Breen Sweeney

COLMSCT Project Final Report
(Version 2 – June 2010)

Project title: Mathematics in a virtual world: Using Second Life for the teaching and learning of mathematics

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Executive Summary

Key Points
The researcher used the virtual world Second Life to investigate how mathematics can be taught in such an environment. However many of the conclusions are applicable to students in any discipline.

Tutorials were held in Second Life with Open University students on a second-level pure mathematics course. Interviews were held with the students, and their experience showed evidence that Second Life is a useful learning environment.

Although technological limitations currently exist, Second Life (or other virtual worlds) holds the promise of using other tools and techniques in future which can increase student understanding, particularly for the teaching of mathematics or scientifically based subjects.

A pilot study was conducted to compare Second Life with the role-playing game RuneScape, in order to study immersion. It is difficult to objectively define and measure immersion in virtual worlds, however the researcher used the percentage time a user spent focused on various areas of a game window to provide a quantitative method for measuring immersion. This was done using state-of-the-art eye-tracking equipment at the Open University’s Institute of Educational Technology.

A ‘proof-of-concept’ video was made to illustrate the possibilities that virtual worlds hold for the future. The researcher carried out a demonstration in Second Life of some mathematical concepts, and recorded the session as a video. By utilising three-dimensional objects he showed the potential for virtual worlds to go beyond the normal class-room setting and facilitate learning sessions that could not be easily carried out in the real world.

The researcher worked with Dr. Anne Adams to investigate how design of the environment in virtual worlds affects participants, particularly in relation to task based and affective attention measures. The research identified that there was increased users attention within gaming environments (RuneScape) compared to social world interactions (Second Life). Further analysis identified that interaction in the virtual world associated with the three-dimensional environment increased participants’ attention more than individual object-based or avatar-based tasks.

During the project aspects of the research was disseminated via journal publications, conference talks and posters. The overarching story of the research, pus the additional work on the proof-of-concept video, will be submitted for further journal or book publication.

**Project highlights**

**Holding tutorials in Second Life**
The researcher is a tutor on the Open University second-level course in Pure Mathematics (M208). Tutorials were held with volunteer students from this course in the virtual world Second Life, and the subjects learned covered linear algebra, group theory, real analysis, and general exam advice/revision. The researcher investigated issues such as how to teach in a virtual world, and how to overcome the difficulties of communicating complex equations and diagrams in these environments.

During the sessions a special experiment was carried out. The tutorials were held in different environments/locations. When the data was being gathered to analyse the effectiveness of the learning via the standard technique of telephone interviews, the students were asked about their experiences. The surprising result was that one of the environments caused a real feeling of claustrophobia among some students. The results indicate the importance of environment when designing learning spaces.

**Comparing the social world Second Life with the role-playing game RuneScape to investigate immersion in virtual worlds.**
The terms ‘immersion’ and ‘immersiveness’ are used to describe the degree of involvement in a virtual world, and the terms are usually applied to games, but apply equally well to social virtual worlds like Second Life. The researcher suggested a hypothesis which would allow a quantitative measurement of immersion to be made, using eye tracking hardware. The researcher designed an experiment to compare Second Life with the Massively Multi-player Online Role Playing Game (MMORPG) called RuneScape, and carried out a pilot study with the help of several of his colleagues. The results were analysed, and the researcher collaborated with Dr. Anne Adams in order to compare in a quantitative manner the relative immersion in the two different types of world. A paper was co-authored and later presented by Dr. Adams at the HCI 2009 conference.

**Utilising the 3-D nature of virtual worlds to illustrate mathematical concepts**
Another strand of the researcher’s work involved investigating how a virtual world can go beyond the normal classroom activities and utilise the 3-D nature of the world for mathematics. In a standard face-to-face classroom environment mathematicians, scientists and technologists have for generations explained 3-D concepts using 2-D surfaces, such as whiteboards or power-point presentations. While in the real world video can of course also be used, in a virtual world you can in theory reproduce everything that a face-to-face session does, but also go beyond this to build and animate 3-D objects to be used in the virtual classroom.

Technology at the moment acts as a barrier to some activities in virtual worlds, as it takes an investment in time and effort to build objects, and much time is taken up with specific technical issues such as lag, student’s access, specifics of the actual virtual world being used (Second Life), and so on. So the researcher produced a proof-of-concept video. A virtual learning session was held in Second Life to explain mathematical concepts, but rather than invite students, the researcher recorded the session to produce a video. Thus the possibilities of teaching mathematics in virtual worlds using their 3-D nature were explored, while allowing a wider access to the resultant video.

The researcher hopes the video is an illustration of what will be possible in the future, as technology, computing power, and virtual worlds advance in design and capabilities.

**Further details**

**Ancillary activities**

There were various ancillary activities that took place, such as preparation for the research, attending seminars, both inside Second Life and in the real world, meetings have been held with various people, the project page on the COLMSCT site has been updated, adding in some background information and relevant links, contributions have been made to the eLearning Communities and Identities SIG wiki, and so on. These are not described here.

During the research data was kept, including the keeping of a learning log and noting tasks and activities that were carried out. This was a continuous and on-going task which aided in the research process. The initial start to the project was threatened as the Open University’s Cetlment Island became unavailable. However Anna Peachey did a lot of work to prepare the Open Life island for Open University use. As the details and location of the Second Life land changes, so plans were adjusted.

The researcher also experienced technical difficulties in accessing Second Life. At the moment a relatively high-specification machine is needed, which has a good graphics card, plenty of installed memory, and runs on a broadband connection. (In the future the technical requirements may become less exclusive.) The researcher’s COLMSCT colleagues were extremely supportive, and provided a suitable laptop which was then used for all serious Second Life access. This was an essential component of the project, as it meant there was reliable access to Second Life during the contact with students.

**Student Involvement**

The first part of the project involved holding tutorials with students, and researching best practice in Second Life. The students were studying M208, the second-level course in Pure Mathematics, on the presentation which occurs from February to October 2008. The course covers introductory material, linear algebra, group theory and real analysis. Volunteers were recruited by posting in the official tutor group forum, and by advertising to the researcher’s own student group. In the end six volunteer students attended the series of learning sessions. (There were three other students who sat in on some tutorials for interest, but as these were not studying the course they were not officially included in the project.)

The merits of various ways to record student involvement during the project were compared, (blog, wiki, etc.), and it was decided to arrange for a First Class forum to be set up. The main advantage was that initial contact would be made with M208 students via the official First Class course forum, so there should be no learning curve for students if they wish to participate in the project. Support for any technical issues with the forum would also be available, as this is common well-used software within the Open University. The in-world voice facilities were used, and conversations controlled via turn-taking. The students could use text-chat to ask questions or say they wanted to speak.

Tutorials took place on the Second Life islands of SchomeBase and Open Life. Three orientation meetings (called ‘icebreakers’) were held, followed by seven mathematics tutorials. The tutorials covered Linear Algebra, Group Theory and Analysis. This was an expansion from the original plan to only

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cover Group Theory. The initial sessions were deemed essential to allow students to overcome technical problems and learn about the environment. Written material was circulated beforehand for the mathematics sessions, and I then discussed the material during the tutorials. An additional exam revision tutorial was held in September, but was held as a question-and-answer session, and was not taken into account when preparing the official research conclusions for input into publications. To provide an additional research objective, (a sub-project within the main project), tutorials were held in a variety of settings, so that the issue of whether the environment affected leaning could be examined. These were two different platforms in trees, one which had couch-like seats, a purpose-built classroom and corridor in the sky which the researcher built, the same room with the roof removed, a purpose-built chessboard room with wall and chairs which the researcher also created, and a bandstand.

At the end the students were invited to take part in a telephone interview, to get concrete evidence regarding how useful the tutorials were. Four did so, and were included in papers. A fifth subsequently also took part in an interview.

Eye-Tracking and Immersiveness
The terms ‘immersion’ and ‘immersiveness’ are used to describe the degree of involvement in a virtual world, and the terms are usually applied to games, but apply equally well to social virtual worlds like Second Life. Although their meaning is intuitively understood by participants in those worlds there is no agreed definition of the terms. The researcher suggested a hypothesis that the more immersed a user is, the more they will concentrate on their own avatar, rather than look at other areas of the screen. This is because they will be more interested in what their own avatar is doing, and identify with it, rather than looking at other activities or objects in the surrounding area.

Eye tracking hardware can determine where a user is gazing at any time and hence record eye movements. While this may be hard to test objectively by examining Second Life alone, The researcher suggested that a comparison might be made between Second Life and a Massively Multi-player Online Role Playing Game (MMORPG), to see if there were any differences observed, as a first step towards quantifying whether users became more immersed in a game or in a social virtual world. He also considered whether the average fixation duration might differ between worlds.

For the MMORPG he choose RuneScape. His COLMSCT colleagues Catherine Reuben, Diane Ford, Frauke Constable, Laura Hills, Katherine Perry, and Claire Dunlop participated in this pilot study. A Second Life avatar was created for the experiment. To comply with RuneScape regulations and to ensure each person had the same starting point in the game, individual RuneScape avatars were created and brought through the game’s orientation tutorial, and placed in the same position in the game world. This was important because in a role playing game as a player progresses their avatar’s characteristics change. Each participant were then asked to log into Second Life and carry out a number of standard tasks, such as navigation, teleportation, changing avatar appearance, and so on. After a break the participants then carried out standard tasks in RuneScape, such as navigation, fighting monsters, fishing, starting quests, and so forth. The sessions lasted about thirty minutes.

The researcher received help, advice and supervision from Dave Perry in the Institute of Educational Technology. A Tobii T60 eye tracking monitor was used for the pilot, connected to a purpose-built computer running Windows. After a calibration exercise, as the user sits and controls the avatar, the

Tobii monitor fires lasers and tracks the position of each eye’s gaze on the screen every 16 or 17 thousands of a second. An average gaze point is worked out. When the eye’s gaze moves across the screen this is known as a saccade, and the person is effectively blind during this movement. Although the position of the eye’s gaze changes fractionally all the time, when the gaze has been in the same area for some time, this is called a fixation. Hence a longer average fixation time (or equivalently a fewer number of fixations in a minute) means the eyes were focussed on fewer points on the screen, whereas a shorter time means the eyes were moving about and observing more parts of the screen.

The researcher divided the Second Life screen into the top controls, the bottom controls, and the game window. He further divided the game window into a top and bottom region, and a left, central and right region. The RuneScape screen was similarly divided into the top browser controls and advertisements region, the bottom controls, and top, bottom, left, middle and right sections of the game window. He choose the size of the regions so that the center region was proportioned similar to the 5:4 screen resolution and such that if a participant’s gaze was directed at all parts of the game window equally, they would spend twenty percent of their time focused on the central region (to within an error less than 0.2 per cent).

The researcher took the raw data from the sessions (TSV files) and placed them in MS Excel so the average fixation duration could be determined. He also converted the data into an MS Access Database. He wrote SQL procedures to analyse the data, and extract what percentage time was spent in each part of the screen.

**Proof of Concept Video**

Use of on-line technologies in education have become increasingly important, especially for a distance-education organisation such as the Open University. Using virtual worlds is part of this trend. However as these worlds are facsimiles of the real world, they offer opportunities that go beyond other technologies. The challenge is to see how education can be delivered in virtual worlds, and how the 3-D nature of such worlds can be used for innovative learning.

The researcher produced a video to act as a ‘proof of concept’ exercise. It explains a particular mathematical concept using the 3-D nature of Second Life, and shows how a virtual world could in principle use 3-D objects as an aid to subject understanding in the (virtual) classroom environment, and even enhance the normal face-to-face experience that students normally receive, where much of the material is presented via 2-D mechanisms such as white-boards or Powerpoint slides. The concept explained was that of a mathematical limit.

This video has been posted to a blog and feedback comments received, and it has been discussed at poster sessions and talks.

**Design of the environment and participant attention**

The researcher worked with Dr. Anne Adams to further investigate the comparison between the gaming environment (RuneScape) compared to social world interactions (Second Life). To understand how different social world design issues impact on attention further eye tracking analysis was conducted on the Second Life data.

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The tasks the participants had engaged in were divided into three types. ‘World’ tasks consisted of activities where participants were dealing with the general environment, for example navigating to various places. ‘Avatar’ tasks were those where participants were concerned with their own avatar, such as changing their Second Life appearance. ‘Object’ tasks were the activities which had participants doing things with objects in-world, such as for example carrying out building tasks.

This analysis identified that the Second Life interactions within the 3D world increased participants’ focus more than with object and avatar tasks. Ultimately interaction with an environment impacts on our attention and thus on our sense of ‘being there’.
Findings

Student Survey
The student survey came up with some very interesting evidence. Some of the quotes and the general results are shown in the published papers and discussed in talks and poster sessions.

As mentioned five students took part in the survey, although the last one participated at a late stage. Of the other four, in general terms three were positive about their experiences, and one was negative. They all agreed that the learning experience in Second Life was useful, and that Second Life had advantages similar to other online learning mediums. But the negative student felt it didn’t give them more than a telephone interview. In fact this student only attended two sessions before dropping out. The students thought that it is a very efficient way to learn. The benefits of the initial orientation meetings were agreed upon. The social aspects of Second Life were considered in a positive light. The students agreed there was tremendous potential with this form of learning, even the student who had been critical. Everyone was positive about the future of learning in Second Life.

When the students were asked about the different environments, in general their opinion was that the differences didn’t have a great effect. Significantly however none of the students likes the classroom without the roof removed, because it was closed and had no windows. Two did admit to being mildly claustrophobic in real life. The student who was mainly negative was more affected by the environments than the others.

The conclusions was that the very least a virtual world such as Second Life can offer the same advantages as other forms of online instruction, although the technological barriers at present will preclude some students from participating. These difficulties and the learning curve required to engage with Second Life means that at present a low tutor/teacher to student ratio is desirable.

While the nature of the environment within a virtual world doesn’t have as much effect as in the real world, the responses clearly show that it can affect learning, which is more evidence that there is a genuine ‘sense of presence’ in virtual worlds. The conclusion is that the design of the learning environment is an important consideration in virtual worlds.

The above conclusions are backed up by student quotes which are reproduced in publications.

Immersion in Virtual Worlds and Eye-Tracking
The eye tracking experiment yielded interesting results. The results showed that overall the average fixation duration in seconds for Second Life was 0.355643571, and the average fixation duration in seconds for RuneScape was 0.358696944. In fact the fixations in Second Life were longer for four participants, but shorter for two, and the final averages were very similar. This part of the experiment was inconclusive.

However when the researcher worked out the percentage times spent in various areas of the screen and tabled them, he did find a trend. In RuneScape the avatar is in the centre of the game window, and under normal circumstances the focus of the Second Life avatar is focused in the centre. As mentioned earlier in this report, if a participant was gazing randomly they would spend twenty percent of their time

focused on the central region. Hence for both Second Life and RuneScape it is to be expected that the gaze would be in this central area more than twenty percent of the time. Nevertheless the validity of the experiment depended only on a comparison between the worlds. The researcher found that the time spent in the central area as a percentage of the game window was 44% for Second Life and 54% for RuneScape to the nearest integer.

This is a significant difference. It suggests that this approach might be used to measure immersion between different types of virtual world, and suggests the participants were more immersed in RuneScape than in Second Life.

The above conclusions are backed up by data and statistical charts in the researcher’s publications.

**Proof of Concept Video**

The project scope did not include time to exhaustively collect data on the video, how from the initial comments the following conclusions may be made;

(A) There is a large overhead of time and effort in producing a video.
(B) It may be necessary to produce sophisticated videos, as people expect a high standard in terms of production values when they view a video, regardless of the content.
(C) The audience must be considered carefully. A general video may be uploaded to web sites and seen by several people repeatedly, which is very cost effective way to teach. However what they take from their video depends on their mathematical background. The video was explaining the concept of mathematical limit, and the learning effectiveness may appear differently to people who had little mathematical background than it does to students of mathematics.

**Design of the environment**

The findings from the work done with Dr. Anne Adams highlighted an increased end-user focus in the gaming environment (RuneScape) compared to social world interactions (Second Life). This difference in participant attention could be due to the goal-based nature of the different environments, and the different natures of these worlds could make comparisons difficult. There is also the question of whether the differences found were large enough to be statistically significant. However, the results rely mainly on objective quantitative data, using at it did the eye tracking hardware and a quantitatively defined measure of comparison.

It was found that different 3D situation designs altered levels of task engagement and distraction through perceptions of comfort, fun and fear. This appears to be a key factor in attention as opposed to distraction within an environment but is very much driven by individual differences. This does highlight the growing importance of personalisation in designing for educational purposes. This also highlights the value of virtual worlds as a supplement learning tools not a replacement for other learning environments.

While the nature of the environment within a virtual world doesn’t have as much effect as in the real world, the finding clearly show that it can affect learning, which is more evidence that there is a genuine ‘sense of presence’ in virtual worlds. The students’ perceptions of ‘claustrophobia’ within a specific virtual context or the ability to spark memories of old situational experiences highlights an affective level of immersion. We need to understand in more depth how these factors interact with the task.

being designed for. When designing learning environments we can increase a sense of fun through designing playful situations (e.g. tutorials in a tree). However, an increased sense of attention and immersion that can be felt through these designs can impact on a wide range of affective responses. For example designing a tutorial in a tree could be perceived as fun for many but for some could ignite negative emotive responses due to a fear of heights. The students’ attention within this context would turn to distraction.

Ultimately when increasing immersion through an increased sense of ‘being there’ it is necessary to understand the full implications of environment design.
List of deliverables

Publications


Talks


Posters

- Poster presentation at the 3rd Open CETL conference, the Open University, November 2008, “Mathematics in a virtual world”.

- Poster presentation at the National Associate Lecturer Conference, the Open University, 21st November 2009, “Learning Mathematics in Virtual Worlds – Experiments in Second Life”.

Opportunities for Future Dissemination

Although many aspects of the research have been reported via journal publications, conference talks and posters, there are still opportunities for future dissemination.

The overarching story of the research might be submitted to a book publication, such as for example the The additional work on the proof-of-concept video will be submitted for further journal publication, perhaps to one of the journals in the Open Research Online (ORO) repository.
References

The following are some of the references used during the research.


Fluckiger, F. 1995 ‘Understanding networked multimedia applications and technology’ Prentice Hall, London.


Appendix A – Some selected figures and tables
The following are some key information which was used in the project.

Table 1: Comparison of Fixation Duration

<table>
<thead>
<tr>
<th></th>
<th>Average fixation duration (seconds) in Second Life</th>
<th>Average fixation duration (seconds) in RuneScape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant 1</td>
<td>0.3853880661</td>
<td>0.3661889843</td>
</tr>
<tr>
<td>Participant 2</td>
<td>0.3088540512</td>
<td>0.2881853435</td>
</tr>
<tr>
<td>Participant 3</td>
<td>0.4757050118</td>
<td>0.4554075305</td>
</tr>
<tr>
<td>Participant 4</td>
<td>0.2382597320</td>
<td>0.3810752630</td>
</tr>
<tr>
<td>Participant 5</td>
<td>0.5068433515</td>
<td>0.4191527130</td>
</tr>
<tr>
<td>Participant 6</td>
<td>0.2188112158</td>
<td>0.2421717268</td>
</tr>
<tr>
<td>Overall</td>
<td>0.355643571</td>
<td>0.358696944</td>
</tr>
</tbody>
</table>

Table 2: Percentage time spent in screen areas

<table>
<thead>
<tr>
<th></th>
<th>Second Life Percentage of total area</th>
<th>RuneScape Percentage of total area</th>
<th>Second Life Percentage of game window</th>
<th>RuneScape Percentage of game window</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaze not captured</td>
<td>17.54832825</td>
<td>21.27215494</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking at top controls (Second Life) / Browser/Ads (RuneScape)</td>
<td>1.145668877</td>
<td>2.046574464</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top of game window</td>
<td>11.14461636</td>
<td>10.49035438</td>
<td>14.2918846</td>
<td>13.83749015</td>
</tr>
<tr>
<td>Left part of game window</td>
<td>5.649756166</td>
<td>7.718010652</td>
<td>7.245261796</td>
<td>10.18058041</td>
</tr>
<tr>
<td>Central part of game window</td>
<td>34.38094236</td>
<td>40.69165337</td>
<td>44.09020865</td>
<td>53.67505538</td>
</tr>
<tr>
<td>Right part of game window</td>
<td>11.19496193</td>
<td>10.68237491</td>
<td>14.35644789</td>
<td>14.09077826</td>
</tr>
<tr>
<td>Bottom of game window</td>
<td>15.60835702</td>
<td>6.22871314</td>
<td>20.01619706</td>
<td>8.216095809</td>
</tr>
<tr>
<td>Looking at bottom controls</td>
<td>3.327369049</td>
<td>0.870164147</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Students attending an orientation meeting

One of the locations used for tutorials
Second Life overall percentage totals

RuneScape overall percentage totals

Appendix B – Forefront of research

The researcher may have been the first person in the world to hold tutorials with university level students for mathematics in a virtual world. The first ice-breaker/orientation meeting was held with students on 15th April 2008 in Second Life, and the first mathematics tutorial (on Linear Algebra) was held on 6th May 2008. The tutorials were for M208, the OU Pure Mathematics course. That year tutorials were also held for M150, the course on Data, Computing and Information, but the researcher believes they were held later ... and in any case it could be argued that they were about data, computing and information rather than mathematics as such. (The researcher is certainly interested if anybody has information about earlier official mathematics lectures or tutorials in virtual worlds – please contact him.)

The schedule in 2008 was;

Ice-breakers/Orientation meetings (3)
First session on Tuesday 15th April
Second session on Tuesday 22nd April
Third session on Tuesday 29 April.

Mathematics tutorials (7)
First tutorial on LA on Tuesday 6th April – covered LA.
First tutorial on AA on Tuesday 3rd June – covered first part of AA
Second tutorial on AA on 10-June-2008 – covered rest of AA.
Second GT tutorial on 22-July-2008 – GTB was covered.
First AB tutorial on 12 August 2008 - AB1 and AB2 was covered.
Second AB tutorial on 26-August-08 – AB3 and AB4 were covered.
Tutorial on 30-09-08 - Talked about exam and revision questions.
Appendix C – Introduction to Virtual Worlds

This is a brief introduction to Virtual Worlds

Introduction to Virtual Worlds

Social Worlds are the Multi-User Virtual Environments (MUVEs) which are primarily used for inter-personal relations, although there is an overlap between these and gaming worlds. For example Second Life is often referred to as a game. Other acronyms in use are MMOG for Massively Multi-player Online Game, or MMORPG for Masively Multi-player Online Role Playing Game. These are used mainly, of course, for the pure virtual gaming worlds.

So a good place to start is with a list of virtual worlds.

http://www.virtualworldsreview.com/ - The Virtual Worlds Review - - this contains a good list of MUVEs, with an overview and introduction to each. The social worlds (which have a lot of similarities) include Second Life, THERE, and Active Worlds.

If your new to Virtual Worlds you might like to review the work of Edward Castronova. There were two things that made people interested in virtual worlds. In a seminal piece of work he is an economist who was the first to recognise that the total economic value of trading within virtual worlds (in particular games) was equivalent to the GDP of a small country. (The second thing was the fact that virtual gaming became a multi-million dollar industry.)


http://mypage.iu.edu/~castro/ - Edward Castronova - Then go to his personal website.

Appendix D - Introduction to Education in Virtual Worlds

Introduction to Education in Virtual Worlds.

One of the purposes that social worlds are being put to is education. Many secondary and tertiary educational establishments are investigating the use of virtual worlds for teaching. http://simteach.com/ - SimTeach: Information and Community for Educators using M.U.V.E.'s. So universities world wide are investigating these worlds for eLearning and distance teaching purposes. http://cyber.law.harvard.edu/ - Bergman Center - the first famous course in a virtual world took place in Second Life, and was Harvard's "CyberOne: Law in the Court of Public Opinion" from The Bergman Center for Internet and Society at Harvard Law School. The Open University have made an investment in Second Life and there are multiple links from the main COLMSCT pages. Also see the main COLMSCT project page by Anna Peachey http://www.open.ac.uk/colmsct/activities/details/detail.php?itemId=478b5caf2c3f7 - Open Life: Teaching and Learning in Second Life which has lots of relevant information.


**Appendix E – Lessons learned from reflections on face to face tutorials**

These are some reflections on the research, which may be useful to capture here.

**Comparison with face to face tutorials.**

The tutorials held within Second Life with students have been ‘traditional teaching’. The researcher replicated his face-to-face methods, rather than carry out ‘innovative teaching’.

The following occurs during face-to-face teaching;
1. Time is spent at board writing complex equations and diagrams. This is done both from prepared notes and handouts, and also on an ad-hoc basis. For example a student may ask a question and it is easy to just write many different graphs on the whiteboard as the question is answered, according to needs.
2. Body language is used, e.g. using hands to illustrate the slope of a curve.
3. It is easy to see whether students are engaged with the material.
4. From their reactions it can be seen whether students comprehend.
5. The tendency is to have a lot of prepared handouts.
6. It is easy for students to interrupt and ask questions.

The researcher’s experience of holding tutorials within Second Life might be compared to being in a real life tutorial, but there is a semi-transparent screen between the tutor and students. Hence you can communicate, you know they are there, but you can’t make eye contact, you can’t show them diagrams or write on a whiteboard, and you can only see their shadows. The researcher did not use in-world tools as such.

Hence the prepared discussion material was the material the researcher would normally hand out at face-to-face sessions to prevent students having to waste time by copying down notes from the whiteboard, however the researcher had to make sure the material included all equations and diagrams that he might want to use, and put in additional comments. Then during the in-world tutorial he could refer to that. For ad-hoc questions he used diagrams in the existing course material, i.e. instead of writing an ad-hoc equation or graph on the board, he referred to ‘diagram xx on page yy of chapter zz’. This worked well, and allowed him to replicate his face-to-face teaching.

**In-world tools.**

The possibility of using 3-dimenional objects within Second Life is exciting. For decades mathematicians, engineers, scientists and technologists have written 3-D objects on a 2-D whiteboard (or blackboard). Using the Second Life programming language (LSL) it’s possible to animate objects as well. However actually building such objects, and animating them takes time and effort. The good point about this however is that once an object is built, and provided the builder agrees, it can be made free to copy and distribute. So in theory a set of useful objects might be built over time to be used in virtual classroom situations.

There are already existing in-world tools, but in the researcher’s opinion their development is currently at an early stage. They are cumbersome to use, or require building skills, or need to be purchased. There are sometimes technical limitations, such as the necessity to be a land-owner to use some of the objects. The wheel is currently being reinvented several times as people build their own objects.

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However Second Life is open source. So as time moves on, it can be expected that more educational tools will end up being available for free in Second Life.

**Mathematical Notation**

The issue of how to display mathematical notation is key to any research into mathematical learning in virtual worlds. So as can be seen from the previous parts of the report, the method of teaching circumnavigated that problem, and provided a method to successfully replicate the researcher’s face-to-face teaching in Second Life.
Appendix F - Useful details of learning lessons

This section contains some details of lessons learned during learning sessions in Second Life, which might be useful to capture here.

Minutes of last 2008 SL Tutorial on 30-09-08 - Attending: Tutor and two students - Venue: SchomeBase Bandstand - Talked about exam and part questions.

Minutes of 2-09-08 tutorial - Venue: SchomeBase 189/54/38 - Time taken: 7-14 to 9. - Attending: tutor and two students. - Talked about exam, level and detailed, some parts.

Agenda was;
*1 Attached is the discussion material (5 PDF files) for our revision tutorial on Tuesday 2nd September between 7-8pm. (See below for venue). As usual I’ll use my headset and speak.
*2 As this is a revision tutorial, there is a difference between this and earlier tutorials. Normally discussion of the maths takes an hour, however because there is no new material, discussion of these documents may take 20-30 minutes. Therefore this is an opportunity to ask questions about any part of the course. (I’m intending to schedule an actual exam preparation tutorial later, but by all means ask questions about the exam if you wish.)
*2 Agenda is, (A) Introduction - brief explanation of how session will be run. (B) Talk through the discussion material. (C) Any questions on the course. (You obviously need access to the discussion material during the session, ideally you should have your handbook near you during the session, and optionally your course chapters.)

*3 Venue for tutorial on 2nd September, the Bandstand at SchomeBase 189,54,38. Slurl: http://slurl.com/secondlife/SchomeBase/189/54/38 (There’s still no official booking procedures for the tutorial venues, so if it is busy we can find somewhere else easily enough.)

Minutes of AB2 tutorial on 26-August-09 - Attending: me and five students. - Time: 7pm to 8-15pm. Someone liked room, also liked chessboard room. – Someone else liked room, open, no interruptions. Talked about exam techniques. In general talked about courses.

Agenda of AB2 tutorial on 26-August-09 - OpenLife TandLS Presentation Board at 60,15,24 (SW of island) – east to 80,30,24 – teleport

1-Introduction - 2-QSL-AB-Q3 and Q4 - 3-Any Questions

*1 Attached is the discussion material (2 PDF files) for our Second Analysis B tutorial, on 26th August between 7-8pm. (See below for venue). It cover units AB3 and AB4. As usual I’ll use my headset and speak.

*2 Agenda is, (A) Introduction - brief explanation of how session will be run. (B) Talk through the discussion material. (C) Any questions on the AB block. (You obviously need access to the discussion material during the session, ideally you should have your handbook near you during the session, and optionally your course chapters.)

*3 Venue for tutorial on 26th August. (I’ll set up the ‘room’ before the tutorial)

*1 Teleport to Open Life (or Teleport to SchomeBase and walk/fly to the Open Life island.)

*2 Go to the Open Life Teaching and Learning Space Presentation Board at about 60,15,24. (It’s at South-West of Island, north of the SchomeBase nOUbie Centre. At the moment there are some pink chairs set up there.)

*3 Walk a few steps East to about 80,30,24. You’ll see a teleport transporter. It’s banded with almost vertical green and black stripes, with writing above it saying what it is. (It’s about the size of an avatar.) Just right-click and select ‘teleport’.
*4 There's a glitch with the camera. Sometimes after teleporting the screen is still looking back at where you teleported from. Sometimes the screen shows your avatar standing in mid-air. Just wait a second, then move your avatar to see where you are.

*5 Sit down on a chair.

*6 At the end you can stand up and there's a red teleport object in the corner which sends you back (or you can just fly away, or just teleport away from Open Life, of course.)

Details of AB tutorial
1 held on 12 August 2008

A tutorial was held on the AB block on 12-August-2008. The venue was the a specially made 'Chessboard Room with wall and chairs', located in the sky above the Open Life Learning and Teaching Space. As usual discussion material was distributed beforehand, and we used voice to discuss this during the tutorial. - AB1 and AB2 was covered. - Attending were me and four students. - The tutorial was scheduled, as usual, from 7-8pm, and actually went from 7 until about 8-15. - Then we chatted a little bit about courses in general, and other things.

Agenda information for AB Tutorial on 12 August.

*1 Attached is the discussion material (2 PDF files) for our Analysis B tutorial, on 12th August between 7-8pm. (See below for venue). It cover units AB1 and AB2. As usual I’ll use my headset and speak. (We can do AB3 and AB4 in the next tutorial.)

*2 Agenda is, (A) Introduction - brief explanation of how session will be run. (B) Talk through the discussion material. (C) Any questions on the AB block. (You obviously need access to the discussion material during the session, ideally you should have your handbook near you during the session, and optionally your course chapters.)

*3 Venue for tutorial on 12 August. (I’ll set up the ‘room’ before the tutorial)

*1 Teleport to Open Life (or Teleport to SchomeBase and walk/fly to the Open Life island.)

*2 Go to the Open Life Teaching and Learning Space Presentation Board at about 60,15,24. (It's at South-West of Island, north of the SchomeBase nOUbie Centre. At the moment there are some pink chairs set up there.)

*3 Walk a few steps East to about 80,30,24. You’ll see a teleport transporter. It’s banded with almost vertical green and black stripes, with writing above it saying what it is. (It’s about the size of an avatar.) Just right-click and select 'teleport'.

*4 There's a glitch with the camera. Sometimes after teleporting the screen is still looking back at where you teleported from. Sometimes the screen shows your avatar standing in mid-air. Just wait a second, then move your avatar to see where you are.

*5 Sit down on a chair.

*6 At the end you can stand up and there’s a red teleport object in the corner which sends you back (or you can just fly away, or just teleport away from Open Life, of course.)

Details of GTB Tutorial
1 held on 22-July-2008

A tutorial was held on the GTB block on 22-July-2008. The venue was the SchomeBase Treehouse. As usual discussion material was distributed beforehand, and we used voice to discuss this during the tutorial. - Attending were me and 2 students.

The tutorial was scheduled, as usual, from 7-8pm. Most tutorials so far have had technical problems 7-8, with the actual mathematics 8-9. This time we started only 15 minutes late, so the tutorial took from about 7-15 to 8-30pm, and then we chatted for awhile.

Someone mentioned that OUSA SL was becoming a very active forum, arranging field trips and building lessons. Someone mentioned that work has been done in allowing avatars to move from SL to an IBM grid, but this was causing controversy, as it caused problems with intellectual property rights. (For anyone reading this nor familiar with the arguments, if you make an object, such as clothes, in second life, you can sell that for money, and set the permissions on the object so the buyer can’t copy the

object, or change it. So it’s a once-only purchase. If you can transfer that object to a different world and change the permissions, you could make multiple copies and bring them back into SL.)

Details of AA Tutorial 2 held on 10 June 08
A tutorial was held on the AA block on 10-June-2008. This was the second tutorial on AA. The venue was the Open Life Treehouse. As usual discussion material was distributed beforehand, and we used voice to discuss this during the tutorial. - Attending were me and 3 students. - The tutorial was scheduled, as usual, from 7-8pm. - The mathematical material was discussed. Afterwards we had a discussion about the venue. Someone thought this place was hard to find. It was also confusing as there were multiple levels. I also pointed out there were few seats here. During the tutorial several people flew by. So the issues of privacy during tutorials is important, as they no doubt thought we were just chatting and so interruptible. I accidentally muted sound at one stage so someone couldn’t hear me. Someone else didn’t like the venue, for example the wind chimes were irritating.
We discussed the ‘Closed Teaching Room’ we had used the previous week on 3rd June. They felt it was claustrophobic, and might benefit from windows being installed. It was suggested that the room might be okay if the roof were taken off.

AA Tutorial 1 - on 7 pm, Tuesday 3rd June.
About AA Tutorial on 3rd June.
*1 Attached is the discussion material (3 PDF files) for our Analysis A tutorial, on 3rd June between 7-8pm. (See below for venue).
*2 The way we run the session and the Agenda will be similar to last time, i.e. (A) Introduction - brief explanation of how session will be run. (B) Talk through the discussion material. (C) Any questions on the AA block. (You obviously need access to the discussion material during the session, ideally you should have your handbook near you during the session, and optionally your course chapters.)
*3 As you know I was keen not to hold all the tutorials in the same place. In the real world where tutorials are held does have some impact (albeit it not the most important aspect of a tutorial). So by having tutorials in different locations I can ask you afterwards which you preferred. I've put instructions below on how to get to the location for the 3rd June tutorial.
*4 Even though we don’t have in-world material to view this time, it still seems to be the case that we all prefer to move our camera controls around (I know I like to move them until I can see everyone in the same view.) In addition to the techniques we mentioned before, I've made notes below on some other camera techniques that you might find useful.

VENUE FOR TUTORIAL ON 3rd JUNE.
*1 Teleport to Open Life (or Teleport to SchomeBase and walk to the Open Life island.)
*2 Go to the Open Life Teaching and Learning Space at 79,21,25. (It's at South-West of Island, north of the SchomeBase General Educators Building.)
*3 At the corner of the platform opposite the screen there's a teleport object (at about 91,29,25). It's green with black stripes, with writing above it. Just right-click and select 'teleport'.
*4 There's a glitch with the camera. Sometimes after teleporting the screen is still looking back at where you teleported from. Sometimes the screen shows your avatar standing in mid-air. Just wait a second, then move your avatar to see where you are.
*5 You'll be in a circular chamber. Walk down the corridor to the room.
*6 Take a seat. It doesn't matter which one you choose, you will be allocated to the seats in a set order.
*7 At the end you can stand up and walk back to the circular chamber, and choose the red teleport object which sends you back (or just teleport away from Open Life, of course.)

CAMERA CONTROLS
In addition to using the camera control screen ('View/Camera Controls') there's some other techniques you can use.

*1 When you are seated in a chair, the arrow keys (or w/a/s/d if you have your text-chat switched off) will move the camera. This is a very easy way to control your view.
*2 Don't forget the middle scroll button on your mouse (assuming you have one) will move the focus in and out.
*3. If you hold down the 'alt' key the cursor changes to a magnifying glass. If you put the cursor over any point in the screen, and left-mouse-click, the view changes so that point is in the center.
*4 If you hold down the 'alt' key so that the cursor changes to a magnifying glass, and you then hold down the mouse left-click button, you can move the mouse around to change the view. (This is powerful but very difficult to control.)

You can use all of the above in different combinations to change your view point.
The following was put on the forum later about the tutorial;
As before, I'm making this post so it acts as a record of the trial. If anyone has any comments feel free to post them in the forum.
The second mathematics tutorial was held on (error insert note, it was Tuesday 3rd June) 6th May, 7pm-8pm. This was the first of 2 tutorials on Analysis Block A (AA-Tutorial 1).

Venue: Special Room
The agenda was;
1. Introduction - brief explanation of how session will be run.
2. Talk through the discussion material.
3. Any questions from students on the AA block.

Students were advised to have the discussion material (online or printed out), the Handbook, and 'pen and paper'.

NOTES ON HOW THE SESSION WENT

Attending were myself, and 5 students.
Prior to the meeting I set up the room, located in the air above the Open Life Teaching and Learning Space at 79,21,25. The room was in 2 parts, plus a teleport object. I put a 'teleport up' object on the ground. However the room must have extended beyond the building area, because it was destroyed a short while later. So when the first student turned up early and used the teleport object, they ended up going nowhere. (I was there a little early so set up the room again ... quickly.)
People thought the room was very claustrophobic, and felt that windows would have been good.
Also because it was enclosed, it took practice to get the camera controls inside the room. (The ceiling was 10 metres high, but that is low in Second Life.)
Interestingly it turned night while were were having the session, I think, and that made it seem more claustrophic.
However, the main technical problem was using voice. We had feedback issues, and someone (I think it was Mary) warned us that we might be clicking the 'padlock' button my mistake, ensuring the mic was permanently on. (I had done this.) Also someone felt he might have been too close to speakers.
Even when (we believed anyway that) feedback was eliminated, there did seem to be bad breakup when I spoke. Eventually we gave up, and we went back to the SchomeBase Treehouse at 56, 130, 51. Then voice worked fine.
The tutorial was scheduled for an hour, but once again, due to the technical problems which delayed the start, we did take 7-9pm. (The actual mathematics part of that was about an hour.)
I would add the following remarks;
1. Before the session I sent more instructions on how to use camera controls. The use of the camera seems to be a key skill in Second Life.

2. There was another tutorial in the Teaching and Learning Space, so there were several people on Open Life. Bearing in mind that we had no problems with voice on SchomeBase, the problems with voice might have been due to any of the following;

(A) Something to do with Open Life being different from SchomeBase.
(B) The extra load on Open Life due to the number of people present.
(C) Something to do with the room.
(D) Just feedback issues (the padlock being set) which happened to be solved just as we went to SchomeBase.
(E) Some other reason.

LA Tutorial 1 - on 7 pm, Tuesday 6th April.- on SchomeBase with 5 volunteer students
Late on Sunday I already sent you the email with the attached discussion material for our first mathematics tutorial on Linear Algebra, to be held on 6th May, 7pm-8pm.
Venue: Tree Tutorial Platform on SchomeBase (at 56,130,51)
The agenda is;
(A) Introduction - brief explanation of how session will be run.
(B) Talk through the discussion material.
(C) Any questions from students on the LA block.
I suggest you have the discussion material (online or printed out), the Handbook, and 'pen and paper'.
5 turned up. The following was put on the forum;
Subject: Notes on the first Mathematics Tutorial on 6th May.
As before, I'm making this post so it acts as a record of the trial. If anyone has any comments feel free to post them in the forum.
The first mathematics tutorial on Linear Algebra was held on 6th May, 7pm-8pm.
Venue: Tree Tutorial Platform on SchomeBase (at 56,130,51)
The agenda was;
(D) Introduction - brief explanation of how session will be run.
(E) Talk through the discussion material.
(F) Any questions from students on the LA block.
Students were advised to have the discussion material (online or printed out), the Handbook, and 'pen and paper'.

NOTES ON HOW THE SESSION WENT
Prior to the meeting we had some technical problems. One student could log in but could not move. On the basis that this is a trial I took the option of leaving the group and giving help to the other student. (Obviously this does not happen in real life.)
The student then had difficulty finding the tree platform, and later fell off the platform. (Obviously this does not happen in real life ... we do not hold tutorials up in trees.)
The tutorial was scheduled for an hour, and we did take about that amount of time talking about mathematics, but because of the delays etc., the entire session took from 7-9pm.
(A) Introduction - We used voice. We use a 'turn taking' technique. I spoke about the material and if anyone wanted to ask questions they typed in the chat box. I then invited them to contribute, either speaking or typing, as they wished.
(B) Talk through the discussion material - As the discussion material was there to be read by everyone, I tried to concentrate on talking around the material, e.g. making some observations on why we carrying out certain techniques, to give an overview of the processes involved.
(C) Any questions from students on the LA block - There were some questions on the material which students asked as we progressed through the session.
I would add the following remarks;

1. Asking those present to draw diagrams during the tutorial wasn't very successful, due to the
difficulties of describing the diagrams verbally. However we could refer to existing diagrams in the
course chapters.
2. It did take a lot of time to prepare the discussion material.
3. I was talking a lot, which is probably not the ideal scenario.
4. It is hard to avoid simply talking through the discussion material, which everyone can read anyway.

Ice-Breaker 3 - on 7 pm, Tuesday 29th April.- on SchomeBase with 5 volunteer students
NOTE ON LAST ICEBREAKER (the third one) HELD ON 7-8pm on Tuesday 29 April.
(D) Experiment with a box. We discussed viewing presentation material again, this time using 'mouse'
control. Most found it easier than the camera controls, although the disadvantage is that you need
to stand near the actual presentation object.
(E) Any suggestions? There weren't suggestions as such from students. However at the end when
discussing how to carry out our first actual mathematics tutorial, it was suggested that I email some
material beforehand, which we could talk through during the session (which was subsequently
done).
We discussed using mathematical notation in SL text chat. We also discussed using Lyx, where
mathematical notation could be copied from Lyx into the SL chat box, then copied back into Lyx so
the notation can be seen. (It's shown in a 'Latex-like' format in SL.)
Elluminate was discussed, and one of the other courses. Everyone present (including me) who had
used Elluminate agreed it was very good, and a great way to learn online.
(F) Chat. We discussed bubble chat and reviewing chat history, although as it turned out everyone
present was already familiar with the techniques.
(G) Voice. We tried voice again. People were getting more confident with using voice in SL.
(H) I mentioned that Open Life island would be open soon.
I think 3 turned up,
Ice-Breaker 2 - on 7 pm, Tuesday 22nd April. - on SchomeBase with 5 volunteer students
5 turned up. About our last and next icebreaker. Next time you log in you'll get a notecard from me (see
below)
We had our second ice-breaker on 7-8pm on Tuesday 22nd April. Five students turned up. In real life an
ice-breaker is largely for the students to meet each other, and have some fun. (Opinions can be divided,
some people believe they are very useful, others prefer to get into studying as quickly as possible.)
In SL however, our ice-breakers are largely about finding out how to do things. It seems necessary to do
this before real study can commence. So we went through the following agenda items;
LAST ICEBREAKER
(I) We tried out voice. It was partially successful. Having a headset with microphone seems essential.
See below about practicing.
(J) We tried out an experiment with the camera controls, which might be useful in future tutorials. I
created a 'box' and asked everyone to just get that box in the middle of their monitor, so they could
see it clearly. This could be useful if we use any presentation material (e.g. pictures, powerpoint-
type slides, etc.) in the future. (One way is to make the camera approach the object 'crab-like', as
Deej said.) (The issue of how to present the mathematical symbols is still not decided, which is part
of the reason for this trial.)
(K) I gave out two notecards, one on educational areas in SL which I had been given (By Elsa Dickins I
think). Another is one I'm building, with some areas I've visited which might be interesting or useful.
(Please email me if you think of sites I could add.)
(L) We practiced navigating to an area on the island, and discussed the best way to find places in SL.
PRACTICING VOICE

mathematics’
I was asked what was the best way to practice voice. I don't know of an easy way, but I thought about it afterwards. One way is to arrange to come to SchomeBase with another of our group, and just talk. But it can be difficult to arrange suitable times. Another option is to go to 'The Bergman Center for Internet and Society at Harvard Law School'. A lot of people use their sandbox to build things, and often you can find people chatting on voice. However this does mean going up to strangers to chat, and you don't know who these people are. (They are not necessarily associated with the Harvard Law School). It is a relatively safe part of SL, as 'griefers' are banned. (I'm not personally endorsing this area, of course, and 'griefers' could enter any non-protected area.) ('Griefer' is the SL term for people who cause disruption, they are called 'trolls' in other areas of cyberspace.)

Another option might be to go to one of the general help areas, and approach one of the people/avatars who are helping people, and ask if you can practice voice.

I've updated our notecard to include some notes on the above, and where these places are, and next time you log in you should get it.

NEXT ICE-BREAKER

Next ice-breakers on 7-8pm on Tuesday 29 April. Our first real tutorial, on Linear Algebra, is on Tuesday 6th May. (After that we'll probably have a tutorial per block.)

Agenda for next Ice-Breaker.

(A) Experiment with a box. I’d like to try another method for viewing presentation material.

(B) Any suggestions? Everyone attending is free to offer a ‘handy hint’ about something they found was useful in SL. (E.g. some option that you find useful, some way of using the maps, etc.)

(C) Chat. We can review some techniques for keeping up with text chat.

(D) Voice. We could try voice once more.

See you there. In the meantime please post in the forum or email me directly if you've any questions or have any ideas you'd like to mention.

Ice-Breaker 1 - on 7 pm, Tuesday 15th April. on SchomeBase with 6 volunteer students

6 turned up,
x. I think it was fun, and it went well.

x I believe everyone felt it was very much like a face-to-face session.

x It takes awhile to learn how to do things like move about, and so on, and it's very easy to get lost in SL, however once you figure out a technique for doing something you know it forever.

x. we visited various areas on SchomeBase, namely the general building, the shop and the tree tutorial platform.

x We practiced getting things from the shop

x We had a discussion about how we would discuss mathematics inworld.

x We tried voice, and this was not so successful.

x Everyone agreed that sorting out now to deal with mathematical notation was important.

Session in Media Zoo (two of them)

In particular in the second, someone couldn't see the screen, which led me to have an agenda item on using camera controls.

18-4-08 at 11am - I gave talk on what I'm doing. 1 6 volunteer students, M208, number of icebreakers, / 2 - two came straight from orientation island. / 3 success it's fun, like face-to-face, used voice ... failure able to move, do things etc. / 4 - sent them instructions beforehand, showed them main buildings, Schomebase, Shop, how to do things. Showed them tree tutorial platform. / 5 - Fears - may need voice, or html-on-a-prim, or whiteboard to teach math. At end of the day they were motivated
students to want tutorial help, not to play and have fun. / 6 - I thanked Bernie Euler (Ben Mestel) who helped me by coming into world beforehand.