Extended Field Trials of a Mixed-Reality Teaching Environment: Practical Issues Beyond the Technology

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Abstract. This paper reviews the results of a set of field trials on MiRTLE - the Mixed Reality Teaching and Learning Environment conducted at Saint Paul College. We report on some of the lessons learnt using the platform and its relationship to the underlying pedagogies.

Keywords: MIRTLE · Virtual reality · Mixed reality · Essex university · Saint Paul College · Multi-user virtual environment (MUVE)

1 Introduction

Early in our research efforts into virtual environments at the University of Essex we felt that extending the virtual environment into the physical world of a classroom and bringing the classroom into the virtual environment could achieve higher levels of tele-presence within such environments thereby heightening student engagement which we felt would increase student academic achievement. Our thought was to mix video streaming and virtual reality to create a mixed reality environment. We began a research and development program that produced a Multi-User Virtual Environment (MUVE) platform that we called the Mixed Reality Teaching and Learning Environment, or MiRTLE, Gardner and O'Driscoll [3] and an extended platform version which we call MiRTLE+.

While our empirical research supports the concepts on which MiRTLE and MiRTLE+ are based we felt that it was very important that the technology be tested in the actual classroom in order to develop a broader assessment of the efficacy of this technology in education. We developed a cooperative research program with Saint Paul College in Minnesota, USA who agreed to construct and operate a large-scale implementation of MiRTLE, use it in a standardized first course in computer science and to record their observations concerning its utility. In parallel to the field trial at Saint Paul we developed and conducted a series of laboratory experiments on MiRTLE and MiRTLE+ at our iClassroom facility at the University of Essex.

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The data from our field trials and laboratory work are encouraging leading us to believe that when systems are put into place that incorporate the wider pedagogical and behavioral aspects effected by the technological platform student achievement within these mixed reality immersive environments is comparable or better than that of face-to-face instruction.

2 Background

Our first project that combined real and virtual worlds was MiRTLE, Gardner et al. [4]. The objective of the MiRTLE (Mixed Reality Teaching and Learning Environment) project was to provide an online virtual classroom to augment live lectures. This was inspired by the observation that even if remote students were able to watch a live lecture remotely (for example using video conferencing or other similar technology), they often would choose to watch the recorded session instead. The main reason for this is that there was very little perceived value in their participation in the live event, as often there was only limited means (if any) for them to interact with the people in the live classroom. This meant that the recorded version of the event usually offered an equivalent experience with the advantage that they could also choose to watch in their own time.

MiRTLE provided a mixed reality environment for a combination of local and remote students (both dispersed and local students are able to see and talk with each other, in addition to the teacher). The MUVE environment was intended to augment existing teaching practice with the ability to foster a sense of community amongst remote students, and between remote and co-located locations. In this sense, the mixed reality environment links the physical and virtual worlds. Using MiRTLE, the lecturer in the physical classroom is able to deliver the class in the normal manner but the physical classroom also includes a large display screen that shows avatars of the remote students who are logged into the virtual counterpart of the classroom. Thus the lecturer will be able to see and interact with a mix of students who are present in both the real and virtual world. A schematic of a MiRTLE classroom built at Saint Paul College is shown in Fig. 1. Audio communication between the lecturer and the remote students is made possible via a voice bridge. A camera is placed in the classroom room to deliver a live audio and video stream of the lecture into the virtual world. From the remote students perspective, they can log into the MiRTLE virtual world and enter the classroom where the lecture is taking place. Here they will see a live video of the lecture as well as any slides that are being presented, or any application that the lecturer is using. Spatialised audio is also used to enhance their experience so that it is closer to the real world. They have the opportunity to ask questions just as they would in the physical world via audio communication. Additionally, a messaging window is provided that allows written questions or discussion to take place. The MiRTLE virtual world also offers a common room where students can meet socially and access other resources for their course. Figure 2 illustrates the virtual world for the online students in a MiRTLE class.

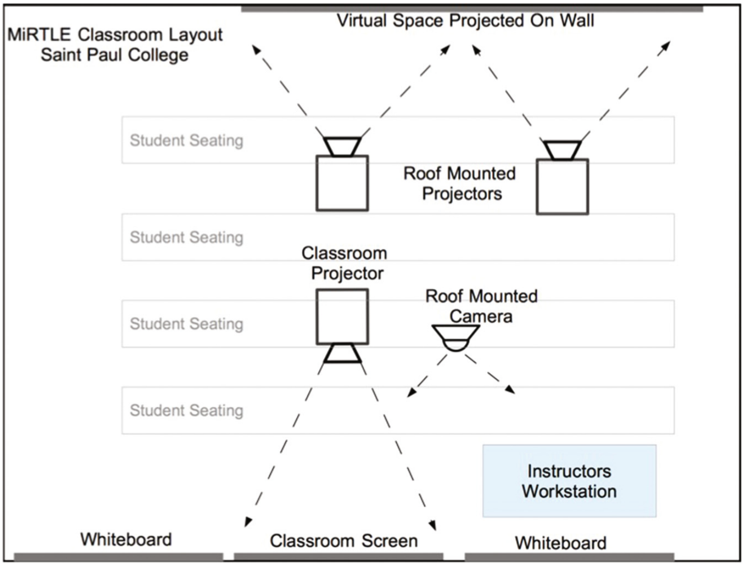

Fig. 1. Saint Paul MiRTLE classroom - General arrangement

Fig. 2. MiRTLE classroom

3 Experimentation and Field Trials

During the 2008–2009 academic year the Computer Science department at Saint Paul College, Saint Paul, MN, USA, remodeled a general-purpose classroom into a MiRTLE classroom. The general arrangement of this classroom was shown previously in Fig. 1. In this facility life size avatars are projected on the rear wall and lectures are captured and distributed using an inexpensive ceiling mounted security camera.

Following the construction of the MiRTLE facility a set of field trials were run from 2008 until 2014 comparing MiRTLE assisted instruction and traditional in-person attendance. Student achievement and retention were thought to be the best indicators of student success and were measured as follows:

1. *Student achievement:* measured by the absolute improvement in the percent of correct answers on a standardized examination administered during the first class meeting and subsequently used as the final examination in the course:

$$Student\ Achievement = Final\ Exam\ Score - Initial\ Class\ Meeting\ Score$$

2. *Student retention:* measured as the percentage of students attending the course relative to the initial enrollment in the course.

A standardized first course in computer science was selected as a test case. During these trials the learning objectives, textbook, content, instructor and assessment instruments were held constant.

Three field trials were conducted in which the student could elect to participate through MiRTLE or attend meetings in person. The trials were conducted as follows:

1. *Field Trial 1:* students chose whether to attend lecture based courses in-person or via the MiRTLE facility. This trial started in Fall of 2008 and ended in Spring 2010. Students in the sample: 240.
2. *Field Trial 2:*[1] students chose whether to attend lectures in a blended delivery course in-person or via the MiRTLE facility. This trial started in Fall of 2010 and ended early in Spring of 2011. Students in the sample: 120.
3. *Field Trial 3:* students chose whether to participate in active learning meetings in person or via the MiRTLE facility. This trial started in Fall of 2010 and ended in Spring of 2014. Students in the sample: 240.

Table 1. Field trial results - Saint Paul College

Student retention and achievement			
Type of class meetings	Trial period	Absolute improvement in the percent score on a standardized examination over the academic term	Percentage of students retained over the academic term
Traditional lecture meetings	2008 to 2010	45.3	60.4
Traditional lecture meetings - MiRTLE attendance	2008 to 2010	44.4	62.8
Blended delivery with traditional lecture meetings	2010 to 2011	33.0	51.8
Blended delivery with active learning meetings	2012 to 2014	50.3	75.8
Blended delivery - MiRTLE attendance with active learning meetings	2012 to 2014	52.0	72.1

[1] This field trial was terminated early due to student complaint, low retention and reduced student achievement. MiRTLE attendance data has been excluded due to unreliable record keeping which occurred during periods of course adjustment following student complaint.

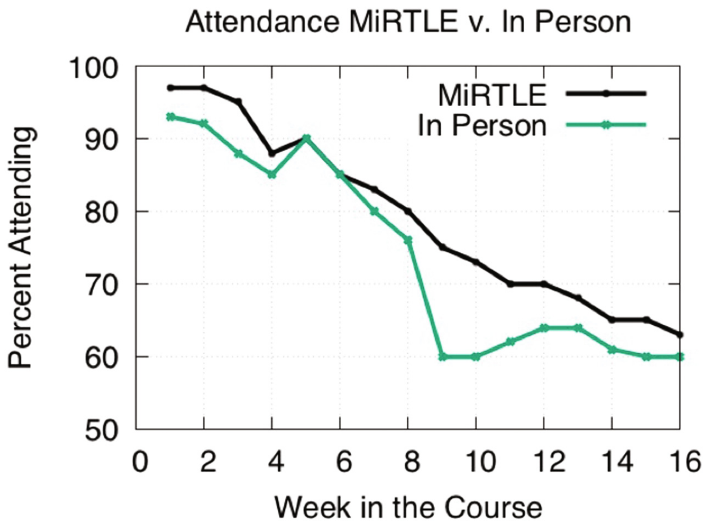

Fig. 3. 2008–2010 MiRTLE implemented with a traditional classroom

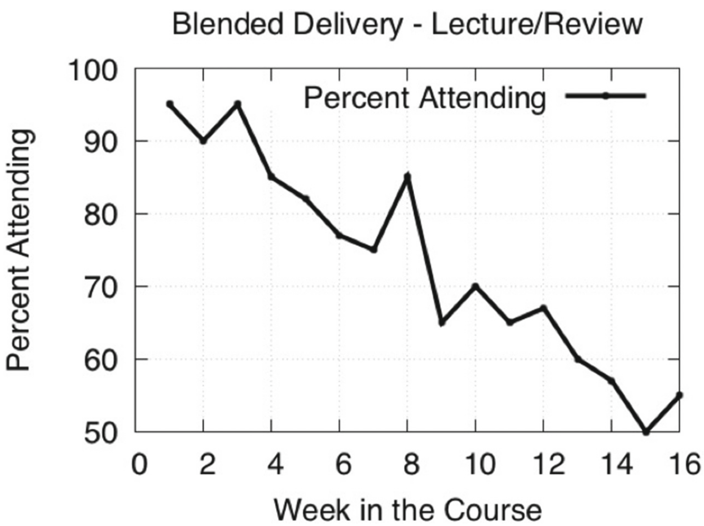

Fig. 4. 2010–2011 blended coursework delivery model

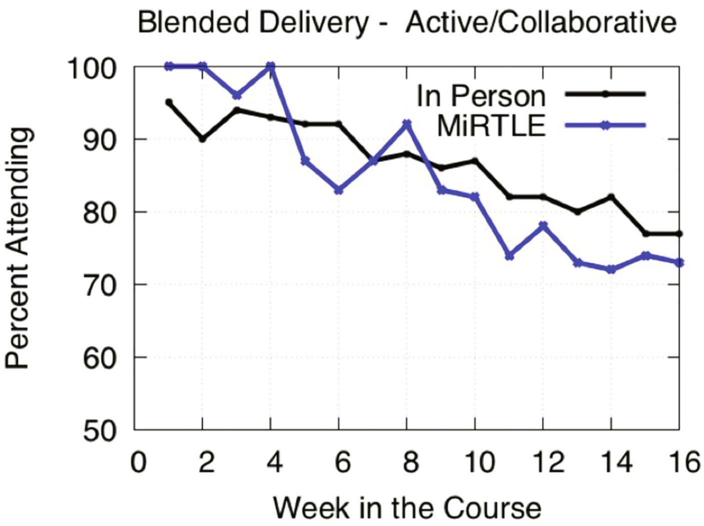

Fig. 5. 2012–2014 MiRTLE with active laboratories

The results of the field trials are summarized in Table 1. Retention levels during each of the trial periods is shown in Figs. 3, 4, and 5.

4 Discussion

The MiRTLE facility at Saint Paul College was built in order to address concerns that the computer science faculty had over the efficacy of asynchronous distance education. MiRTLE was selected as the primary platform for distance learning for the following reasons:

1. MiRTLE is not intrusive. Faculty and students can use it without any changes or modifications to their normal pedagogical routine.
2. MiRTLE brings the classroom to the distance learner and the distance learner to the classroom in a very engaging manner, Gardner et al. [4]. It has many features that support both co-creation and collaboration in a virtual world environment, Potkonjak et al. [10]
3. MiRTLE is a mixed realty platform which extends the virtual world that supports it. When this virtual world is not being used for lecture activities it can be easily utilized as a virtual world platform on which students and faculty can communicate and collaborate, Gardner and ODriscoll [3].
4. Since it was based on the Open Wonderland platform MiRTLE, easily supports the typical teaching tools used in a first course in computer science. Terminals, editors, compilers, presentation software and web access are readily available within a MiRTLE implementation, Gardner, Scott and Horan [5].

5. With a properly configured client computer MiRTLE is easily accessible and simple to use.
6. A MiRTLE facility is multipurpose in that the classroom technology platform is not restricted to MiRTLE enabled virtual worlds. It can support alternative platforms such as Second Life or OpenSim with very little effort.

The MiRTLE facility was placed into classroom operation in the Fall of 2008. It was remarkably easy for various faculty to use and required no training other than how to turn it on. Faculty conducted their lecture sessions in the normal manner and found the interaction with avatars to be very natural.

4.1 Field Trial 1 - Comparing MiRTLE to Traditional Lecture

During the first field trial conducted from the Fall of 2008 through Spring of 2010, 8 sections of 30 students were given the option of attending a traditional first course in computer science either by MiRTLE or in-person attendance. Initially about 15 percent of the class chose to attend via MiRTLE. As the the term progressed the number of students attending via MiRTLE increased to about 40 percent of the class.

As shown in Table 1 student scores on a standardized examination improved by 45.3 percent points for those attending lectures and by 44.4 percent points for those attending via MiRTLE. Retention during this period was 60.4 percent for those who attended in-person and 62.8 percent for those who attended via MiRTLE. Examining the weekly attendance plot in Fig. 3 it seems MiRTLE attendance was uniformly better, particularly during the usual dropoff period following midterm examination.

We feel the results show that MiRTLE when used in this manner provides distance students with similar learning outcomes to those in the physical classroom. This is considered a successful trial since MiRTLE met all of its design expectations, students performed as well on the MiRTLE platform as in the lectures and it appeared that as students and staff became more comfortable with the MiRTLE platform they migrated to it.

4.2 Field Trial 2 - Implementing Blended Delivery Using MiRTLE

Due to the initial success of MiRTLE the computer science faculty elected to run a second field trial beginning in September of 2010 utilizing the MiRTLE platform and a learning management system to offer the course in a blended delivery format. This approach reduced face-to-face instruction by 50 percent resulting in weekly rather than twice a week classroom meetings. The idea was to move the static curriculum content to the asynchronous learning management system and utilize weekly meetings to answer questions and conduct lecture reviews of the material for the week. Students were also encouraged to attend the weekly meetings remotely using the MiRTLE facility and to meet and collaborate on problems together when lectures were not being conducted.

The second field trial was terminated in May of 2011 due to lower student retention and measurable decreases in learning achievement. The frequency and nature of student complaints and interventions by the college administration also played a role in electing to end the trial. The data gathered from this trial involved 4 sections given over two academic terms or 4 cohorts of 30 students. Data from the four sections was aggregated. Based on the aggregated data the first meeting scores on the standardized examination were again around 30 percent however the absolute improvement in student scores on the standardized examination were only 33 percent points compared with 45.3 percent points in the lecture led sections. Overall student retention dropped from 62 percent to 52 percent of the initial enrollment. There was also a troubling drop in retention during the beginning weeks of the course. Students made little or no use of MiRTLE and did not utilize the virtual world meeting rooms available to students in these sections as in the earlier trials with MiRTLE.

Following the rather dramatic failure of the second field trial a lengthy retrospective review was conducted by a group of faculty and students. The group developed a set of recommendations to address what were thought to be the most critical issues. Based on this review is was decided to re-examine the pedagogy in light of the technological approach being used. This led to the development of an alternate model of course design and a modification of the instructional pedagogy. This model envisions a course design of sequential learning modules that utilize a mixture of behaviorist and constructivist based pedagogies. Figure 6 illustrates this general design.

This pedagogical approach utilizes active/collaborative learning laboratories for in-class instruction and divides on-line learning into behaviorist and con-

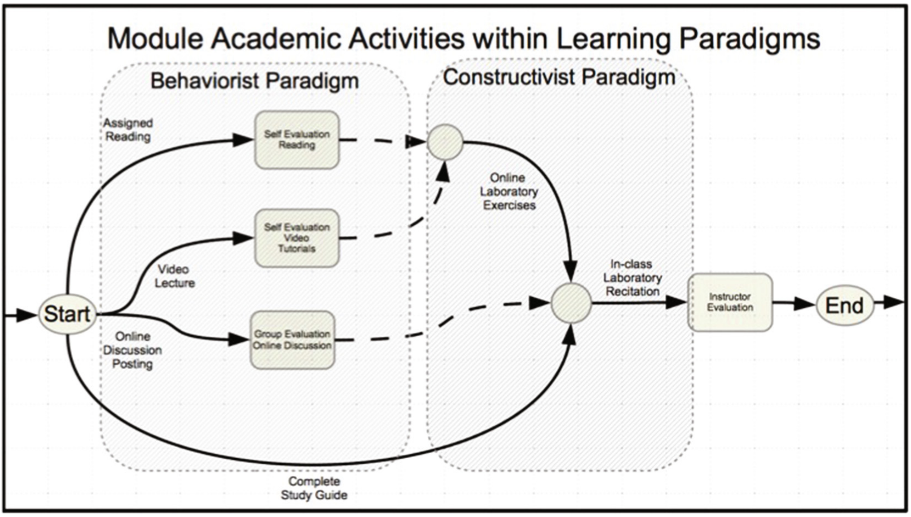

Fig. 6. Modified pedagogy explicitly recognizing MiRTLE technology

structivist learning activities. The asynchronous on-line behaviorist instruction utilizes familiar behaviorist tools such as programmed instruction, structured study guides and a token economy. The appropriate use of such methodologies was outlined in the work of McDonald et al. [8] and Doll et al. [2]. This portion of instruction is completed asynchronously and entirely within the learning management system. Learning tools such as instructional videos and self-evaluations are used extensively. Adding structure to the asynchronous on-line materials was considered a critical component of this design as the study group found that if as few as 10 percent of students came to the blended meetings unprepared the meetings were essentially useless and a large portion of the class became dissatisfied. The asynchronous portions of the pedagogical model based on constructivist theories were influenced by the work of Ben-Ari [1] and the actual pedagogical designs were largely based on the work of Jonassen, [6,7]. Once the work on the pedagogy was complete the course materials were redeveloped and field trials resumed in the Fall 0f 2012.

4.3 Field Trial 3 - Active Collaborative Instruction with MiRTLE

During the third field trial conducted from the Fall of 2012 through Spring of 2014, 8 sections of 30 students were given the option of attending a traditional first course in computer science conducted using the modified pedagogy shown in Fig. 6 either by MiRTLE or in-person. Initially about 20 percent of the class chose to attend via MiRTLE. As the the term progressed the number of students attending via MiRTLE increased to about 40 percent of the class.

As shown in Table 1 student achievement in the standardized examination was a 50.3% point improvement for those attending in person and by 52.0% points for those attending remotely using MiRTLE. Retention during this period was 75.2 percent for those who attended in-person and 72.1 percent for those who attended via MiRTLE. Examining the weekly attendance plot in Fig. 5 it seems in-person attendance was slightly better over most of the term.

The results of this third field trial showed essentially equal performance between those students using MiRTLE and those who attended the sections in person. Once again MiRTLE attendance was shown to be essentially as effective as in-person attendance. Remarkably both achievement and retention measures were significantly higher using the modified pedagogy which implemented structured asynchronous activities and active/collaborative laboratory sessions rather than periodic lectures. If we assume the increase in retention and achievement was largely attributable to the modified pedagogy we observe that despite this shift MiRTLE students had similar outcomes. We feel this further validates the efficacy of MiRTLE as an alternative distance learning platform.

5 Conclusions and Directions for Future Research

The Saint Paul case study clearly shows that the technology is only one part of the picture, and the other aspects (particularly behavioral aspects) are equally important when designing new learning activities. This work has also shown that the mixed-reality approach can work well, particularly when incorporated into a sound pedagogical/behavioural approach. This is also reinforced by the evidence from the Saint Paul case study.

It could be said that this early work only demonstrates a glimpse of the potential benefits from the use of a mixed-reality technological approach. MiRTLE was deliberately very simplistic in terms of the pedagogy being supported (but effective because it was so simple). MiRTLE was successful not because it was technically advanced but because it was so natural for the instructors to use, requiring no new training or lesson planning. Effective use of any of these platforms in an educational setting is very dependent on the structure of the pedagogy. Here pedagogy is king and technology is servant. This might explain the reason for the relatively slow uptake of virtual and mixed-reality where often due to the complexity of the platforms a lot of effort is spent on the technology and little effort on how to apply it. Here the relationship the technological system has to the environment it will be operated in is a key success factor. In addition the work being done at the University of Essex to extend the MiRTLE platform particularly with the use of new devices and more collaborative learning activities, shows great promise, and seems to lead to more engaging, and effective learning (when compared to more traditional approaches) see Pena-Rios et al. [9].

A simple unifying observation can be made for the tests conducted at Saint Paul to date. When implementing any system of technologically supported learning, care should be taken to consider the overall course delivery mechanisms, systematically recognizing as key system components the nature of the platform, the structure of the pedagogy and the capacity of both students and instructors to adjust their respective approaches to learning and instruction in the new environment. The constructivist pedagogy is preferred over other approaches but there may be a role for behaviorist techniques to be used to support enhanced learning within the constructivist framework.

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