprentissage en ligne en 3D ont la capacité d'accroître l'interaction dans les cours en ligne ainsi que la rétroalimentation, de façon plus significative que la transmission actuelle de documents par

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Internet et ce, d'une façon économique et mesurable. Cet article étudie les attitudes vis-à-vis des TIC chez les étudiants se trouvant dans un environnement d'apprentissage en ligne en 3D par rapport à ceux qui reçoivent un enseignement présentiel à l'Université de North Texas. Nous avons cherché à voir comment les avantages en termes d'immersion, d'interaction et de rétroalimentation que présente un environnement d'apprentissage en ligne en 3D, pouvaient influer sur les attitudes de ces étudiants vis-à-vis des TIC dans un cours traditionnel.

3 D Online-Lernumgebungen: Einstellungsüberprüfungen zu Informationstechnologie zwischen Studenten in internetbasierter 3D und Frontalunterricht

3 D Online-Lernumgebungen können Benutzern mit beschränktem Zugang zum Internet ein Hilfsmittel sein, so vollständig wie ihre Breitband nutzenden Kollegen an kooperativen Erfahrungen, Informationsaustausch und Feedback teilzunehmen. Fast 90% der Universitäten in den Vereinigten Staaten, die Austausch von Lehrprogrammen unterstützen, verwenden netzbasierte Distributionsmethoden. Direktoren dieser Programme geben an, dass netzbasierte Belieferung ihnen erlaubt, den breiten Bereich der Konnektivität unter den Studenten zu überwinden. 3 D Online-Lernumgebungen können die Online-Kursinteraktion und das Feedback über gegenwärtige netzbasierte Belieferung kostenwirksam und skalierbar steigern. Dieser Artikel berichtet über Einstellungen zu Informationstechnologie von Studenten in einer 3 D Online-Lernumgebung gegenüber jener von in direktem Unterricht beschulten Studenten an der University of North Texas. Wir waren daran interessiert zu erkennen, wie die Vorteile von Vertiefung, Interaktion und Feedback, die der 3 D Online-Lernumgebung eigen sind, die Einstellungen der Studenten zu Informationstechnologie für einen eingeführten traditionellen Kurs beeinflussen würden.

Introduction

Internet-based distributed education has become firmly embedded in education due to the explosive growth of networked digital communications (Walker, 2003). In 2003 more than 66,000 fully online courses and 1200 complete online programmes were available in the USA and Canada (Paulsen, 2003). The number of college students taking online courses has grown from 3.4 million in 1995 to over 13 million in 2002 (Cisco Systems, 2002). The web has received widespread acceptance and been widely use for creating and supporting learning activities across disciplines within higher education (Hill, 2001). Nearly 90% of universities in the USA that support distributed learning programmes use web-based course delivery methods. Directors of these programmes state that web-based delivery allows them to handle the disparity between various Internet connections among student populations (Jones, 2004). Satisfaction with web-based courses for the purposes of learning have not been as strong as proponents may have hoped (Hill, 2001).

Dissatisfaction with courses can have several adverse consequences, such as: students dropping out of a course, students not taking distance delivered courses in the future, low evaluation ratings for the instructor or low evaluations for the programme of which the course is a part (Hill & Raven, 2000; Hill, 2001). Research indicates that the environment being presented for course delivery impacts on the attitudes and satisfaction of students taking online courses (Sogabe & Finley, 2002). 3-Dimensional online learning environments create new forms of online course interaction and feedback that fit the limitations of many students still without broadband Internet access. 3-Dimensional online learning environments allow immersive and interactive situations to be created among students and between instructors such that they better reflect the type of interactions and synthesis possible in more traditional university settings. Virtual reality is predicted to be the most significant technology transformation in educational media (Chen *et al.*, 2004).

With the current emphasis on offering courses via web-based delivery systems the importance of real time face-to-face communications between course instructor and student and among the students is more apparent than ever. 3-Dimensional online learning environments can increase online course interaction and feedback beyond current web-based document delivery in a cost effective and scaleable way. It is important to evaluate and understand how immersive environments with better feedback and interaction can impact on students and instructors. This paper discusses first year research into using a 3-dimensional online learning environment to teach computers in education, a course at the University of North Texas for pre-service teachers (students who are training to become teachers). Our interest was to examine the effectiveness of a 3-dimensional online learning environment compared with the traditionally offered classroom course to see what interesting patterns emerged. Several interesting patterns emerged during the analysis that will be discussed in the results and discussion.

3-Dimensional online learning environments

A new generation of 3-dimensional online learning environments (multi-user, object orientated, online constructivist environments) is becoming available for Internet-based distributed learning. These new interfaces have strong ties to their text-based cousins of the early 1990s but now provide highly collaborative, immersive environments that promote interactions among students and with the instructor. As a result of this popularity the number of systems capable of supporting online learning environments is increasing. Some online games boast subscriber populations that rival those of many actual North American cities (Whiting, 2002). As the performance of low cost personal computers increases, these types of systems allow teachers to provide students with unique online collaborative learning opportunities in the areas of language, science, computer graphics and other fields (Jones, 2003; Chen *et al.*, 2004). An online 3-dimensional virtual environment supporting text, audio and overheads allows immersive environments to be created so that the students and instructors can interact as if they were at the university.

3-Dimensional online learning environments provide a way to create Internet resources that are stimulating, appealing, easy to use and educationally sound, without the need to develop highly elaborate technical skills (University of Sheffield, 2004). These environments are commonly implemented in computer games, where they are a called MMOG (massively multiplayer online game), MMOPW (massively multiplayer online persistent world) or MMORPG (massively multiplayer online role-playing game) (Kent, 2003). In education they are termed a 3D MOOs (Multiuser Object Orientated), MUVEs (Multiuser Virtual Environments) or 3D online learning environments. The commonality between all these approaches is they create a context/scaffolding for interaction using 3-dimensional presentations to engage and/or immerse the student in a situation for learning (situated learning) or entertainment. The concepts used in these systems are based on research with text-based environments dating back to the 1980s (Holmevik & Haynes, 2000). The MIT Media Laboratory in the early 1980s demonstrated that using an alternative context to build a framework for interaction and learning can provide new and powerful methods of learning. Bruckman (1992) showed, in her research, that virtual meeting spaces/environments have significant potential for training, learning and collaboration. The same technology that allows an immersive experience presented in a game context can be harnessed to present learning environments to an ever-growing population of learners that have computers with built-in 3-dimensional graphics capability. These systems can provide a way to study classroom-based situated learning and the ways in which virtual environments may aid the transfer of learning from classroom contexts into real world settings (MUVEES Project, 2003).

When the environment is built and displayed correctly the user/student intuitively understands the space as displayed and should feel as though they are walking the halls of a building, using a library or shopping at a store. The user moves through and interacts with the environment using the keyboard and mouse. As the user moves, the computer generates new graphics in real time to give the user feedback on their position in the environment. This gives the user a feel of motion and change of location in the space. By placing objects in a contextual 3-dimensional framework users have known reference points and it creates a framework for communications and interactions. Figure 1 shows a captured screen image of one of the Created Realities Group 3-dimensional online learning environments used in this research.

Students at remote sites assume control of a representation of themselves, also called an avatar, in a shared created environment such as a school building, park or any other space. The virtual space is segmented into conversation areas (portals) so that learners can move their

Figure 1. Example of a university environment

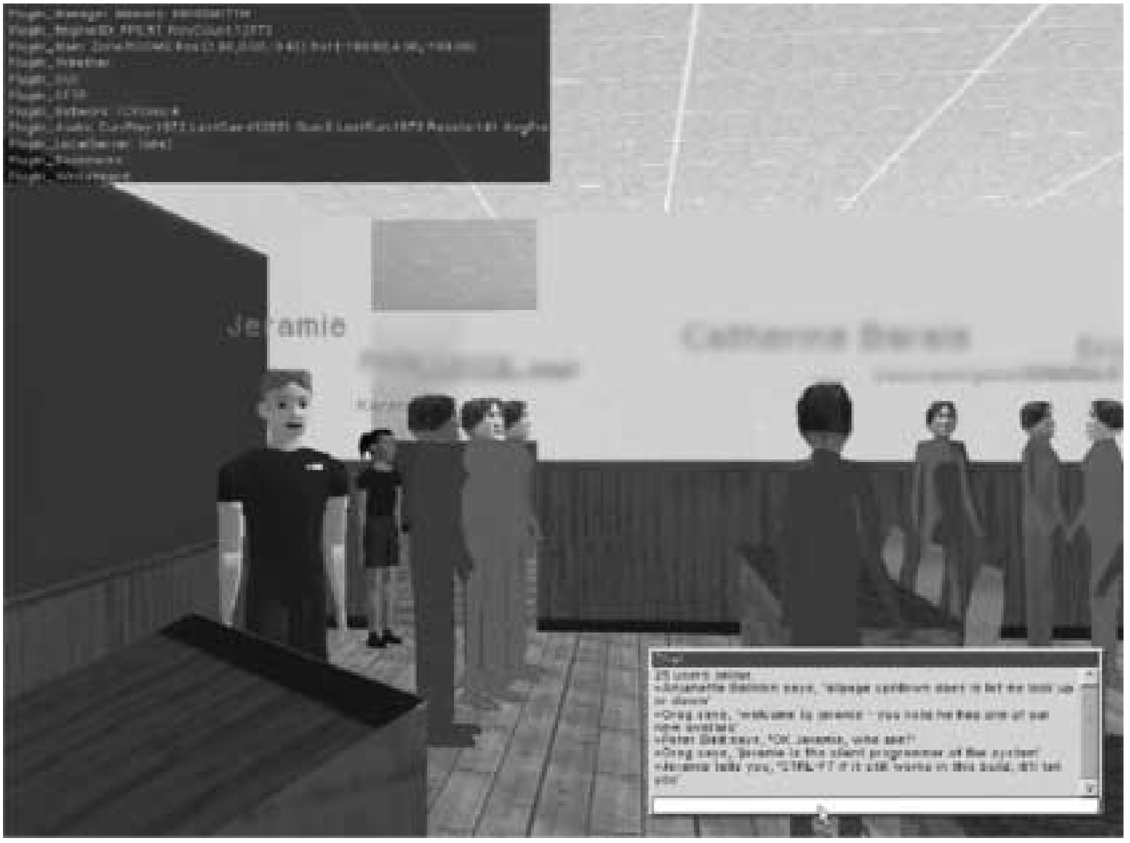

Figure 2. Screenshot from an online class by the University of Hawaii

avatars to areas for small group or private discussions. Figure 2 shows a screen capture of a class meeting being held online by the University of Hawaii using the system during the summer of 2004.

Benefits of 3-dimensional online learning environments

Students and teachers, when interacting with each other within the 3-dimensional online learning environment, almost always comment that they feel more engaged. The engagement in the environment is a natural outcome from the user interface. The student has to take control in order to interact and move in the environment. This interaction leads to immersion in the environment (Jenson, 2002). Led by futurist Chris Dede, researchers at Harvard University are employing US National Science Foundation funds to examine 3-dimensional learning environments (MUVEs) as a vehicle to study classroom-based situated learning and the ways in which virtual environments may aid the transfer of learning from classroom contexts into real world settings (Dede *et al.*, 2004). The MUVEES Project found that students using 3-dimensional environments had high levels of motivation, increased interactions and improved academic efficacy (MUVEES Project, 2003). The spontaneous exploration feature of the 3-dimensional online learning environment can be harnessed to better implement under-utilized forms of pedagogical practice and perhaps to create new forms of teaching/learning.

3-Dimensional online learning environments provide a vehicle for situated learning, allowing students to do activities created in the virtual environment (MUVEES Project, 2003). The 3-dimensional approach shows the potential to provide transferability from performing tasks in the virtual environment to performing the same tasks and interactions in the real world. A 3-dimensional online learning environment can easily support multiple modes of interactions at the same time. The modes are only limited by the bandwidth available, the technology for display and the capabilities of the student. The modes available in the system that the University of North Texas uses are text, audio, overheads, whiteboard, etc. Students and instructors use different modes depending on their needs. Students who are uncomfortable speaking can use text-based chat to voice their questions in a course. The instructor can use the audio chat mode in order to provide more information than they can easily type in. Multimodal interactions allow the system to utilize more than one mode over time to ensure that students with different learning styles are effectively reached.

3-Dimensional online learning environments have the ability to break down both physical and social barriers. Physically disabled students can communicate as well as students without disabilities using the same 3-dimensional online learning environment (Au, 2004). Berman and Bruckman (2001) explored identity in online environments and found that 'cultural boundaries, nearly impermeable in traditional discourse, are now at least apparently easy to cross online'. They also found that online environments provided a means for a user to generate new roles of persona. This is possible because the students can interact in ways that eliminate previous bias found in real life situations.

A 3-dimensional rendered environment is highly bandwidth efficient and can provide communications to the lowest speed users (dial-up). This is possible because the learning environment is rendered and not retransmitted; the initial bandwidth is minimum and can easily support those without access to faster Internet connection, as discussed earlier. At the same time this same approach can grow to accommodate higher bandwidth and more multimedia objects as faster Internet access is available over time. Users can interact (chat, audio, E-mail, conference, overheads, etc.) with other students and the instructor inside environments in real time using a 33 kbp modem connection to the Internet. Fast performance over thin-client Internet connection is ensured by small file sizes, delivery of just-in-time information and incremental rendering that only request and then render active visible areas on the user's screen (Jones *et al.*, 2002). This is a very important issue for those facing the digital divide in rural and urban settings (Benton Foundation, n.d.). A majority of homes and users in the USA today still do not have access to broadband Internet, with these types of connections (i.e. cable modem or DSL) being either hard to get or cost-prohibitive for many rural and inner city students (Federal Communications Commission, 2003; Jones, 2001).

3-Dimensional environments have been shown to be excellent vehicles for the exploration of complex systems. Games like Sim City, Railroad Tycoon and Dues Ex: Invisible War allows students to explore complex systems and at the same time be faced with problem-solving issues during their exploration (Gee, 2004). By allowing the students to save their work, they can then explore alternative outcomes. When an outcome is less than desirable, the student can then return to a previous state and may explore additional alternative outcomes (Spector, 2004). In simulations students are participating in an abstract form of a realistic situation (see situated learning above) that can relate back to learning objectives. Through simulation an environment can impart significant learning in an area that is very difficult to teach using other learning designs. A game can be an effective way to teach empathy. Amy Bruckman at Georgia Tech has extended her earlier research at MIT using text-based MOOs into aspects of 3-dimensional games and online environments focusing on mathematics and science, teaching in online learning communities and the possibilities for educational gaming (Bruckman, 1992, 2003; Bruckman *et al.*, 2000). Students have the opportunity with some gaming environments to take on various roles and, therefore, have a better insight and understanding of each perspective from varying viewpoints (Franklin Learning Systems, n.d.).

Initial research

During the autumn semester of 2003 (September–December 2003) the authors began an initial examination concerning attitudes to information technology between students situated within a 3-dimensional online learning environment and students located in a traditional face-to-face classroom. The course selected for research was the University of North Texas (UNT) CECS 4100 course, which focuses on computer topics that would be covered in introductory primary and secondary school courses with an emphasis on curriculum integration. This course has been delivered in a traditional classroom format on the UNT campus and at the UNT Dallas campus for several years. The course was selected for two reasons. The first was that the course had been using the instruments to gauge student attitudes to information technology for several years, begun as part of the US Department of Education PT3 grant entitled 'The Millennium Project: pathways for preparing tomorrow's teachers to infuse technology'. This project examined ways to increase the use of technology in the classroom of the future at the pre-service level (Christensen, 2000; IITTL, 2001). The second reason was that the students who attend the Dallas campus tend to have more limited time available for the course (see details about participants below) and that by providing a blended course combining the 3-dimensional online learning environment with a few face-to-face meetings would provide a more convenient and just as effective course for these students.

Three sections out of nine of the UNT CECS 4100 course (Computers in the Classroom) were chosen for delivery using the 3-dimensional online learning environment. Six sections took the course in the traditional face-to-face method. Instructors and students participated in pre- and post-course questionnaires and follow-up interviews concerning the classes in the current mode of offer as well as those in the 3-dimensional online learning environment mode. How often the classes met was very different between the treatment and control groups. The face-to-face courses (control) met each week on campus for a total of at least 3 hours each week. The 3-dimensional online courses (treatment) were taught as a blended course. Blended courses combined face-to-face meetings with online communications. For this semester the treatment groups met in person a total of seven times throughout the semester and used the 3-dimensional online system for an additional six online meetings. The control group, therefore, had much more instructor contract time than the treatment group.

It should be noted that students participating in the treatment group experienced a number of technical problems related to both delivery and laboratory issues at the start of the course.

The CRG 3-dimensional online learning environment had been used for three semesters prior to the start of this course in other UNT courses and we felt comfortable that technical problems would not play a major factor. The 3-dimensional online software was installed and demonstrated during the first two in-person meetings of the UNT Dallas campus course. Forty per cent of the treatment group sent E-mails to the technical support asking questions regarding the install. These problems were solved within the first two E-mail exchanges. Only two of the students were unable to get the software operational for the class. These two students found other systems to use for class meetings. The training sessions were judged by the instructors of the courses and the developers of the system to have been successful in promoting comfort in using the system and enthusiasm about its potential benefits. Then the course encountered approximately 40 days of problems. This began with a problem related to the server supporting the 3-dimensional environment. Students could not stay connected to the server for extended periods of time because of a combination of issues that took about two weeks to resolve. After this issue was corrected, a further problem was encountered when it was discovered that the computer laboratory at the Dallas campus had upgraded the operating system for the computers in the classroom being used. This change kept the students who were using the laboratory from attending the online course until other arrangements could be made. The instructor during this period provided the materials as attachments in E-mails sent to the participants. These problems affected the treatment group's initial use of the 3-dimensional online learning environment. The traditional format sections had no unusual problems in the delivery of the course.

Participants

One hundred and seven undergraduate students at the University of North Texas taking the CECS 4100 course participated in the research. Fourteen students participated as the treatment group in the three sections being taught at the UNT Dallas campus. Due to data collection difficulties, fewer than half of the potential students enrolled in the three sections of the treatment courses were available for analysis. As will be discussed later, this limited sample of data affected the overall research. Ninety three students participated in the control group in six sections being taught on the UNT campus. The demographics for the sample showed a median of 21 years of age, although there were some differences in the compositions of the groups by gender analysis. The 14 participants in the treatment group were all females who ranged in age from 19 to 40, with a median age of 23, whereas the 93 participants in the control group ranged from 18 to 46 and comprised eight males with a median age of 25.5 and 85 females with an average age of 21.

There are differences between students taking classes on the main campus of the University of North Texas (in Denton) and classes offered 50 km away at the UNT Dallas campus. Students in Dallas tend to be slightly older and typically hold down full-time jobs or have other similar commitments. This can be seen when the students are asked how far away they are from graduation. The majority of students (83.9%) hold a bachelor's degree and there is no definite date for graduation as a cohort. Most of the students taking courses at the UNT Dallas campus were at least 2 years away from graduating. While students taking the course on the main campus reported that they would be graduating within the next year to 18 months. Most of the students (70.1%) planned to teach at the K-3 level, thus it was not a surprise that most of them have interdisciplinary (elementary school) as their area of specialty.

Another interesting difference between the two groups was that of home computers. Home computers owned by the participants in the treatment group were slightly older than those owned by the control group, based on the number of support questions answered by the technical support group. One hundred and one students (94.4%) had a computer at home and 90 (84.1%) had the Internet at home. One student in the treatment group did not have either a computer or the Internet at home, whereas in the control group five students were in that condition and an additional nine students had a computer but no access to the Internet at home. In future the demographics questions will be enhanced to better track this issue.

In terms of the number of hours spent using the computer at home and at school, although most of the students reported spending about the same average time in both settings (2–3 hours), the distribution of the time is different. The majority of students spent 2–3 hours or more at home, whereas they spent 2–3 hours or less at school. Furthermore, there were differential tendencies between the two groups: 51.6% of the students in the control group reported using the computer in the classroom 2–3 hours a week, whereas 50% of the students in the treatment group reported no use of the computer in the classroom.

Method and data collection

The primary assessment used was a collection of instruments gathered in the publication *Instruments for assessing educator progress in technology integration*, made available by the Institute for Integration of Technology into Teaching and Learning (Knezek *et al.*, 2000). The battery of instruments measures attitudes, dispositions and technology proficiency among teachers. The Concerns-Based Adoption Model (CBAM) is a self-assessment instrument that measures the level of adoption of an educational innovation. Stages of Adoption is a self-assessment instrument that measures the teacher's level of adoption of technology. Teachers' Attitudes Toward Computers (TAC) measures attitudes toward computers in nine areas, which include interest (enjoyment and satisfaction in using computers), comfort (lack of anxiety and comfort using technology), accommodation (acceptance of computers and a willingness to learn), E-mail (usefulness of E-mail with students), concern (fear that computers will have a negative impact on society), utility (belief that computers are useful for productivity and instruction), perception (overall feeling about computers), absorption (belief that computers are a part of many areas of work and leisure) and significance (belief that computers are important for student use). Technology Proficiency Self-Assessment (TPSA) determines the educator's own perception of his/her skill levels in four areas: E-mail, the World Wide Web, integrated applications and teaching with technology. Apple Classroom of Tomorrow (ACOT) measures the teacher's level of understanding and use of technology. General Preparation Profile for Prospective Teachers (GP3), which measures the general preparation of pre-service teachers to use technology in the classroom, is based on the ISTE standards. The instruments have been developed and validated over the past 10 years by researchers associated with the Institute for the Integration of Technology into Teaching and Learning. All have built upon the work of previous scholars in many states and nations, with support from numerous agencies, including the Meadows Foundation, the Japan Society for the Promotion of Science, the Fulbright Foundation and the Texas Center for Educational Technology.

Regarding reliability, TAC has shown reliability coefficients of from 0.84 to 0.97 across the nine subscales (Knezek & Christensen, 2002). The validation of GP3 yielded an α value of 0.93

Table 1. Summary information on pre- and post-tests available for data analysis

Groups	Pre-tests taken	Post-tests taken	Matches pre- and post-tests
Control	160	112	93
Treatment	32	17	14
Total	192	129	107

(Knezek *et al.*, 2003). CBAM, Stages of Adoption and ACOT are single item measures, thus no reliability coefficient is obtainable. Nevertheless, test–retest reliability for CBAM has been estimated to be between 0.72 and 0.73 and for Stages between 0.80 and 0.91 (Knezek & Christensen, 2001).

Table 1 shows the final pre- and post-course data collections that were available for analysis. Due to a problem with students not taking either the pre- and/or post-course test the ability to perform data analysis was hampered. There was 35% attrition between the pre- and post-course tests, with the outcome being that only 55.8% of the possible sample size was available for examination. The lack of matching tests creates unbalanced groups, which results in limited data analysis alternatives. Upon discussion with the instructors involved with the research it was determined that the problem with missing pre- or post-course testing could be corrected by better tracking of the students taking the tests. This problem will be addressed in the next phase of the research.

Results

In order to account for possible differences between the treatment and control groups, the first step was to test the equivalence of the groups at the starting point on the measures administered. Pre-test data were analysed, and the results are shown in Table 2. None of the measures yielded statistically significant differences between the control and the treatment groups, which suggests equivalence of the two groups on adoption, attitudes, proficiency and preparation regarding technology. Having equivalent conditions in the pre-test, an ANOVA for the post-test was performed. The results are shown in Table 3. The results yielded three statistically significant differences: TAC/accommodation, TAC/concern and TPSA/teaching with technology.

Figure 3 shows the analysis for the subscale computer interest. A key finding is that the 3-dimensional online learning environment (treatment) tracked the face-to-face course delivery (control). The computer interest subscales of the control and treatment groups decrease at the same rate between the pre- and post-course tests. For the computer interest subscale this decrease between the pre- and post-course tests is a normal occurrence. The differences in starting level between the control (4.23) and treatment groups (4.12) is most likely a result of the different compositions of the student groups that take classes at the main campus as compared with those who attend courses at the Dallas campus. Students who attend courses at the remote Dallas campus tend to be older, less experienced computer users who also maintain a job or household full time.

Figure 4 shows the analysis for the subscale computer comfort (anxiety). Of primary interest is that the 3-dimensional online learning environment (treatment) again paralleled the

Table 2. ANOVA for different technology integration and technology beliefs measures administered as a pre-test to 14 treatment and 93 control CECS 4100 UNT students

	Mean		SD			
Measure	Treatment	Control	Treatment	Control	*F*	Significance
CBAM	3.857	3.717	1.875	1.535	0.095	0.759
Stages of adoption	4.785	4.489	0.892	1.074	0.964	0.329
TAC/computer interest	4.128	4.234	0.419	0.548	0.478	0.491
TAC/computer comfort	4.242	4.320	0.533	0.722	0.149	0.701
TAC/computer accomodation	4.700	4.784	0.413	0.365	0.637	0.427
TAC/interaction	3.800	3.967	0.908	0.788	0.530	0.468
TAC/computer concern	3.446	3.717	0.659	0.813	1.415	0.237
TAC/computer utility	4.080	4.247	0.510	0.526	1.233	0.269
TAC/perception	5.942	5.789	0.778	1.227	0.206	0.651
TAC/absorption	2.985	2.922	0.754	0.786	0.079	0.779
TAC/significance	4.128	4.311	0.512	0.473	1.787	0.184
TPSA/E-mail	4.342	4.458	0.516	0.621	0.434	0.511
TPSA/World Wide Web	3.871	4.126	0.635	0.622	2.038	0.156
TPSA/technical application	3.471	3.673	0.825	0.879	0.650	0.422
TPSA/teaching with technology	3.614	3.569	0.878	0.741	0.042	0.839
ACOT	3.714	3.195	0.913	0.986	3.422	0.790
GP3	3.520	3.566	0.563	0.601	0.071	0.790

Table 3. NOVA for different technology integration and technology beliefs measures administered as a post-test to 14 treatment and 93 control CECS 4100 UNT students

Measure	Mean		SD		*F*	Significance
	Treatment	Control	Treatment	Control		
CBAM	4.461	5.290	1.853	1.571	3.036	0.084
Stages of adoption	5.000	5.086	0.960	0.985	0.093	0.761
TAC/computer interest	4.028	4.189	0.536	0.601	0.890	0.348
TAC/computer comfort	4.071	4.215	0.775	0.687	0.514	0.475
TAC/computer accomodation	4.400	04.718	0.811	0.453	4.714	0.032
TAC/interaction	3.885	4.086	0.791	0.719	0.919	0.340
TAC/computer concern	3.348	3.845	0.853	0.731	5.381	0.022
TAC/computer utility	4.044	4.266	0.551	0.549	1.974	0.163
TAC/perception	5.800	5.972	0.855	1.187	0.272	0.603
TAC/absorption	3.114	3.124	0.946	0.917	0.002	0.969
TAC/significance	4.200	4.344	0.549	0.510	0.952	0.332
TPSA/E-mail	4.514	4.651	0.678	0.519	0.781	0.379
TPSA/World Wide Web	4.485	4.612	0.621	0.503	0.729	0.395
TPSA/technical application	4.300	4.428	0.650	0.651	0.469	0.495
TPSA/teaching with technology	4.057	4.492	0.809	0.596	5.877	0.017
ACOT	3.857	3.849	0.949	0.736	0.001	0.972
GP3	3.948	4.220	0.524	0.538	3.129	0.080

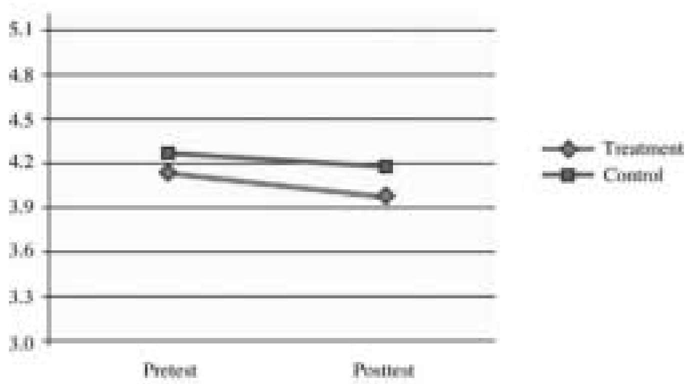

Figure 3. Pre/post-course comparisons on the computer interest subscale

face-to-face course delivery (control). The computer comfort subscales for the control and treatment groups decrease at the same rate between the pre- and post-course tests. This means that the control group showed a slightly smaller increase in anxiety (decline in comfort) from the beginning to the end of the course.

Viewed together, both of these subscales show that the pre- to post-course trends for the 3-dimensional online learning environment for delivery of the CECS 4100 course were very similar to those of the face-to-face course when looking at computer comfort and computer interest.

Figure 5 shows that while accommodation (lack of avoidance) to technology use remained at about the same level between the pre-course and post-course tests for the control group, for the treatment group there was a clear decrement. This means that the feeling of avoidance of technology use increased between the pre-course and post-course tests for the treatment group.

Figure 6 shows that there was a decrement in computer concern between the pre-course and post-course tests for the treatment group, but for the control group there was an increment. The treatment group using the CRG environment had some of their fears about the dehumanizing

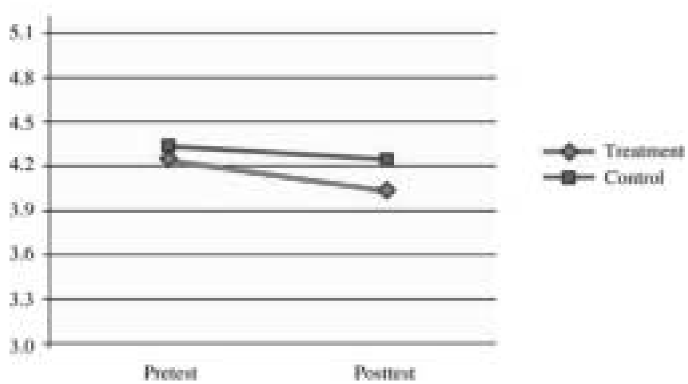

Figure 4. Pre/post-course comparisons on the computer comfort (anxiety) subscale

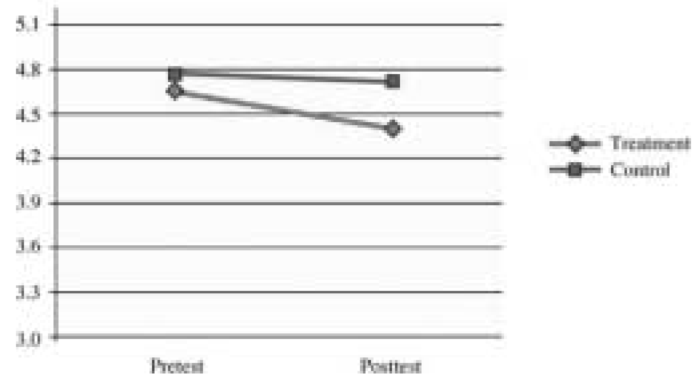

Figure 5. Pre/post-course comparisons on the computer accommodation (avoidance) subscale

effect of computers alleviated during the course, while for the traditional face-to-face class these kinds of concerns increased.

Figure 7 shows that both groups started with about the same mean score on the teacher with technology subscale, but in the post-course test the control group rated themselves significantly higher than the treatment group. Pre-service teachers on the traditional, on-campus course apparently gained more in lesson plan development, collaborative classroom techniques for student learning and awareness of software programmes for K-12 student use.

Discussion

Some of the differences reported in the previous section are likely due to differences in the teaching/learning resources available at the main campus in Denton compared with the South Dallas campus. For example, differences in teaching with technology are likely due to availability of a software evaluation laboratory for on-campus students and the greater emphasis placed on modeling cooperative learning and unit portfolio creation in the on-campus class. However, other differences, such as the change in the level of concern, have no obvious explanation outside the fact that there was a more immersive involvement with

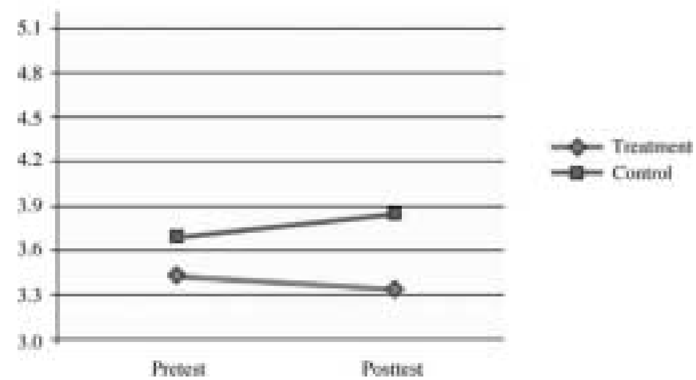

Figure 6. Pre/post-course comparisons on the computer concern subscale

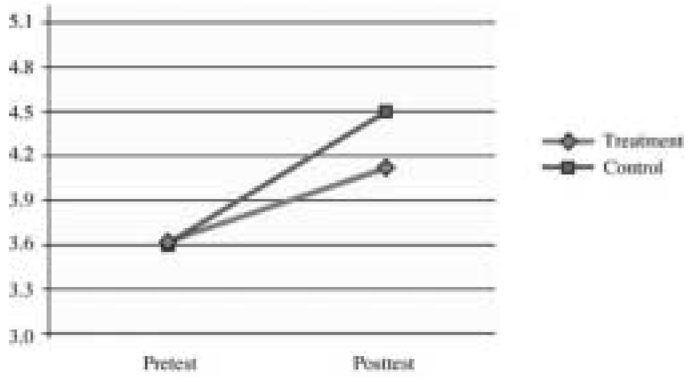

Figure 7. Pre/post-course comparisons on the teaching with technology subscale

the technology itself in the treatment group, which possibly lowered concerns about dehumanization.

One unexpected, universal student behavior was encountered during our baseline study that we conjecture to be unique to the 3-dimensional online learning environment. Each time the system was first demonstrated remotely to a class, the students dispersed throughout the environment to explore (learn by play) and it was very difficult to collect them back again to complete the initial training in the online mode. Because of this, we found that completing the online walk-through was more difficult than during a structured classroom session. Since the initial trials we have implemented a means to globally text chat with everyone in an area ('make announcements') in order to be able to coordinate these types of introductory sessions. We hope this will make online training sessions more easily accomplished in the future.

We also conjecture that this 'spontaneous exploration' feature of the 3-dimensional online learning environment can be harnessed to better implement under-utilized forms of pedagogical practice and perhaps to create new forms of teaching/learning some day. The broad area of discovery learning (Bruner, 1961) and popular outside of school learning techniques such as orienteering (map-based navigation) and scavenger hunts are a few of the prospective methods that immediately come to mind. It would appear that such approaches could be implemented in a 3-dimensional online learning environment in such a way that Vygotsky's (1978) social context for learning could be made available through virtual game-playing partners or groups of virtual peers. Virtual peers selected at the appropriate novice-to-expert or child-to-adult level, like chess partners at or near a player's own level of skill, might provide safe, low cost, unique avenues for expanding the sphere of readiness referred to by Vygotsky as a learner's zone of proximal development. These and other theory-based pedagogical frameworks are targeted for future research.

The selection of participants in the study was not optimal. We believe that the student populations attending each campus might be a significant factor in addition to the 3-dimensional online learning environment that affected the outcomes seen in the treatment group. It is our goal in the future to ensure that we have control groups based on campus location, so that we can maintain a more uniform environment. In the future we will need to ensure that we have at least one control group at each campus for the approach being studied, so as to rule out factors related to the types of student that attend each campus.

The prolonged technical difficulties encountered at the start of the semester by the treatment group had to have an impact on student's post-course tests. The technical difficulties might be enough by themselves to account for the decrease in outcomes on accommodation (Figure 5), computer concern (Figure 6) and teaching with technology (Figure 7). Only additional research will allow us to answer this question.

Conclusion

The task before us is to continue to look at new ways to accomplish educational goals while still meeting the requirements of access as discussed earlier in the article. The research discussed in this article shows some of the potential of 3-dimensional online learning environments. If 3-dimensional online learning environments can approach face-to-face classroom interaction and learning over low bandwidth Internet connections, then this approach merits serious consideration as a method to support interactive online classrooms and course delivery.

While the presented research needs additional studies to provide more depth to issues discovered in this first round, we feel that these initial results show positive trends in several key issues concerning the use of 3-dimensional online learning environments for the delivery of college courses. The experience of this exploratory research is driving our future initiatives. The next phase of our research will be to structure the participating sections such that we have a clearer picture of changes within the treatment groups. We are very interested in seeing where 3-dimensional online learning environments might fit between total asynchronous course delivery (web pages) and face-to-face instruction. The course examined during the autumn semester of 2004 will allow us to compare a web-based, 3-dimensional online learning environment and face-to-face delivery all located on the main campus. This study design should allow us to obtain a much clearer insight into what we saw during this initial research. Additional universities will also be using the 3-dimensional online learning environment in the coming months and data collection from those courses will be compared with this data and future data as it is collected in order to gain more insight.

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