Development of an Immersive Environment to Teach Problem Oriented Engineering

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Preface

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Abstract

In this thesis I explore current trends in computer based learning, and evaluate the application of existing multimedia design principles to 3-D environments or MUVEs, which are becoming increasingly popular for the possibilities they present for situated learning opportunities. I look into how methods of learning in computer mediated environments have changed, and how this has led to a set of cognitive learning based design principles. I use the design principles I have identified, and apply them to the development of a learning environment, to teach the basic principles of Problem Oriented Engineering. Using student tracking within the environment I create, together with post experience student questionnaires, I assess the value of the principles used. I find that multimedia design principles have some value in the design of a Second Life learning environment, for Problem Oriented Engineering. There is however evidence both from my own research, and from that of Minocha and Reeves (Minocha & Reeves, 2009) that Second Life users, like computer gamers becoming familiar with a new game, expect more from an environment as they become more experienced. In particular the design guidelines identified do not address the issues of immersion or how to design interactions within a 3-D environment. As a result further work is required to build on the multimedia design principles, to help inform the design of 3D virtual world learning spaces.
Chapter 1  Introduction

Over the last five to ten years advances in both computer software and hardware, have enabled the evolution, into a mass market, of a wide range of 3D virtual environments, or virtual worlds. Combined with advances in network connectivity the success of these 3D worlds has provided the opportunity for people to interact in ways that were previously impossible.

Second Life (Linden Lab, 2009) is one of the leading commercial online 3D worlds, providing users with a representation of themselves, in the form of an avatar, which can then be used to build and script a virtual environment. Some access this environment to play or interact socially, whilst others are starting to use the environment for commercial and educational purposes. In this thesis I look at the use of design principles to guide the development of the last of these applications to promote effective learning.

Problem Oriented Engineering is a design framework, developed from research within The Open University, with the ability to be applied to a wide range of engineering design problems. As an emerging tool, with a limited public knowledge base, it provides an ideal vehicle to test design principles, without prior knowledge acting to influence a learner’s perceptions.
1.1 Background to the research

With the rise of increasingly sophisticated computer games consoles (Kiley, 2006) (Cowen, 2009), it has become apparent that the users of these games become highly engaged in the immersive environments portrayed (BBC News, 2007). A cursory look through the relatively small manuals that come with modern computer games reveals that the developers provide little printed documentation. Rather than providing highly detailed manuals the developers rely on the use of facilities that can be found in most games such as training or tutorial levels e.g. in the Tomb Raider series from Eidos Interactive (tombraidergirl, 2006) and Air Rivals from Gameforge 4D (Gameforge 4D, 2009), and on-screen hints, tips and directions e.g. Speed Racer from Sidhe Interactive (Warner Brothers Games, 2008). Gamers are thus drawn into an environment where without any conscious effort they learn, by a process of trial and error, the rules that the game imposes in much the same way that situated learning does, creating:

“…authentic contexts, activities and assessments coupled with guidance based on expert modelling…” (Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005).

This similarity between computer game playing and learning encouraged some researchers to investigate the use of highly immersive 3D environments, to provide situated learning environments for purely educational purposes as documented in table 1 of Dieterle & Clarke, 2007.

The benefits of using this approach are expected to be increased engagement and motivation amongst the student population, together with an improved understanding of the material being taught (Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005).
The environment that has probably received the greatest attention is the Harvard River City simulation which is aimed at teaching scientific inquiry skills to K12 (Farlex Inc, 2009) students (Dieterle & Clarke, 2007). On the back of this research a number of design principles have been developed to assist in the process of building effective learning environments (Nelson & Erlandson, 2008) (Mayer R. E., Multimedia Learning: Are We Asking the Right Questions?, 1997). The design principles derived and the associated implementation pragmatics are however, mainly based around K12 student populations; a search of the available literature reveals a relative paucity of available research in the use of these immersive environments for higher education students.

Second Life with its similar interface to that of River City has attracted a large number of educational institutions, who aspire to replicate the documented successes of the River City simulation (Ketelhut, Nelson, Dede, & Clarke, 2006), (Nelson & Erlandson, 2008) & (Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005). Second Life however is specifically targeted at adult audiences, with a separate Second Life simulation having been created for teenagers. As such, Second Life presents an ideal opportunity to study the applicability of the design research undertaken for school age children when applied to higher education students.

In order to test the applicability of the design principles developed by Nelson and Erlandson I intend to develop a learning environment within Second Life where the principles are applied to build a Problem Oriented Engineering (Hall & Rapanotti, 2009) learning space. Problem Oriented Engineering has been selected for this investigation because, whilst some aspects of it are taught as part of a Masters Degree programme, (The Open University, 2009) and it requires significant understanding of engineering design, the underlying principles can be applied to simple examples, thus
providing an equivalent to computer game training levels. The expectation is, therefore, that once the “training levels” have been completed and understood, the students will be able to take the knowledge they have gained and apply it to problems in the wider (both real and virtual) world.

Whilst it is expected that student perceptions of the value of a Second Life situated learning environment will be positive, there is some evidence that the relatively primitive 3D environment provided within Second Life and the lack of skills transferability, has a detrimental effect on some higher education student’s views of the environment (Hetherington, Bonar-Law, Fleet, & Parkinson, 2008). Despite this, the hybrid, gaming/social networking, nature of Second Life has however resulted in an opportunity for higher educational institutions to devise rich multimedia activities in a constructivist learning environment, where social and distributed cognition are typically the norm (Anon, Supporting online learners - MUVE Teaching and Learning, 2007) & (Dieterle & Clarke, 2007).

1.2 Aims and objectives of the research project

The aim of this project is to research design principles for 3D learning environments, and to apply these to a learning environment to teach the basics of Problem Oriented Engineering in Second Life.

The specific objectives of the project are to

1. To locate and review existing educational MUVE and multi-media design principles and/or guidelines.

2. To locate and review examples of the application of Problem Oriented Engineering.
3. To build a Problem Oriented Engineering learning space in Second Life, based on the principles/guidelines located, and using appropriate applications of Problem Oriented Engineering from the review.

4. To validate the design of the learning environment against the design principles and/or guidelines used.

5. To evaluate assimilation of Problem Oriented Engineering knowledge and skills by those learners using the environment developed.

6. To evaluate student perceptions of the learning space created in terms of its usability and ease of use.

1.3 Overview of the dissertation

In order to address my aim and meet my objectives this dissertation mirrors the overall direction and progress of the project. I start in Chapter 2 with a literature review, looking at some of the longer term trends and recent developments in computer assisted learning, and also at engineering design focusing on Problem Oriented Engineering. In Chapter 3 I look briefly at the approaches other researchers have taken as a basis for the direction of my own research. Chapters 4 and 5 then look at the design and development of my trial learning environment in Second Life, with Chapter 4 concentrating on the design, while Chapter 5 concentrates on the development. It should be noted however, that the design and development process was iterative and there is therefore a certain amount of overlap between these chapters. In Chapter 6 I present and analyse my results and finally in Chapter 7 I review the project and lay out possible directions for future research in the field of virtual 3D learning environment design.
Chapter 2 Literature Review

In this chapter I review the current literature available to address my first two objectives.

To review existing MUVE and multi-media design principles or guidelines, I initially look at game design and the changes that have informed the way in which gamers are ‘taught’ how to play the increasingly sophisticated games that are available on the market. I then look at the advances in technology that have enabled the development of Multi-User Virtual Environments and how these have been adopted as environments for educational games.

In order to address my second objective I look at engineering design in general and specifically at Problem Oriented Engineering and some of its underlying principles.

I then look in general at the existence of design principles and guidelines and specifically at guidelines developed by Nelson and Erlandson (Nelson & Erlandson, 2008) based on work done by Mayer (Mayer R. E., 1997), and finally bring all this together into a research question.

2.1 Stealth Learning

Over the past 30 to 40 years home entertainment in the form of video games has grown from the primitive two-dimensional games of the 1970’s, typified by the Atari’s Pong (Anon, Pong, 2009) through to the highly detailed immersive games available on the current crop of consoles (Xbox 360, PlayStation 3 and Wii) and PCs.
With the increasing sophistication of these games the documentation that went with them became ever more detailed and complex (the manual that accompanied Sim City 2000 was an A5 sized book of 140 pages) reflecting the increased complexity of the gaming environments. It is possible to speculate on the size (and relative cost of production) that games manuals would be today if this trend had continued. The trend however turned to more concise documentation (the manual for the Wii version of Ben 10 Alien Force, is 12 pages and the size of a CD case) alongside a general move to include training or tutorial levels at the start of a game, and on screen hints, tips and directions throughout the game. The game developers were effectively teaching the players the rules of the game by using situated learning techniques, from Dede et al. (2005) the context formed part of the game’s storyline, and the activities were models built by the experts (the developers) providing experiences relevant to the rest of the game.

In effect, whilst the players would not necessarily recognise it, game developers have adopted a method of teaching by stealth.

2.2 Multi-User Virtual Environments

Paralleling the improvements in computer technology that have enabled the huge changes in computer games, there have been similar advances in wide area networking. Society has witnessed a move from the acoustically coupled modems of the late 1950’s and 1960’s that operated around 300-1200 bits per second (bps) (Anon, Acoustic coupler, 2009) to the modern broadband capabilities which in the UK can now readily
provide wide area connections up to 8Mbps (wireless UK broadband Internet for less, 2009) with speeds of 20Mbps or faster on the horizon (even faster broadband, 2009).

This improvement in network speed has enabled the evolution of online communities. These communities which originally started as text based bulletin boards and games, have over a relatively short period of time, transformed into social networking sites such as Facebook, (Facebook, 2009) and Multi-Player Online Games such as World of Warcraft (Blizzard Entertainment Inc., 2009) which presents a player with a fully immersive three-dimensional virtual environment; a specific game based implementation of what has come to be known as a Multi-User Virtual Environment or MUVE (Dieterle & Clarke, 2007) environments that have been gaining in their popularity for gaming and social networking facilities.

2.3 Educational games

With the emergence of the commodity computer game market, researchers noticed that players became totally immersed in the game play, to the extent that they exhibited typically addictive behaviour (Lim, Nonis, & Hedberg, 2006). Researchers in the area documented evidence of computer game players investing vast amounts of time and money in play (Lim, Nonis, & Hedberg, 2006), which had marked similarities with situated learning environments.

Hmelo-Silver (2004) describes Problem-Based Learning in terms of a situated “experiential, learning method” that initially provides the students with “minimal information about a complex problem” and requires them to question, experiment and research to obtain additional problem information. This description of a situated or
Problem-Based Learning experience is analogous to the “stealth learning” employed during training or tutorial levels by computer game developers.

Although both these examples approach situated learning from different perspectives it is clear that the techniques employed by computer game designers have applicability within an educational context. And as (Squire, 2003) points out:

“…educators have begun using video games, particularly simulations in classrooms.”

This use of educational games is also demonstrated by Dieterle & Clarke (2007), where they present a view of how advances, in both the science of learning, and available technology, have facilitated the development of educational games as immersive MUVEs.

2.4 Second Life

Due to a significant amount of publicity over recent years, Second Life (Linden Lab, 2009) is probably the best known example of a MUVE combining computer gaming style representations of the “players”, and a rich 3D environment. Although Second Life does exhibit some of the traits of a computer game such as challenge, fantasy and curiosity (Squire, 2003), it departs from the gaming format in the absence of clear objectives, a storyline and a set of consistent rules (Rouse III, 2004). From this point of view it more closely reflects the attributes of a social networking site.
The “players” however can build specific simulations on varying scales which can employ the game type attributes of objectives, storyline and rules, to the extent that Second Life can be viewed as a social network with in-built gaming and entertainment facilities.

The social nature of Second Life means that not only can “players” benefit from the immersive nature of a Second Life simulation, but when designed with distributed cognition (Dieterle & Clarke, 2007) in mind, they can also benefit from the shared experiences of other “players”. Ultimately Dieterle and Clarke (2007) argue that MUVEs, like Second Life, provide a distributed, situated learning environment, which is closer to the way in which people learn in the real world, than the abstract methods used in traditional classroom based learning.

2.5 Engineering Design

In general terms Hall and Rapanotti (Hall & Rapanotti, Wednesday 17 October 2007, 2:00-3:00 pm, 2007) summarise the process of engineering design as:

… the identification and clarification of requirements, the understanding and structuring of the context into which the engineered system will be deployed, the specification of a design for a solution that can ensure satisfaction of the requirements in context, and the construction of arguments, convincing for all validating stake-holders, that the engineered system will provide the functionality and qualities that are needed.

Further to this, they propose that the traditional method of validating the “fitness for purpose” of an artefact after it has been designed can, due to late identification of errors, result in significant additional cost to any engineering based endeavour.
In order to counter the disconnect between the design of an artefact and its validation, Hall and Rapanotti, have developed a process of assurance-driven design (Hall & Rapanotti, Assurance-driven development in Problem Oriented Engineering, 2008), where stakeholders are integral and key to the validation of a design as it progresses through the identification, clarification, understanding and structuring stages Hall and Rapanotti have identified.

Problem Oriented Engineering has evolved, as a supporting framework, alongside this assurance driven design work.

2.6 Problem Oriented Engineering

Problem Oriented Engineering is a formal framework for developing a design for a given real world problem (Hall & Rapanotti, Requirements Analysis in Context with POE Design, 2009). The basic process behind Problem Oriented Engineering is captured in the UML activity diagram shown in Figure 1.
The process starts with the identification of a problem which is then explored, clarified and formally documented with specific reference to the context in which it exists. At this point the problem is (iteratively) validated with appropriate stakeholders to mitigate the risk that the designer has failed to correctly understand the problem (Hall & Rapanotti, The discipline of Natural Design, 2008). Once the stakeholder and the designer have reached a consensus on the problem and its context the designer can move forward to investigate the available solutions. Again in an iterative process the solution exploration is documented and validated with interested stakeholders. The key behind this is a desire again to minimise risk, however, the mitigated risk here is that the solution does not address the problem. The solution will then either be validated, or will indicate that the current problem or, where the process itself has been iteratively applied a previous problem, is invalid and must be re-explored.
POE is however more than just a process, the framework is embodied in the POE design triad (Hall & Rapanotti, Requirements Analysis in Context with POE Design, 2009), consisting of problems, transformations and justifications. Problems are the base on which the framework is built. Information about a need or requirement is captured together with the context in which the problem is observed and the solution to that problem. Transformations act upon problems to give a stepwise solution to a wider problem, and justifications are the documented reasoning behind the selection of the transformations, which result in the ability to validate a problem or solution.

What the POE framework does not do is define a documentation standard that a designer should use. The form of the documentation can be in any form that the designer feels appropriate. This could mean that the validation documentation could take the form of anything from a PowerPoint presentation to a formal document or even a multimedia presentation. The framework does however provide for a graphical representation of a problem as shown in Figure 2.

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**Figure 2** POE graphical representation (adapted from (Hall & Rapanotti, 2009))
On the left of the diagram the initial problem will be blank, but either the initial or the conclusion problem will, during problem and solution exploration, be transformed into one or more premise problems. The justification for the transformation then forms the validation problem. At a deeper level as shown in Figure 3 each of the problems is then broken down into a context, one or more constituent contextual parts and a solution.

Figure 3 Graphical components (adapted from (Hall & Rapanotti, 2009))

Problem Oriented Engineering, whilst presented in relatively simplistic terms above, as a theoretical framework is complex to apply. If MUVE design standards, that have led to improvement in high order inquiry skills observed in K12 students, are used to build a Second Life Problem Oriented Engineering learning space it is expected that students will gain a greater understanding of how to apply POE to real life problems.

As a final observation Problem Oriented Engineering is a “broad church” framework (Rapanotti & Hall, Problem Oriented Engineering in action: experience from the frontline of postgraduate education, 2008) and as such can be applied to any problem that is amenable to an engineered solution. It has thus been applied to such diverse
applications as requirements analysis (Hall & Rapanotti, Requirements Analysis in Context with POE Design, 2009), educational course design (Rapanotti & Hall, Designing an online part-time Master of Philosophy, 2009), and software engineering (Hall, Rapanotti, & Jackson, Problem Oriented Software Engineering: Solving the Package Router Control Problem, 2008), and knowledge capture (Hall & Rapanotti, Capturing Knowledge through Problem Oriented Engineering, 2008). This ability to be applied to a wide range of problems ensures simple examples can be generated to facilitate the teaching of the process.

2.7 Design guidelines

Despite the amount of research into cognitive loading and the value of MUVEs for K12 students there is very little in the way of guidelines on how to design a simulation. Mayer (1997) seems to be the first to actually perform a systematic analysis of what it is about multimedia learning that makes it suitable for teaching complex scientific subjects. In his review Mayer asks a number of questions and from these generates predictions based on these questions. The work lays out a clear set of predictions about how different multimedia strategies can be expected to affect students learning, but fails to create a set of guidelines that can be applied in practice. Nelson and Erlandson (2008) however, take these questions and predictions and from them, in Table 1 of their paper (reproduced below), generate a number of multimedia learning principles. These principles are then mapped to a set of pragmatics which can be viewed as a set of guidelines for the design of MUVEs.

<p>| Table 1 Multimedia learning principles from (Nelson &amp; Erlandson, 2008) |</p>
<table>
<thead>
<tr>
<th>Principle</th>
<th>Definition</th>
<th>Pragmatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multimedia</td>
<td>People learn better from words and pictures together than from words alone</td>
<td></td>
</tr>
<tr>
<td>Coherence</td>
<td>People learn more deeply when extraneous material is excluded</td>
<td>Use few rather than many extraneous words and pictures</td>
</tr>
<tr>
<td>Signalling</td>
<td>People learn more deeply when cues highlight the organization of essential material</td>
<td>Guiding the learner in selection organization and integration of explanatory information</td>
</tr>
<tr>
<td>Redundancy</td>
<td>People learn more deeply when multiple forms of identical information are NOT presented simultaneously</td>
<td>People will learn better from a combination of graphics and narration than from graphics, narration and on-screen text</td>
</tr>
<tr>
<td>Modality</td>
<td>People learn more deeply from a multimedia message when the words are spoken rather than printed</td>
<td>Dual-coding can take place allowing for more information to be processed in working memory</td>
</tr>
<tr>
<td>Spatial contiguity</td>
<td>People learn more deeply when corresponding words and pictures are closer to each other</td>
<td>Graphic element referenced on a page of text should appear within a certain distance of the referencing text</td>
</tr>
<tr>
<td>Temporal contiguity</td>
<td>People learn more deeply when corresponding animation and narration are presented simultaneously rather than successively</td>
<td>Animation and descriptive narration should be synchronized based on content</td>
</tr>
<tr>
<td>Segmenting</td>
<td>People learn more deeply when a multimedia message is</td>
<td>Learner controls the pacing he or she has the option to repeat</td>
</tr>
</tbody>
</table>
presented in learner-paced segments rather than as a continuous unit

any step in the lesson as many times as necessary

| Pre-training | People learn more deeply from a multimedia message when they know the names and characteristics of main concepts | Having a list of previously-explained terms “in hand” can considerably help the learner to grasp the overarching concepts within the lesson |

It should be noted that there are no pragmatics for the first principle – Multimedia – this is how the table is presented in their paper, but is explained by the fact that the definition effectively dictates the pragmatics, with the pragmatic being that words should always be accompanied by pictures.

Nelson and Erlandson do point out that the principles in Table 1, having been developed from Mayer’s earlier work, are based on “2-D presentational learning environments”. They also however argue that because the principles use the ideas of dual-coding and “cognitive processing capacity”, (Mayer & Anderson, 1991) & (Sweller, 2005) quoted in (Nelson & Erlandson, 2008), they can be used as a framework for the development of educational MUVEs.

In addition Nelson and Erlandson in Table 2 of their paper present a list of cognitive overload scenarios (again reproduced below) which whilst they are not truly a set of guidelines do present a set of principles that guide actions that should not be performed. In effect they have generated a list of do’s and don’ts.

Table 2 Cognitive overload scenarios from (Nelson & Erlandson, 2008)
<table>
<thead>
<tr>
<th>Overload scenario</th>
<th>Related design principle</th>
<th>Load reducing methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual channel is overloaded by processing of essential information</td>
<td>Modality</td>
<td>Off-load information from visual to verbal channel (using narration)</td>
</tr>
<tr>
<td>Both channels are overloaded by essential processing demands</td>
<td>Segmentation, Pre-training</td>
<td>Present information in learner-controlled segments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide pre-training of segments of information within larger system</td>
</tr>
<tr>
<td>One or both channels overloaded by essential and incidental processing of extraneous material</td>
<td>Coherence, Signalling</td>
<td>Eliminate interesting but extraneous information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide cues to how to process information</td>
</tr>
<tr>
<td>One or both channels overloaded by essential and incidental processing of confusingly presented material</td>
<td>Split attention (spatial contiguity), Redundancy</td>
<td>Place related words and pictures near each other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eliminate multiple forms of identical material</td>
</tr>
<tr>
<td>One or both channels overloaded by essential processing and representational holding</td>
<td>Split attention (temporal contiguity)</td>
<td>Present pictures and words simultaneously to minimize need to access past-information in working memory</td>
</tr>
</tbody>
</table>
As I have already indicated, locating other sources of design guidelines has proven extremely difficult. Whilst cognitive load is considered by, for example Cooper (1990) there are not definitive guidelines that are produced.

This lack of a range of guidelines from different researchers (the Nelson and Erlandson guidelines are even based primarily on the work of Mayer), effectively restricts those guidelines that can be adopted. Whilst this is a negative aspect it does have the advantage that I will be able to validate the design principles as documented by Nelson and Erlandson and attempt to confirm whether they apply equally to higher education students as to K12 students for whom they were developed.

2.8 Interaction design

During the pre-development literature search I found very little in terms of design principles or guidelines, however shortly after the design and development of the Problem Oriented Engineering simulation had been completed, Minocha and Reeves (2009) circulated a paper looking at the design of 3D learning spaces. They found, by empirical investigation, that there are a number of problems associated with interaction design, most notably with usability and navigation. They also however have found that:

“When the [physical characteristics] of an object correspond with its intended function, the design will perform more efficiently and will be easier to use.”

A number of other findings from this paper such as the use of iconic “real world metaphors” are also of direct relevance to my design of the Problem Oriented
Engineering learning space, and will be discussed in detail in Chapter 7. It is however instructive that Minocha & Reeves find a need for wider ranging design principles over and above the multimedia principles I have used.

2.9 Research question

Whilst Nelson and Erlandson's design principles (2008) were developed based on a simulation designed for K12 students the principles themselves do not contain anything that could be seen as a differentiator between higher education and K12 students.

My hypothesis is therefore that Nelson and Erlandson's design principles, and the consequent potential for knowledge transfer and positive learner perception, would be equally applicable to any MUVE like environment regardless of the age of the target audience.

This dissertation attempts to answer the question; how effective, in terms of knowledge transfer and learner perception, are MUVE design principles and guidelines, developed for K12 learning environments, when applied to a Second Life Problem Oriented Engineering learning environment for higher education students?

2.10 Summary

Since the arrival of home computers and their evolution into games consoles, the methods used to teach players how to play games have evolved in parallel, from highly detailed written documentation, into situated learning environments, teaching the techniques required as the player requires them. Educators have taken advantage of this
approach, and developed games intended to engage students in a situated learning environment to teach more technical subjects.

Second Life is probably the best known commercial multiple user virtual environment, and while it has some of the characteristics of more traditional computer games it is a departure in that it has no defined aims or end point. Second Life can be regarded as a form of hybrid between computer games and social networking sites. As a result of this it provides an ideal opportunity to provide educational facilities via situated learning environments. The development of principles to guide the design and construction of 3D multi-user situated learning environments, such as those that could be built in Second Life, have not been addressed. Principles however, designed to guide the development of multimedia learning environments, do appear to have the potential to guide design in facilities like Second Life.

Problem Oriented Engineering is an emerging framework which captures the elements of an engineering problem, using a defined process, and allows the process of design, together with its assumptions and validations, to be visualised and recorded. As an emerging framework it provides an ideal vehicle with which to test the applicability of the multimedia design principles applied to a situated learning environment in Second Life.
Chapter 3  Overview of Research Methods

In this chapter I look at the methods that have been used by previous researchers in the field and those that I will be adopting and, where appropriate, adapting to the environment I will produce in Second Life.

3.1 Research methods

The literature search has identified multimedia design principles which are rooted in cognitive research by, amongst others, Mayer (1997), Mayer and Anderson (1991) and Sweller (2005). These design principles have then been collated and their presentation simplified by Nelson and Erlandson (2008) into a set of multimedia design principles and associated pragmatics. This has lead in the same paper to the development of a set of cognitive overload scenarios (Mayer & Moreno, 2003).

Nelson and Erlandson in their 2008 paper state that

“To date, little research has been done on the usefulness of multimedia design principles in the creation of complex 3-D situated learning environments”

I have to agree with this summary and add that in general there appears from my research little development of the work by Mayer et al. on the early 2-D presentational environments.

In the process of my research I have however also visited a number of “learning” environments in Second Life to form my own opinions of what I think works and how the principles, as documented by Nelson and Erlandson (2008), can be used to explain
what works and what doesn’t. As an example of this the second life environment “Here” (Olmstead, Linden, Tester, & Ravenelle, 2009) could be regarded as an environment where almost all of Nelson and Erlandson’s principles are broken with examples of cognitive overload due to both spatial and temporal split attention, a complete lack of any pre-training, and coherence issues. On the other hand, environments such as the “Ivory Tower of Primitives” (Noir, 2009) and “The Particle Laboratory” (Pendragon, 2009), seem to adhere to Nelson and Erlandson’s principles and avoid cognitive overload, whilst others such as “The College of Scripting Music and Science” (March, 2009) seem to use basic 2-D representations in a 3-D environment to the same effect.

When visiting these sites, while I took notes of their various elements that conformed (or broke) the Nelson and Erlandson principles, such as modality conformance in the Particle Laboratory, (multiple versions of a particle emitter were displayed to allow comparison between different labelled emitters), and spatial contiguity conformance in the College of Scripting, Music and Science (code examples and their associated descriptions located on discrete panels) I did not adopt a rigorous approach to their assessment. Before I had located the Nelson and Erlandson principles, I was unable to perform a rigorous assessment, however with hindsight, knowing that elements of a number of Second Life simulations influenced my design, ideally I should have performed such an assessment on all further visits.

In order to develop their design principles Nelson and Erlandson (2008) applied the principles identified to The River City environment, where a specific topic, was used
to assess their assimilation of knowledge and understanding. As this study is also attempting to assess the assimilation of knowledge in a similar way this study will apply the Nelson and Erlandson design principles to a simulation developed in Second Life; the details of which are covered in Chapter 4.

The simulation will utilise the key structural elements of Problem Oriented Engineering, in combination with a basic case study to ensure the situated learning environment is rooted back to a real world example; again the details are discussed in Chapter 4.

However to assess the educational benefit it is necessary to assess the amount that a student has learnt. When assessing this I considered two key methods, namely interviews and questionnaires. Whilst interviews provide a more flexible approach, where formative assessment can be used to probe a student’s knowledge, questionnaires provide an immediate and consistent method of knowledge assessment. As Second Life is an internet based application students from around the world would be able to use the environment. With the potential for such a wide ranging student population, whilst the flexibility of interviews may have been preferable, their management potentially across multiple time zones would, as a lone researcher, have been likely to significantly impact the project timescales. As a result, whilst lacking the flexibility, the simulation developed will include a post experience questionnaire similar to those used by Mayer, Heiser & Lonn (2001) & Dede et al (2005) to assess students’ prior knowledge and level of recall, and also to determine their qualitative
Finally, in order to determine the extent to which students interact with the environment, and therefore be able to make a qualitative assessment of their use of the environment, tracking of the users’ activity similar to that used by Coen (1998), will be carried out. The use of automated tracking of a user rather than direct observation is again driven by the nature of Second Life as an internet application. As a lone researcher it is not practical (or possible) to be constantly monitoring the environment. In common with the interview vs. questionnaire issue, whilst tracking lacks the flexibility of direct observation, it does provide a consistent means of capturing a user’s activity.
Chapter 4  Design of the Environment

In this chapter I look at the design of the learning environment, covering the selection of material to include and how I then used the principles I had found in the literature search to inform the construction of the final environment. I also look at the design of the tracking system I used within the environment, and the final questionnaire.

The design and development of the final environment was an iterative process which has meant that while this chapter concentrates on the design of the environment some elements of its construction are referred to in this chapter. Not least amongst these is the development of a supplementary informal objective looking at how people tend to move around virtual 3D spaces.

4.1 Problem Oriented Engineering Content Selection

Having identified Nelson and Erlandsons principles I now needed to identify learning scenarios for Problem Oriented Engineering and adopt, develop or adapt those to a structured learning environment in Second Life. From the literature search there are two key structural elements in POE, namely the process diagram, and the fish diagram. Both of these elements have clear simple structures that readily lend themselves to encoding within Nelson and Erlandsons principles.

However Problem Oriented Engineering in order to be of value outside an academic environment must be seen to be applicable to, and be able to solve, a real world problem (a case study). To this end the literature search uncovered a number of concrete examples that could be used, however one example, the design of a decoy
launcher for a helicopter defence system (Mannering, Hall, & Rapanotti, 2007) stood out as being highly suitable. It did so because, in addition to the FASE 2007 paper, Hall and Rapanotti have put together a presentation on POE which uses the Helicopter Decoy problem (Hall & Rapanotti, http://design.open.ac.uk/the_department/videos/Jon Hall presentation.pdf, 2008), illustrated with a picture of a helicopter decoy in use. This is a highly graphic image and provided an ideal opportunity to step away from purely iconic representations of the process, and to reinforce the learning by using further images of decoy launchers in action.

4.2 Environment design: Applying the principles

Without any specific MUVE design principles the development part of the learning space within Second Life was based around Nelson and Erlandsons principles. After some small scale trial developments that I used to understand the capabilities of Second Life scripting, I used the table of Nelson and Erlandsons principles to drive the design of various aspects of the final environment. I adopted this approach after deciding on the use of the helicopter decoy problem. The decoy example clearly used the multimedia, coherence, signalling and spatial contiguity principles. It then became a case of attempting to apply all the principles to the design of the environment. Once I had completed this stage of the design I transposed the design features to highlight those principles being applied to individual parts of the environment. The idea behind this was that I may be able, at some later point, to identify specific principles that are or are not applicable in a 3D environment. Table 3 below identifies those design features of the learning environment that map to the Nelson and Erlandson Principles.
<table>
<thead>
<tr>
<th><strong>Description</strong></th>
<th><strong>Relevant principles</strong></th>
</tr>
</thead>
</table>
| The building in which the environment is housed will be shaped like the process diagram on a large scale | **Coherence** – The building shape has some relevance to the learning space  
**Signalling** – The shape of the building highlights the importance of the process diagram |
| On entry to the building the learner will be presented with a “notecard” that describes the basic structure of the environment, the elements that are being taught, and any controls that are available within the environment. The contents of the notecard will be summarised in a wall based “slide” in the inside the first room. | **Pre-training** – The learner will have (by virtue of the content of the notecard, and links to basic Second Life training materials) at least the basic tools and information to enable them to use the environment.  
**Segmenting** – The user can choose to ignore the notecard in the interests of time but is still given the information required to use the environment via the wall based slide. |
| Each room will contain some elements of all the three identified aspects of the learning experience | **Signalling** – The learner is expected to be able to select and organise information better to create their own model of the |
### 1. The process diagram

The overall process of Problem Oriented Engineering will be presented in each room with its name and the relevant stage within the icon will be enlarged.

### 2. The fish diagram

The repeated use of the fish diagram with its constituent parts is expected to help in the understanding of the overall process.

**Coherence** – As a learner walks through the space they will be presented with consistent but expanding information about the fish diagram.

**Signalling** – The continued use of the process diagram highlights its importance.

### 3. The case study

A “slide based” representation(s) of the fish diagram will be presented in each room gradually introducing the constituent parts of the diagram, and the way in which they fit together.

**Multimedia** - The repeated use of the fish diagram with its constituent parts is expected to help in the understanding of the overall process.

**Coherence** – As a learner walks through the space they will be presented with consistent but expanding information about the fish diagram.
<table>
<thead>
<tr>
<th><strong>Signalling</strong> – The continued use of the fish diagram as with the process diagram will highlight its importance.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Segmenting</strong> – the learner can take as long as they feel they need to go through each of the stages in each of the rooms. And review each of the slides as many times as necessary.</td>
</tr>
<tr>
<td>The Helicopter Decoy Launcher problem will be developed in a slide format as the learner moves through the building.</td>
</tr>
<tr>
<td><strong>Multimedia</strong> – The use of pictures of launchers in use is expected to aid in the understanding of the other material. <strong>Coherence</strong> – Using images of decoy launchers in use is expected to reinforce the fact that this is like an ongoing case study. <strong>Signalling</strong> - Changing the image used based on the room is expected to allow the learner to select and organise the case study material. <strong>Spatial contiguity</strong> – Placing images of launchers in use alongside the text describing the on-going case study is expected to provide a deeper</td>
</tr>
<tr>
<td>The Helicopter Decoy Launcher “slides” will incorporate different images in each room of decoy launchers in use.</td>
</tr>
<tr>
<td>Understanding of the material.</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Short “sound bite” narrations will be attached to relevant items throughout the rooms of the building.</td>
</tr>
<tr>
<td>An emergency exit logo will be available in all the rooms to allow the learner to teleport out of the environment when they wish.</td>
</tr>
<tr>
<td>The structure of the building - mirroring the process diagram will mean that there is an opportunity for a central courtyard. The process diagram will be reproduced</td>
</tr>
</tbody>
</table>
in the central courtyard as a sculptural item.

4.3 Learner tracking

Whilst I knew that I was going to have a learner post experience questionnaire, to supplement the information gathered learner tracking was also used. Coen (1998) used learner tracking within an “intelligent room” to determine user activity and thereby provide information in advance for the user of the room.

Although the environment I have created is fixed and specific content is not made available on the same basis as Coen’s work, tracking a learner’s activity while they are in the building provides a means to determine whether their perceptions – captured by the questionnaire – are affected by the time or level of interaction that they have with the various parts of the building.

To this end each of the touchable items within the environment has been engineered to enable a central record of a learner’s activity to be created and captured. When a student is invited to take the questionnaire the activity record for that particular student is extracted and emailed to me using the facilities available within the Linden scripting language (Omega, LSL Wiki : Homepage, 2009).

This detailed activity monitoring was then analysed alongside the questionnaire response to determine if there is any correlation between a user’s perception of the
environment and their activity within it e.g. whether the length of time spent within any given room either positively or negatively influences a user’s perception of that room. Lastly the activity tracking data was used to identify any areas of the environment that are either highly or under used.

4.3.1 Left or right

As has been said the design of the environment was an iterative process. As a result of this, towards the end of the design/development process it became clear that I had made a fundamental assumption about how people would move around the environment. The learning environment was developed as a set of slides, initially put together in a specific sequence within PowerPoint, combined with narratives that were displayed as wall based exhibits within the POE Lodge structure. When I first put the structure together I laid out the slides in what to me appeared to be a logical left to right reading manner. However it became clear during my initial trials that this apparently logical layout was not so immediately intuitive. Working through the Nelson and Erlandson design principles there appeared nothing to inform the decision as to how the information should be laid out. This is a specific shortcoming of the Nelson and Erlandson design principles.

Unfortunately this issue was not discovered until too late in the project to incorporate it as a formal objective, it did however drive the addition of an informal objective:

To determine whether students move around a 3-D environment based on whether they are right or left handed.
With the user tracking information available I felt that it may be possible to determine whether the students followed the intended path i.e. reading around the rooms in a top left to bottom right pattern, or whether there was a more complex behaviour happening that would justify further research.

Having identified the additional objective I believed that the user location logging information would provide a good opportunity to analyse whether a learner’s handedness affected the way they would interact with the environment. Specific information about the way that a user turned was not captured, however when a learner interacts with an object I considered it reasonable to assume that there would be a period when they were assessing the information or action they had just taken, followed by a period of movement to the next interaction. As an example in Figure 4 if a learner touched the speaker icon for the slide in front of them (headed Problem Oriented Engineering Notation (5) – combining documentation), there would be a period during which they would be listening to the narration before they then turned to either the notecard giver below the slide or the Web launcher (shown as a spider’s web) to the right.
Knowing the layout of the interaction objects in POE Lodge, and by selecting a time window during which I assumed a user would not be able interact with one object, turn nearly 360°, and interact with another object it was possible to work out (within the assumptions) which way a user had turned.

4.4 Survey Design: Learner questionnaire

In order to determine the student’s perception of the usability of the Second Life simulation, and for the geographic and practical reasons I have given in Chapter 3 it was clear that I would need to use student experience questionnaires.

Initially I attempted to use the inbuilt facilities of Second Life however it rapidly became clear that Second Life scripting was not suited to administering a questionnaire of the type I required. I knew that I needed the survey integrated within
and administered as a function of the simulation so that student responses are obtained as they exit the environment (Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005).

To this end I needed a survey facility that could be accessed from Second Life. The readily available facilities provided by SurveyMonkey (SurveyMonkey.com, 2009), providing an HTTP (Fielding, et al., 1999) URL (Campione), meant that the questionnaire could be directly administered from within the simulation, and I therefore selected this method. The questionnaires were designed to determine both the students’ qualitative assessment of the learning experience (Hetherington, Bonar-Law, Fleet, & Parkinson, 2008), and the students assimilation of the Problem Oriented Engineering learning material (Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005).

The questionnaire was designed in three distinct sections. The content of each of the sections are detailed below, however the first section maps to objective 5, the second to objective 6. The third section gathers general background information that I felt could reasonably be expected to influence a user’s perceptions, and also addresses the informal left or right handedness objective.

The first section tests the students’ assimilation and recall of the POE content using multiple choice questions. Ten multiple choice questions are used with each of the questions having four possible responses. The assimilation and recall questions test the knowledge of

- The POE process
- The fish diagram and,
- The decoy launcher problem.
The second section asks for the student’s qualitative assessment of various aspects of the environment, together with specifics of how they interacted with the simulation. Where value judgements are sought for the qualitative assessments, a scale with at least 4 options is used, together with a “did not use” option where appropriate. In addition student comments are also be requested. This section consists of 10 question groups with 20 individual questions.

The third section deals with the students themselves, their prior exposure to Second Life, their use of Second Life in general, and whether they are right or left handed. This section consists of 7 questions.

A final design consideration for the questionnaire was to keep the expected duration to less than 10 minutes (with the students being told this in advance), in the hope that this would encourage a high take up (Crawford, 2001), on the basis that this would present in Crawford’s terms a low perception of burden.

Wall slides The questionnaire is given in full in Appendix A.

By using the facilities of SurveyMonkey the results of the questionnaire are stored online. Access to the results of the survey is restricted to the specific user who developed the survey. Once the simulation was “closed” to further student activity the survey results were downloaded and analysed.
Chapter 5  Environment Development

This chapter is primarily concerned with some of the more technical development details and methods I employed in the construction of the learning environment. Where possible I have followed the same structure as the previous chapter, however in common with Chapter 4, due to the iterative nature of the design and development process some aspects of the design are reflected in this chapter.

5.1 Problem Oriented Engineering Content

5.1.1 Wall slides

Before starting construction of the POE learning environment (dubbed POE Lodge) I had a clear idea that I wanted to present the POE learning information as “slides” which would be attached to the surface of the walls as shown in Figure 5.

This decision was based on the idea that I was trying to extend the use of the Nelson and Erlandson principles from a purely 2-D environment into a 3-D world. I then rationalised that if I attempted to make the exhibits three dimensional as well then this would be introducing an additional variable into the final assessment, which would have extended the scope of my research beyond the available timeframe. In addition while experimenting at the start of my research, I found, based on feedback from my supervisor, that although it was possible to create sculptural pieces, they were difficult to use or understand without some form of two-dimensional documentary information.
To facilitate the creation of the wall slides I initially created the wallpaper as PowerPoint slides. This ensured that the sequence of the information I wanted to present was clear, ensuring the segmentation aspects of Nelson and Erlandsons principles were applied. This approach also allowed the content to be readily updated and amended during consultation with my supervisor. Once finished the slides were uploaded and attached to the walls.

![Wallpaper Image](image)

Figure 5 POE Lodge "Wallpaper"

### 5.1.2 Audio sequences

Alongside the creation of the slides I also created narration sequences which were designed to address the redundancy and modality aspects of the Nelson and Erlandsons principles. Again these were developed using tools (MS word in this case)
that allowed the content to be readily amended before I finally recorded them as audio sequences.

It was my original intention that the narrative sequences would be piped through as a single stream, which would have meant that a narrative sequence could have been recorded as a single stream for each of the slides. However, in order to stream music or audio sequences to a parcel of land within Second Life, the owner of the scripted object that will play the audio stream must be the same as the owner of the parcel of land (Fairlight, LSL Wiki : llSetParcelMusicURL, 2009). As I was developing on the Open University Deep Think sandbox I was not the owner of the parcel of land as a result I had to fall back on a sound bite approach, where each narrative was broken down into sentences with a maximum duration of 10 seconds. These sentences were then named alphanumerically so that they could be automatically identified and played in the correct sequence for each slide (e.g. N1.wav, N2.wav etc.).

I had originally intended to attach the audio sequences directly to the slides which would have meant that when a learner clicked on a particular slide it played the correct sequence. However when I had to fall back on the sound bite approach the resultant coding to manage the notification to the central controller, and the state changes to play the audio sequences would have created some quite complex code. In the interests of simplicity therefore I adapted the approach to use Nelson and Erlandsons pre-training principle, in a similar way to that used for the emergency exits, and attached a button to each of the slides with a speaker icon on its surface to
indicate the presence of a narrative sequence.

Figure 6 Speaker and Emergency exit icons

5.2 Learner tracking

5.2.1 Central controller

At the very start of my experimentation in Second Life construction, and even before I started formal construction on the learning environment, I was conscious of the fact that if I was going to understand how students were interacting with any environment I would need some means of collecting information on their movement and their interaction with the structure.

To address this I created a central controller which took information from all the parts of the environment and managed the logging of information and the presentation of items such as the survey.
5.2.2 Location logging

Emailing using the Linden scripting facilities does impose limits on the amount of data that can be sent in any one email (Omega, LSL Wiki : llEmail, 2009), however the content of the email was encoded such that the size limits do not cause an issue.

The engineering to capture the user’s activity was attached to all the primitives (Cuh, 2009) within the environment. All the primitives where possible were linked as a single object and as such each primitive had a unique link identification number (Omega, LSL Wiki : Link, 2009). This link identification number was paired with the key for the Avatar (Fairlight, LSL Wiki : Key, 2009) and a timestamp (Fairlight, LSL Wiki : llGetTimestamp, 2009). This enabled detailed tracking of the students’ activity within the environment. A second email was generated at the same time which contained a list consisting of the link identification numbers paired with the name of the primitive with which it is associated. This allowed the link identification numbers to be decoded to specific primitives by name, but does not use large amounts of storage to repetitively record the names.

During my initial development I experimented with different types of door opening mechanisms, such as normal hinged doors, revolving doors, and up and over garage style opening doors. However all these required relatively large amounts of code to manage the user’s interaction. After a number of different trials and taking the code complexity into account I eventually, during the detailed design, decided to use a simple door opening mechanism whereby doors are made transparent and are then assigned the phantom attribute (AmaOmega, 2005) which prevents the door from
acting as a physical object, allowing users simply to walk through the apparent space where the door had been. However it is not possible to assign the phantom attribute to a linked primitive without it being applied to an entire object. This would have meant that a user could simply walk through any walls, or potentially fall through the floor. This restriction meant that it was not possible simply to retrieve a link number from the primitive and use this to track users’ interactions with the primitive. The link identification numbers however start at zero and increase one at a time, making it possible, knowing the number of primitives, to know the highest link identification number. This was then used to develop a similar method to track user’s interactions with these unlinked primitives, but rather than using a link identification number a specific code (significantly higher than the highest possible link identification number, arbitrarily in this simulation I started at 701) was manually assigned to each of these primitives.

All the primitives then reported their information to a central control primitive that was responsible for collating all the information and sending the emails. A copy of the tracking code fragment for both linked and unlinked primitives is shown in Appendix.

5.3 Learner questionnaire

As discussed in Chapter 4 my original intention was to implement the questionnaire directly from the simulation, however text based interactions in Second Life are currently not robust enough to enable this approach. As a result the questionnaire was developed within SurveyMonkey, and the URL link to the survey was then embedded
within POE Lodge, as part of the action of opening the main exit, or of using the emergency exit to teleport out of the simulation.

It is possible for learners to exit the simulation by the simple expedient of closing the Second Life viewer; however there is no method available if they choose this route to ask them to fill out a questionnaire. It may seem unlikely that a user would choose to use this option to exit the environment; however Second Life does still have a number of teething troubles and it is quite common to get logged out of a region by the Second Life servers because they are having difficulties. When this happens it is common for the only recovery action available to be to close the viewer. From the data collected this appears to have happened twice however on one occasion the learner then revisited the environment and completed the survey the following day. In the other occurrence the learner appears to have had multiple hits of this type of problem as there are significant gaps between activities being recorded. After 2 days of visiting for short periods of time this user stopped returning and did not complete a survey.

5.4 Data pre-processing

When the student tracking data is emailed from Second Life it is transferred as a list converted to a Comma Separated Variable (CSV) format. An example of the format received is shown in Figure 7 below.
When received, without complex Excel macro processing, this data can be difficult to reformat. As a result the list data (shown in red) is first copied as unformatted text to an MS Word document. The facilities within Word are then used to convert the raw text data into a three column table as shown in Table 4 below.

Table 4 Example pre-processed tracking data email content

<table>
<thead>
<tr>
<th>Avatar ID</th>
<th>Primitive ID</th>
<th>Timestamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>8dbe071e-c33c-46d2-8931-7f2e170206c9</td>
<td>48</td>
<td>2009-10-25T18:05:37.374844Z</td>
</tr>
<tr>
<td>8dbe071e-c33c-46d2-8931-7f2e170206c9</td>
<td>701</td>
<td>2009-10-25T18:05:41.951614Z</td>
</tr>
<tr>
<td>8dbe071e-c33c-46d2-8931-7f2e170206c9</td>
<td>701</td>
<td>2009-10-25T18:06:19.596951Z</td>
</tr>
<tr>
<td>8dbe071e-c33c-46d2-8931-7f2e170206c9</td>
<td>701</td>
<td>2009-10-25T18:06:22.429901Z</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Once converted the entire table can then be manually copied and directly pasted into Excel.

The primitive information data is treated in a similar way using the examples below.

<table>
<thead>
<tr>
<th>Primitive ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>66</td>
<td>Narration 10</td>
</tr>
<tr>
<td>144</td>
<td>Slide 4</td>
</tr>
<tr>
<td>61</td>
<td>Narration 13</td>
</tr>
<tr>
<td>131</td>
<td>Slide 24</td>
</tr>
<tr>
<td>143</td>
<td>Slide 21</td>
</tr>
<tr>
<td>4</td>
<td>POE Overview</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

Object-Name: POE Lodge controller  
Region: Deep Think East (285696, 289280)  
Local-Position: (139, 176, 303)

66, Narration 10, 144, Slide 4, 61, Narration 13, 131, Slide 24, 143, Slide 21, 4, POE Overview,…

Figure 8 Example raw POE Lodge primitive data email content

Table 5 Example pre-processed primitive data email content
5.4.1 Left or right

Having identified the means by which I would determine the direction a user turned while interacting with the environment I selected, based on my own experience working within POE Lodge, a two second movement window. From my experience, although there would be some uncertainty in the movement pattern, I considered it unlikely that a user would interact with an ordinary object and then in less than 10 seconds turn the “long way” to get to another object. Where a user interacted with a narration object I did however use a window equivalent to the length of time that the narration was expected to play plus 10 seconds. Table 6 shows an example of this pre-processing of the direction of turn data.

Table 6 Example of direction of turn analysis

<table>
<thead>
<tr>
<th>Avatar ID</th>
<th>Timestamp</th>
<th>Object</th>
<th>Direction of turn</th>
</tr>
</thead>
<tbody>
<tr>
<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>2009-10-09T09:40:27.990635Z</td>
<td>Welcome Giver</td>
<td>N/A</td>
</tr>
<tr>
<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>2009-10-09T09:41:52.497970Z</td>
<td>Door 1</td>
<td>Unknown</td>
</tr>
<tr>
<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>2009-10-09T09:42:16.089899Z</td>
<td>Door 2</td>
<td>Unknown</td>
</tr>
<tr>
<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>2009-10-09T09:42:22.369941Z</td>
<td>Decoy Controller II</td>
<td>Unknown</td>
</tr>
<tr>
<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>2009-10-09T09:42:56.411361Z</td>
<td>Door 2</td>
<td>Unknown</td>
</tr>
<tr>
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<td>N/A</td>
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<td>2009-10-09T09:44:24.733180Z</td>
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<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>2009-10-09T09:44:35.745971Z</td>
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</tr>
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<td>Right</td>
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<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
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<td>Unknown</td>
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<tr>
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<td>Controller</td>
<td>Door</td>
<td>Narration</td>
</tr>
<tr>
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<td>-----------</td>
</tr>
<tr>
<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>Controller I</td>
<td>Door 1</td>
<td>Unknown</td>
</tr>
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<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>Controller I</td>
<td>Door 1</td>
<td>Unknown</td>
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<tr>
<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>Controller I</td>
<td>Door 1</td>
<td>N/A</td>
</tr>
<tr>
<td>c5a5e46c-d8f4-48ec-936c-fd6648131184</td>
<td>Controller I</td>
<td>Door 1</td>
<td>Left</td>
</tr>
</tbody>
</table>
Chapter 6 Results

Visitors to POE Lodge were invited to participate in the research by three methods. Initially I posted an invitation together with the Second Life URL on the Open University M801 chat board. I then posted a general invitation to participate on the Virtual Worlds at JISC mail list (VIRTUALWORLDS@JISCMAIL.AC.UK), and finally my supervisor sent invitations to participate to those with specific interests in POE within the Open University. The POE Lodge environment was first used on the 9th October 2009, and was visited a total of twenty times by ten distinct individuals by the 25th October 2009.

Following the visits six questionnaires were started, however some questionnaires were not fully completed.

With no further visitors after the 31st October analysis of the data collected started on the 2nd November 2009.

6.1 Implementation based results

The research question and those objectives that specifically address the users’ perceptions, knowledge assimilation and “handedness” are expected to be directly related to the build and associated scripting of the objects within the environment. As a fully developed environment, if the design principles used have been effective, then they should provide both a positive experience and effective knowledge transfer for the students who take part.
Effective knowledge assimilation will be able to be assessed, at least for those with little or no knowledge of POE, by the post experience questionnaire. A low score on the first part of the questionnaire would indicate that knowledge transfer had been ineffective. This will however have to be weighed against the amount of time a student spends within the environment, and the interactions that they have with the objects in the simulation.

Similarly the test of learner perception will be able to be answered from the questionnaire. Specifically the questions regarding the ease of use and usefulness will be able to be used to test the learners’ perception of the environment. However this again will need to be balanced against the actual interactions that the learners have with the environment. If a learner’s perception is low but they have had a low number of interactions with the objects then I will need to assess whether this is a cause or an effect of the environment. In this situation I would expect to refer to the freeform comments that students will be able to make when filling in the survey.

6.2 Analysis of results

6.2.1 Knowledge assimilation

POE Lodge was originally intended to teach the basics of Problem Oriented Engineering to those with little or no previous knowledge of POE. Of the six respondents three stated in their questionnaire answers that they had little or no knowledge of POE.
Of these three respondents two answered all the knowledge assimilation questions with the third only answering the first five. The chart below summaries the results obtained.

![Knowledge assimilation question analysis](image)

**Figure 9** Knowledge assimilation question analysis

The first thing to note is that the respondent who did not answer all the knowledge assimilation questions gave no reason for not answering the remaining questions, and indeed completed the rest of the questionnaire. This respondent only scored 30% in terms of the total number of questions, however if we look at just those questions that were answered then two of the respondents scored 60%. With such a small sample and with one respondent not completing this part of the questionnaire it is very difficult to draw conclusions, however it would appear that POE Lodge is successful at least in part in its aim of teaching the basics of Problem Oriented Engineering.

A contributing factor to the participant’s assimilation of knowledge could have been the time the respondents spent in the simulation. However from Table 7 below there
appears to be no relationship between the time spent in POE Lodge and the overall assimilation score.

Table 7 Respondents with no knowledge of POE - time spent in POE Lodge

<table>
<thead>
<tr>
<th>Respondent number</th>
<th>Time spent in simulation</th>
<th>Score (all questions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>00:31:47</td>
<td>60%</td>
</tr>
<tr>
<td>2</td>
<td>00:12:40</td>
<td>30%</td>
</tr>
<tr>
<td>3</td>
<td>00:15:26</td>
<td>20%</td>
</tr>
</tbody>
</table>

It must however be remembered that this is a very small sample, and in drawing this conclusion I have assumed that the participants did at least have some interest in the content and did not just wander around aimlessly.

6.2.2 Interaction with the simulation

The assumption that the participants did not wander around aimlessly can by virtue of the tracking systems built into POE Lodge be confirmed. Table 8 uses the same numbering for participants as Table 7, but includes all the interactions recorded for all the other participants as well; those in shaded rows did not complete a survey.

Table 8 Distinct interactions per participant

<table>
<thead>
<tr>
<th>Respondent number</th>
<th>Number of distinct interactions with POE Lodge objects</th>
<th>Total number of interactions with POE Lodge objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>37</td>
</tr>
</tbody>
</table>
Within the whole simulation there are 70 objects that a learner could touch or interact with. However some such as the slides would not be expected to be touched as often as for example the narration buttons. There are therefore 38 key distinct interactions (distinct in this context means that multiple interactions with an object are only counted once) that participants could have made with the simulation.

The average number of distinct interactions across all the POE Lodge users (including those who did not complete a survey) was 14.90, however for those who completed a survey the average was 20.67. This higher average tends to support the idea that those participants who responded did have an interest in the content, and were therefore not wandering around aimlessly. This is obviously a small sample and the results must be considered in that light, however this provides good evidence that all the survey respondents had good levels of interaction with the simulation.

### 6.2.3 Knowledge assimilation and number of interactions

Despite being a small sample the users who had no prior knowledge of Problem Oriented Engineering exhibited a large variation in their knowledge assimilation...
scores. From Table 8, there was however a limited difference in both the total number of interactions that these three users had, and also in the number of distinct interactions. This prompts the question as to whether the type of interaction these users had actually affected their knowledge assimilation score.

Table 9 Number of interactions with object types

<table>
<thead>
<tr>
<th>Respondent number</th>
<th>Number of interactions with</th>
<th>Prior level of POE knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slides</td>
<td>Narrations</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
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<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

Within POE Lodge there are two high level types of interacting objects; those that only record an interaction for the purposes of tracking and those that provide some knowledge in addition to tracking a user’s location. Table 9 shows the users interactions with those objects that could be considered knowledge giving. From Table 9 the users having no prior knowledge of POE appear to have had a similar number of interactions with the knowledge objects as those with a basic
understanding of POE. However, apart from respondents 1 and 2 making slightly higher use of notecards, there appears to be no significant differences between their interactions. Unfortunately with this number of subjects it is not possible to determine whether the slightly higher use of notecards by respondents 1 and 2 has been significant in the users’ knowledge assimilation.

6.2.4 Ease of use

From the survey results there is a difference in the perception of the ease of use of the various structures of POE Lodge, as well as differences in the perception of the environment. In Figure 10 below the rating of usefulness has been converted to a numeric score and then averaged. A lower score indicates a structure that was viewed as more useful, with a mark of 3 indicating the mid-ground. From Figure 10 it can be seen that whilst there was no apparent preference for most types of objects the notecards and the URL links were both regarded as the most useful.
This preference for the URLs and notecards tends to suggest that if the multimedia principle (i.e. that people learn better if narration and pictures are presented together) is having any effect it is not felt as beneficial by the learners.

Interestingly when we cross tabulate the ease of use with the learners’ frequency of use of Second Life as in Figure 11 there is an apparent anomaly, in that occasional and regular users of Second Life actually view POE Lodge in general as relatively useful or at worst are undecided. However the one frequent user of Second life, who uses the service for between one and two hours every day, actually regards POE Lodge as very difficult to use. It is possible that a frequent user actually has higher expectations of simulations because they have been exposed to a higher number,
either with a generally higher quality of delivery and/or with a style of delivery the student prefers.

Figure 11 Ease of use by frequency of Second Life access

This is to some extent borne out by the fact that the frequent user has a similar attitude to the usefulness of the structures within POE Lodge as seen in Figure 12 where the frequent user ranks all aspects other than the narratives as less easy to use than the regular and occasional users.
Figure 12 Usefulness by frequency of Second Life access

6.2.5 Left or right

Across all the visitors to POE Lodge there were 232 interactions with objects, however of these interactions only 43 were able to be identified from the selection criteria applied as being left or right movements. Thirty of these were from right handed learners and thirteen from left handed learners. Of those learners who completed a survey four of the learners were right handed and two left handed. Figure 13 below compares the percentage of left and right turns made by the left and right handed users.
Sixty six percent of the turns made by right handed learners were right turns whereas for the left handed users this dropped to fifty four percent, indicating a small difference between the ways in which a left or right handed user would use the simulation.
Chapter 7 Discussion and Conclusions

In this chapter I reflect on the POE Lodge development and try to identify what has been successful and the potential for improvements, in relation to my original research question. I also look in more detail at the work carried out by Minocha and Reeves (2009), and compare elements of their paper, and my own findings. I then look at some of the issues I encountered during the development of POE Lodge to inform other researchers in the field, and finally look ahead to future research possibilities.

7.1 Reflection on POE Lodge

My original research question was to find out how effective existing design guidelines and principles are when applied to Second Life learning environments; POE Lodge has gone at least some way towards answering this question.

Despite a small sample size it is clear that for those users who had no prior knowledge of Problem Oriented Engineering, knowledge assimilation of the fundamental principles of POE was at least to some degree successful. The users with no prior knowledge of POE spent an average of just under 20 minutes in POE Lodge, and scored an average of just over 45% in the knowledge assimilation part of the survey. Whilst it would have been satisfying if the knowledge assimilation score had been higher I have to acknowledge that for a brief 20 minute experience in an experimental environment anything higher would probably have been exceptional.
Where I think POE Lodge has been more successful is in the understanding of the ease of use, and usability of the environment. The fact that the notecard givers and the URL links were overall regarded as the easiest to use and the most useful objects indicates a preference among this small sample for familiarity. The URL link launches a browser window, which despite being different in style to more common browsers like Internet Explorer, still retains familiar content. Notecards could be regarded as unfamiliar, however any user new to Second Life quickly becomes familiar (even before leaving the welcome/orientation area) with the concept of touching an item and receiving either an object or a notecard with a format similar to that of a windows .txt document. Notecards therefore, despite being a Second Life concept, quickly become an accepted way of gaining information amongst new users.

The anomaly here is that the wall slides, which it could be argued, based on the design principles used, are familiar objects, were not regarded as being as easy to use or useful. However the slides were developed in PowerPoint and as such have been developed with a specific sequence of presentation in mind. In the 3D space of POE Lodge the sequence information that a PowerPoint user would have by virtue of moving from one slide to the next is broken. Based on comments from the post experience survey (e.g. “...SL's not good for encouraging lots of reading.”, and “The signs were confusing as to where to begin reading, i.e. in which order…”), I suspect that this is the reason the slides have not been regarded as being as useful, or usable, as for example the notecards. This issue is what prompted the addition of the handedness question; knowing the content, I laid out the slides in what seemed a reasonable order. It was not however until my supervisor reviewed the build that it became clear that the slide sequencing information had been broken.
These issues, around the ease of use and the usability of items within Second Life, clearly indicate, that although the Nelson and Erlandson guidelines, have informed the design of an environment, that can teach the basics of Problem Oriented Engineering, the guidelines do not go far enough for a 3D environment. In more general terms the difficulty in finding any guidelines at the start of my research, or during the POE Lodge design phase indicate the potential for significant gaps in the principles I used.

Looking at my research question, whilst the existing design guidelines may be somewhat effective in terms of knowledge assimilation, they are incomplete and cannot therefore be regarded as very effective in terms of guiding the construction of an environment, or the learner perception of the environment created.

7.2 Minocha and Reeves work

The conclusion that Nelson and Erlandson guidelines, when applied to a 3-D environment are incomplete and are therefore not very effective from a learner’s perspective is supported by the work of Minocha and Reeves (2009). In their paper they find that “…designs of learning spaces in SL may influence student learning…” they also however find that “…design principles from the fields of urban planning, HCI, Web usability, geography and psychology…” also need to be taken into account. My research suggests that multimedia design principles should be added to this list, but that they are only one of a range of design principles that are needed within SL.
This extended range of design principles, suggested by Minocha and Reeves, may also help in addressing the issue of how to design a space, so that sequences of information delivery are clear. The handedness issue associated with the order of information delivery has not been sufficiently addressed by my research. Whilst my research has uncovered some evidence of right-handed users exhibiting a preference for moving right-handed around a 3-D environment, a similar preference is not evident in the left-handed users. As this issue was not realised until late in the development it did not attract any specific tooling in order to address the issue, but relied on using data already being recorded. With hindsight this data recording was not sufficiently detailed to decide whether there is an issue with the order of information delivery, or how it may be improved. However using the ideas of Minocha and Reeves it is clear that handedness in the real world has attracted prior research e.g. (Fischer, Nakakoji, & Ostwald, 1995), and (Schmauder, Eckert, & Schindhelm, 1993), and is therefore likely to be a valid issue in the design of virtual 3D spaces.

Minocha and Reeves also highlighted the need for “wayfinding” information. This again was something that following review I added to the environment; however there is some evidence that my signposting was insufficient; one potential learner teleported to the environment entrance and then attempted to enter POE Lodge via the exit door and after three attempts at entering via this door apparently gave up. In addition comments from the survey indicated a certain amount of navigational confusion e.g. “With the clear walls, it was like being in a slightly confusing maze”, and “…it may be an idea to clearly mark doors “next room” as I had to look about a bit…”.
As an example of how wayfinding information may have helped, looking at the POE Lodge arrival area shown in Figure 14 it is possible that the student who failed to gain entry, arrived facing along the longer path which leads to the main exit. This would have meant that they would not have seen the main entrance or the notecard giver (located to the right of the figure). To mitigate this problem it would probably have been worth adding signposting to the entrance, rather than assuming the students would look around and locate it on their own.

Figure 14 The POE Lodge arrival area

On a more positive note Minocha and Reeves suggest the use of real world metaphors, and in their work use the example of a mailbox. Despite not being included in Nelson and Erlandson’s design principles, this use of metaphors is
something that I consciously adopted during my design, with the narrative buttons having an iconic representation of a speaker, and the emergency exit signs using the familiar running white stick figure on a green background. Whilst the emergency exit signs and narratives were not regarded as useful, the iconography used clearly identified their function. Reflecting on my use of metaphor I can find no compelling reason, other than influence from my experiences both in real life, where for example MS Windows uses a magnifying glass as an iconic representation for searching, and Second Life, where I would undoubtedly have been influenced by iconic representations such as Minocha and Reeves mailbox example.

When I built POE Lodge the Minocha and Reeves guidelines were not available, and as such I did not build POE Lodge to validate the findings of Minocha and Reeves. However comments from the survey respondents and my own experience of the design of POE Lodge both lend support to the idea, and lead me to conclude, that the design of a learning space should be based on a wide range of different design principles.

7.3 Validity

The main criticisms of my research and the conclusions I am drawing must be the sample size and population, on which I have based my findings. The size of my sample raises significant issues around the validity of my results and conclusions because with such a small sample I am unable to apply any statistical relevance to the findings. Whilst the tracking of the individuals inside POE Lodge has generated a significant volume of data, the volume itself is insufficient to be regarded as representative of a larger sample. This is most vividly illustrated in the proportion
of left handed survey respondents. In my small sample approximately 33% is left
handed, however in the general population this figure is 10% (Hardyck & Petrinovich,
1977).

I also however have the issue over the demographics of the population that took part
to take into account. With invitations sent out to student forums and academic mail
lists, those who took part were certainly not representative of the general population.
For the particular subject matter being taught the lack of generality may not be a
problem, however to extend the applicability of my research would require a sample
set more representative of the general population. It is however worth noting that the
subject matter would also then need to be adjusted for a more popular appeal. Finally
I have been unable to find any evidence that the guidelines developed by Nelson and
Erlandson have been applied or tested with adult populations, as opposed to the K12
populations they were originally developed for, and this too raises a question over the
validity of my findings.

7.4 Development issues

Whilst working on the POE Lodge development I came upon a number of
development issues, as opposed to design issues or considerations. Whilst these are
not directly related to my aim, objectives or research question I have included a brief
discussion of some of the more important issues as a guide for future researchers. It
should be appreciated that this is not a comprehensive treatment list, and in some
circumstances the problems I encountered may be “fixed” over time, or reflect a long
term or ongoing issue that other researchers should consider when performing future research.

Second Life Failures

Although I have headed this as Second Life failures, there is a whole range of issues over not just the failure of the Second Life servers, but also network connectivity, the bandwidth available, Second Life backups and many more generic failures. Despite Second Life being reasonably robust there are a host of problems that can occur that effectively cause a failure of your Second Life session. At times this can be a mere inconvenience, and you will be able to log back in with little or no delay. At other times however there is the potential for significant delays in being able to sign back in. From my personal experience the worst delay I had meant that I lost half a day in Second Life. I was by that time used to the occasional problem and did not have a deadline looming, but I would advise all researchers to ensure they are not relying on Second Life being available when running up against a deadline.

Build Management and version control

Second Life currently has no version control for objects and their associated scripts. If you make changes to an object or the scripts inside it then you have to take a copy into your inventory, but there is no simple way of identifying one version of an object from another. I would advise all researchers to adopt a naming convention that allows an object when stored in the inventory to be clearly identified. Personally I did not start doing this early enough in the development cycle, and with the build being an iterative process I ended up on a number of occasions rezzing objects into a sandpit whilst trying to find the one I had last developed. A complex naming convention is not required - I simply added a version number to the name of the object and then just
before taking it back into my inventory updated the version number. Another option which makes the process more automatic is to use a simple script in the root primitive of an object to change the object’s name each time it is rezzed, an example of the kind of script required is given in Appendix D – Version control code fragment.

**Graphics card capability**

Whilst my computer is not very old Second Life supports some of the most recent graphics cards available. As far as my development was concerned this was not a problem until the build was reviewed by my supervisor, who noticed that some of my building elements had different textures to other parts of the building. I was unable to see this effect until my supervisor took a Second Life snapshot and emailed it to me. The problem was that the graphics card my supervisor was using had superior texture mapping to my own card. There is really no simple solution to this problem other than going through each and every visible primitive and setting the colour, texture and other attributes before the build is finally rezzed. You should however be aware that what you see may not be the same as another Second Life user depending on the capabilities of their graphics card and that there is no substitute for getting people with higher and lower capability cards to review your build.

**Streaming video and audio sequences**

An integral part of my design meant that I needed to use narrative sequences to address the Nelson and Erlandson redundancy principle. However while working through the initial development processes I found that in order to stream either audio or video into a parcel of land in Second Life you have to be the landowner or administrator for that parcel of land. When I came across this limitation I had a choice to make between purchasing some land to host my simulation, or continuing with my
development on the Open Universities’ Deep Think island. With the first option I
would be able to stream audio (and if required video) sequences directly to the parcel
of land, whereas with the second option I would be restricted to creating sound bites
of 10 seconds or less, and then playing these in sequence to achieve a result similar to
that of streaming. As I did not expect to use video streaming (which would have
necessitated ownership or administration rights) I selected the latter option; with
hindsight I would however purchase a parcel of land. Although the sound bite method
worked, the sound levels were almost impossible to control with one survey
respondent even commenting that the “audio was of varying qualities”, with the
volume, especially when a learner clicked on a speaker icon from some distance
away, being the greatest problem. With audio streaming the audio is sent to a parcel
of land and is audible throughout the parcel of land. Using this approach would have
meant that the audio was of a consistent quality and consistently audible. I would
recommend that other researchers who expect to supply audio feeds buy a parcel of
land in which to house any research simulation.

7.5 Future research

Looking back at my research there are essentially three areas where I would expect
further research to add to our knowledge of the design of 3D learning spaces in
Second Life.

Firstly, although the Multimedia design principles I used were to some extent
successful in teaching the basics of Problem Oriented Engineering, it is clear from the
learners’ comments and from the work of Minocha and Reeves that significantly more
is required of a learning space in Second Life. Although Second Life is a virtual
world, user’s expectations of both its ease of use and aesthetic qualities are as high (if not higher) than those of the real world. I would expect research to extend Minocha and Reeves guidelines by incorporating the Nelson and Erlandson principles I used to be a rich area of research.

Secondly although the work of Minocha and Reeves does look at the wider aspects of design there was some evidence from my research that there are different classes of users, who view Second Life and its constructs in very different ways. From my work there appears to be a clear difference between the views of experienced and/or frequent Second Life users, to those of newer or less frequent users. I would suggest however that research looking at classification of users, including other categories e.g. their gaming experience, and their reactions to Second Life simulations would also be a valuable area of research.

The last area where I think there is a valuable research opportunity is in the question of handedness in 3D virtual environments. My own work was insufficient to decide whether there is a handedness element that needs to be included in the design of 3D learning spaces, but there was enough evidence to suggest that this may be the case. Indeed, referring again to the work of Minocha and Reeves, it would be a surprise if the varied fields of design that they have identified had not already looked at handedness in the real world, which, assuming the existence of such work, prompts the question of whether this would be applicable in Second Life or other 3D environments.
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http://www.lslwiki.net/lslwiki/wakka.php?wakka=TextSearch&phrase=Link

http://www.lslwiki.net/lslwiki/wakka.php?wakka=TextSearch&phrase=llEmail


Rapanotti, L., & Hall, J. G. (2008). *Problem Oriented Engineering in action: experience from the frontline of postgraduate education.* The Open University (Received by personal communication with author).


http://www3.open.ac.uk/study/postgraduate/course/m883.htm

http://www.tombraidergirl.com/tr1/croftmanor.php

http://speedracerthevideogame.warnerbros.com/
Appendix A – Extended Abstract
Development of an Immersive Environment to Teach Problem Oriented Engineering
Andrew Moore

Extended Abstract of Open University MSc Dissertation Submitted 1st March 2010

Introduction

Over the past few years online environments accessible via the internet have allowed computer users from all over the world to interact in various flavours of online virtual worlds. These environments range from simple messaging services through social networking sites to sophisticated 3D online games. Increasingly, commercial and educational institutions are using these readily available online worlds to train, their staff and students using immersive “games” in these 3D worlds to provide an environment similar to the real world. Second Life is one of these 3D online virtual worlds, where users have the ability to interact in a social space, but where they also have the capability to design and build their environment. As one of the leading providers in the 3D online field, Second Life provides a good platform from which to study the design, construction and use of virtual educational environments.

Problem Oriented Engineering is an emerging framework, being developed by The Open University, which formalises engineering design by using a four stage process, to explore and validate a problem and then its solution. As an emerging framework, with a limited knowledge base beyond The Open University, Problem Oriented Engineering, as a very powerful engineering design tool, provides an ideal vehicle to study how students interact with an environment when they have limited knowledge of the subject matter.

In my thesis, I investigate the applicability, of a set of 2D multimedia design principles, applied to the 3D environment of Second Life using Problem Oriented Engineering as the means of assessing knowledge assimilation via the built environment.

Method

I designed a building (POE Lodge) which contained teaching elements, covering the essential process and documentation aspects of Problem Oriented Engineering (POE). With a lack of guidelines or principles, to guide the construction of a 3D environment in Second Life, the building and its contents were designed using principles developed for multimedia applications. The building was designed and built to the same shape as the POE process diagram, and a case study, augmented with narratives and structural elements from both the POE process and
documentation frameworks, along with internet links were included in the design.

As users of the simulation moved around and interacted with objects in the building their interactions were recorded and as a result their activity was tracked through the POE Lodge. As students exited the building they were invited to complete a questionnaire to assess their knowledge assimilation, their perception of the environment, and their previous experience in Second Life.

Abstract 2 POE Lodge courtyard showing POE process & documentation elements

Results
The POE Lodge environment was visited a total of twenty times by ten distinct individuals. Following the visits six questionnaires were started, however some questionnaires were not fully completed. Of these only three of the respondents had no prior knowledge of POE. Two of these respondents scored 60% on their knowledge assimilation (although one did not complete all the questions) which could be regarded as a reasonable level of assimilation. The third respondent did not score so highly and remains an anomaly, as this user stayed in POE Lodge for longer than respondent number two, and had more interactions in total and with more distinct objects than both the other respondents.

% of questions answered correctly with no prior knowledge of POE

Abstract 3 Knowledge assimilation in no prior POE experience users

Users of the environment were also asked about how they viewed the ease of use of the various components within POE Lodge. The responses to this question varied depending on how much experience a user had of Second Life. In Abstract 4 below, a
lower score indicates a POE Lodge entity that was regarded as easier to use. From this it is clear that frequent users found the narratives and Second Life notecards easiest to use whilst regular and occasional users for the most part found the items of near equal value.

Abstract 4 Ease of use of POE Lodge facilities

This difference between frequent users perceptions and those less familiar with Second Life is probably associated with a gradual change to use those parts of Second Life that are closer to real life. This is reflected in the learners’ perceptions of the usefulness of the various parts of POE Lodge. Despite the fact that experienced users

Abstract 5 Usefulness of POE Lodge facilities
found the wall slides the least easy to use, from Abstract 5 above (again a high score indicates something regarded as less useful), it is possible to see that experienced users ranked them as equally useful alongside the narratives and notecards. Less experienced users tended to rank items as having different usefulness focusing on the slides and notecards; items that are more familiar in a real world educational setting.

**Analysis**
In the absence of any 3D environment design guidelines, adopting multimedia design principles to teach Problem Oriented Engineering appears based on the knowledge assimilation to have been successful

In general however whilst less experienced users found the facilities of the environment easy to use, those with more experience of Second Life ranked the facilities as less easy to use.

The more experienced Second Life users also ranked the facilities of equal usefulness while those with less experience tended to have a preference for what can be regarded as the more traditional learning aids, namely the wall slides and notecards.

This differentiation between experienced and less experienced Second Life users is expressed directly by one survey respondent who wrote

“*I think cut down the information to read in the exhibit - the bits that it's good at getting across are the four stages and the avatar can walk those steps, but SL’s not good for encouraging lots of reading.*”

**Discussion**
Although the use of multimedia design principles has in this study been at least a partial success, there are a number of aspects of design in virtual worlds that need to be investigated further.

There appears to be a small but noticeable difference in the way in which experienced users, and those with less experience, view the facilities available in POE Lodge and I would expect this to be the case with other environments. This difference can be explained at least in part, by the fact that experienced users are more familiar with how the environment works and how to manipulate and use the facilities available.

Rather like computer gamers learning a new game, those with less experience seem to favour real world analogues. The assumption must be that this is because they are familiar with how these work. As they gain experience they tend to use the more novel facilities that may not exist in the real world.

Multimedia design principles do go some way towards informing the design of virtual world educational simulations. Further work is however needed to ensure that those with less experience in a 3D environment are not disadvantaged, whilst taking full advantage of novel teaching approaches possible in worlds where “game” world experiences such as flying and teleporting are possible.
Appendix B – POE Lodge exit questionnaire

1. POE notation and process

Some questions about your understanding of POE after using the simulation

1. How does POE regard a problem?
   - As a process
   - As a triad of requirements, context information and solution
   - As a form of documentation
   - All of the above

2. The stages of the POE process are…
   - Problem exploration, Fish diagram construction & iteration
   - Problem exploration, problem validation, solution exploration and solution validation
   - Problem approval, exploration, validation, documentation
   - Problem approval, conclusion problem, premise problem, validation

3. In the standard POE notation, what is represented by a plain rectangle?
   - A context domain
   - A problem
   - A requirement
   - A solution

4. Validation problems are documented on which side of the fish diagram?
   - Right
   - Left
   - Either
   - Both

5. A fish diagram...
   - ...documents problem transformations
   - ...can be used to replay design decisions
   - ...relates validations and transformations
6. In the standard POE notation, what is represented by an oval?
   - A context domain
   - A problem
   - A requirement
   - A solution

7. In the decoy controller problem the pilot is an example of what?
   - A context domain
   - A problem
   - A requirement
   - A solution

8. Problem and solution validation both…
   - Allow stakeholder validation of the problem
   - Help minimise risk
   - Are a control system
   - All of the above

9. The POE process…
   - ...should only be applied to a problem once
   - ...should only be applied sequentially, in parallel, or fractally
   - ...can be applied flexibly as required
   - ...all of the above

10. The POE framework can be applied to…
    - ...software problems only
    - ...engineering design problems only
    - ...both software or engineering design problems
    - ...any form of design or engineering problem
2. POE Lodge

Some questions about the POE Lodge simulation and your perceptions of it.

1. How would you rate the ease of use of

<table>
<thead>
<tr>
<th></th>
<th>Very Easy</th>
<th>Easy</th>
<th>Neither easy or difficult</th>
<th>Difficult</th>
<th>Very difficult</th>
<th>Did not use</th>
</tr>
</thead>
<tbody>
<tr>
<td>POE Lodge in general</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The wall slides</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The narratives</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The URL Links</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The notecards</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The emergency exits</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

2. How would you rate the usefulness of

<table>
<thead>
<tr>
<th></th>
<th>Very useful</th>
<th>Useful</th>
<th>Neutral</th>
<th>Un-useful</th>
<th>Very Un-useful</th>
<th>Did not use</th>
</tr>
</thead>
<tbody>
<tr>
<td>The wall slides</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The narratives</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
3. How did you find the level of detail provided

<table>
<thead>
<tr>
<th>Level of detail</th>
<th>Too detailed</th>
<th>Slightly too detailed</th>
<th>About the right amount</th>
<th>Slightly too little detail</th>
<th>Not detailed enough</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☒</td>
<td>☒</td>
<td>☐</td>
</tr>
</tbody>
</table>

4. How likely as a result of the simulation are you to

<table>
<thead>
<tr>
<th></th>
<th>Highly unlikely</th>
<th>Unlikely</th>
<th>Undecided</th>
<th>Likely</th>
<th>Highly likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Look further into POE</td>
<td>☐</td>
<td>☒</td>
<td>☐</td>
<td>☒</td>
<td>☒</td>
</tr>
<tr>
<td>Use SL for a learning environment</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
</tr>
</tbody>
</table>

5. How would you rate your perceived level of control whilst in the POE Lodge simulation

<table>
<thead>
<tr>
<th></th>
<th>Totally in control</th>
<th>In control of my</th>
<th>Undecided</th>
<th>Only limited control of my</th>
<th>No control of my</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>☒</td>
<td>☒</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. How did you exit from the simulation
   • Used the emergency exit
   • Used the exit from the solution validation room
   • Teleported out
   • Closed the SL viewer
   • Other (please specify)

7. How many notecards were you given

8. Did you keep or discard the note cards that you were given?
   • Kept all
   • Kept some
   • Discarded all

9. Were you given an animated process diagram, and if so did you keep it?
   • Not given animated process diagram
   • Given animated diagram and kept
   • Given animated diagram and discarded

10. Do you have any additional comments about the POE Lodge simulation

<table>
<thead>
<tr>
<th>Level of control</th>
<th>of my actions</th>
<th>actions</th>
<th>actions</th>
<th>actions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
3. You and Second Life

A last few questions about you and how you use Second Life

1. Are you...
   - ... right handed
   - ... left handed
   - ... ambidextrous

2. How long have you been a Second Life user
   - <6 months
   - 6-12 months
   - 1-3 years
   - 3-5 years
   - >5 years

3. How frequently do you access SL?
   - Frequently (every day)
   - Regularly (once or more per week)
   - Occasionally (once or more per month)
   - Rarely (a few times per year)
   - Other (please specify)

4. Approximately how long on average do you spend in SL in a session?
   - Less than an hour
   - Between 1 and 2 hours
   - Between 2 and 3 hours
   - More than 3 hours (please specify)

5. How would you categorise your main use of SL?
   - Social networking
   - Education
   - General entertainment
   - Game playing
   - Other (please specify)

6. How would you categorise you knowledge of POE

<table>
<thead>
<tr>
<th>No knowledge of POE</th>
<th>A little knowledge of POE</th>
<th>A basic understanding of POE</th>
<th>Full working knowledge of POE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before using the simulation</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>After using the simulation</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

7. Do you have any comments you would like to add?
Appendix C – Tracking code fragment

The following code fragment was included in all the linked primitives. Additional function was also included within each script for each primitive dependant on the function of that particular primitive.

```c
integer CPrim; // The link number of the controlling primitive
default
{
    // Process any time this primitive is touched
touch_start(integer total_number)
    {
        // if the object is touched inform the controlling primitive
        llMessageLinked(CPrim, 0, "Touched", llDetectedKey(0));
    }
    // Process messages from the other linked primitives
link_message(integer Sender, integer num, string SndStr, key Avatar)
    {
        // if the linked primitive sending the message is the controller
        if(SndStr == "Controller")
        {
            // Store the controlling prim number again (in case it’s changed)
            CPrim = num;
            // Send a message to the controller to make sure we are registered
            llMessageLinked(CPrim, 0, "Register" + llGetObjectName(), NULL_KEY);
        }
    }
}
```

Where a linked primitive could not be used the following code fragment was embedded in each of the primitives.
integer Initially_Registered = FALSE;  // Primitive registration state
text integer door_number = 701; // Primitive assigned registration number
default
{
    state_entry()
    {
        // Setup a listener channel for the controlling primitive
        llListen(20, "", NULL_KEY, "");
        // If this primitive is not yet registered then start the registration process
        if(!Initially_Registered)
        {
            // Shout our registration message to the controlling primitive
            llShout(21, "Register" + (string)door_number + "," + llGetObjectName());
            // Set the state to registered
            Initially_Registered = TRUE;
        }
    }
    // Process any time this primitive is touched
touch_start(integer total_number)
    {
        // Shout the fact that this primitive has been touched to the controlling primitive
        llShout(21, "Touched" + (string)llDetectedKey(0) + "," + (string)door_number);
    }
    // Listen for messages from the controlling primitive
    listen(integer chan, string sender_name, key sender_id, string msg)
    {
        if(chan == 20 && msg == "Controller")
            llShout(21, "Register" + (string)door_number + "," + llGetObjectName());
    }
}
Appendix D – Version control code fragment

The fragment of code below can be inserted into the root primitive of any object and will ensure that when the object is rezzed the version number will be updated. If the Object is then taken back into the inventory the new version number will be readily visible.

The only caveats are that the name must be of the form NAME followed by a space followed by the word Version a further space and then the version number, and the entire name must currently be less than 63 characters long.

```plaintext
on_rez(integer start_parm)
{
    // Get the current object name
    string name = llGetObjectName();
    // Find the location of the current version number
    integer Version = (integer)llGetSubString(name, (llSubStringIndex(name, "Version ") + 8), -1);
    // Increment the version number
    Version++;
    // Set the new name
    llSetObjectName(llGetSubString(name, 0, llSubStringIndex(name, "Version") - 1) + "Version " + (string)Version);
}
```
Appendix E – POE Lodge Welcome notecard

Welcome to POE Lodge.

POE Lodge is a small simulation that is intended to teach the basic principles behind Problem Oriented Engineering, and at the same time investigate the design of a Second Life learning environment. It does assume some basic understanding of S.L. navigation and terminology, so if you are a little unsure of anything you may like to visit the Deep Think orientation area at Deep Think orientation area.

The simulation makes use of audio sequences, so please ensure you have your in-world sound switched on to gain the most benefit.

If you are unsure how to enable audio streaming, the section at the bottom of this notecard gives brief details of how to do this.

The audio clip icons change colour when they are playing, if someone else is listening to a clip you wish to hear you can rerun it when it returns to its base colour.

If you find that a clip is difficult to hear please ensure your sound is turned up. If you are still having difficulty hearing the clip you may find that getting closer to the icon will help.

Also please be aware that although the audio clips are preloaded network or server lag can mean that they occasionally take a few seconds to start playing.

Please feel free to fully explore the simulation. and return after your visit if you wish.

When you exit you will be asked to complete a short questionnaire which should take less than 10 minutes to complete about your experiences in POE Lodge.

Touch the door in front of you to enter POE Lodge. Thank you for your time and I hope you enjoy your visit.

Enabling Audio/Media streaming in S.L. (reproduced from Deep Think orientation area)

----------

Hold CTRL and tap P once to open the Preferences window. Choose the ‘Audio & Video’ tab and ensure all check boxes are checked. These include:

Play streaming music when available
Play streaming media when available
Automatically play media
Mute audio when window minimized

Click ‘OK’ when you’re happy with your settings and close the Preferences window. Now media streaming is enabled.

----------
Appendix F – Survey additional comments

The comments here are extracted from those returned on the questionnaire. They are formatted alternately in normal and italic text to differentiate one respondent from another.

Couldn’t get the sound to play (actually first time through didn’t notice the speaker icons). Skipped some of the questions in survey part 1 (was just guessing answers) although i got the basic four steps.

1. At the welcome point the notecard should have been entitled read-me first before entering
2. The signs were confusing as to where to begin reading, i.e. in which order, as the numbering didn’t seem consistent
3. The corridors were too narrow and the signs blocked viewpoints when moving between areas
4. The audio was generally ok, but delays meant i moved away from a sign and then extra audio arrived a bit later. Also the audio was of varying qualities
5. I did not realise you could click on the emergency exit signs
6. At the end i.e. near the survey door there are two possible exits, and it wasn’t clear which one to take. I had to go around again to see what the other one did.
7. With the clear walls, it was like being in a slightly confusing maze
8.
Doors should open both directions. It's really difficult to get in or out of the rooms.

I didn't fill in the early Qs as I didn't realise I'd have to learn about the POE and its application. This should have been clearer - also I'm unsure why I would need tested? Also it may be an idea to clearly mark doors "next room" as I had to look about a bit and could have visited previous rooms. Great effort though and a great idea - very well done!!! Brendan (tutor in computing at the OU)

Did not like the doors, some opened, others didn't; did not like the transparency of the walls as it made things confused; would prefer not have had walls at all; also the order I expected to go was not the order that I was offered

There's a nice feeling to be inside a process. I think I expected to be validated by a second person, as this might emphasis the interactive nature of validation, but I imagine it's a difficult thing to do.

My name is jjooj

Nice, very nice!
I'm not an expert in POE, so can't really comment on that side of things. The simulation was on the right lines, but with the usability issues mentioned previously could have affected my ability to take in information.

all the best, hope it helps!

One - don't tell people it's a 10 minute survey - it's a lot less than that and it might put people off doing it. 3 minutes seems closer. I think cut down the information to read in the exhibit - the bits that it's good at getting across are the four stages and the avatar can walk those steps, but SL's not good for encouraging lots of reading. I didn't realise I was actually IN the diagram until the end, maybe you could have people tp to a point above the lodge and then go down to it so they have a view of it from above. I like the giveaways of the objects.

I'm glad to see a student trying this technology.

I would have placed the wall charts at ground level as I had to fly to read them. Also no matter what I did the sound was very quiet - might be an SL thing? Maybe you could develop your narrative to give a bot more info?

Great diagrams!

Brendan Murphy