HOW CAN MULTIPLE USER VIRTUAL ENVIRONMENTS BE DESIGNED
FOR VOCATIONAL EDUCATION AND TRAINING?

A thesis is submitted in partial fulfilment of the requirements
for the degree of
Doctor of Philosophy
at the University of Canterbury

by Todd Cochrane
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Dedication

For my daughters Leise and Alexandra, their mothers Peggy and Anthea, my father Thomas Thurston Cochrane and in loving memory of my mother Kathleen Ann Coronno who said “It’s never too late”.
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ABSTRACT

Polytechnics in New Zealand and abroad are mainly concerned with vocational education and training (VET); it is their mission to have graduates work ready. However, this is challenging for economic and practical reasons. Employers may not be able to accept liability particularly when the workplace is dangerous. Virtual environments that simulate these contexts have been successfully designed for gaming, but can such environments be systematically designed for VET?

An authentic, vocational situation can be designed and coded into a multi-user virtual environment (MUVE) to provide a simulated, immersive, vocational learning experience for a number of students. Using an avatar, each student can share their social presence in the MUVE, including voice communication and spatial movement. Within a MUVE, a student is able to practise without physical risk. In this way, MUVE-based learning could provide an opportunity to develop more work-ready graduates. However, there is little research into the design of MUVEs for VET. In addition, such virtual learning environments must continue to be updated and redesigned to fit the continual development of the vocation and the technology platforms. Therefore, there is a need for interdisciplinary educational and informatics research into the processes of designing MUVEs to fit education and training.

While a number of MUVEs have been created and their implementation has been researched and documented, the processes of their design have not been studied. For example, for children in middle school in the United States, the River City MUVE and its following generation EcoMUVE (Dede, Grotzer, Kamarainen, & Metcalf, 2017a) adopted design based research (DBR) to produce, at large scale, a MUVE that simulated an authentic situation. These and other studies of MUVEs have only gathered evidence from implementing the interventions, but have not presented any findings in relation to the design and coding processes. In addition, while specific theoretical perspectives were included for some MUVEs, the way in which educational theory informed the design and development of the MUVEs have not been studied or described.
The research presented in this thesis addresses the need to understand how educational theory can become intrinsic to the design and development of MUVEs and how it informs the design and development of the software for VET. Two case studies of MUVE design processes are presented in this thesis. Both vocational contexts involve some danger and risk: (1) temporary traffic management (TTM) and (2) communication on a ship’s bridge.

The three phase study was informed by two theoretical frameworks; the legitimate peripheral participation theory (LPP) (Lave & Wenger, 1991) and the technological and pedagogical content knowledge framework (TPACK) (Mishra & Koehler, 2006). The first case study is of a hybrid DBR Agile methodology that was enacted to produce a MUVE for TTM. The methodology was further refined in the development of a MUVE for maritime ship’s bridge communication training in the second case study. Techniques from research in information systems (IS) software design and Agile software engineering methods were systematically integrated with those in educational research, including the participant researcher who had the additional roles of software developer, designer of virtual environments, and technician. In addition to students, the participants in the case studies included tertiary educators and professionals, such as, a civil engineer and a Master of a maritime vessel.

Interviews and observations were recorded throughout the enactment of the hybrid DBR Agile software development process. The analysis included a novel swim approach that framed and reflected on the roles of participants in each MUVE project overall, and in the context of a particular classroom intervention. The swim framed the direct and indirect analyses of observations of the fit of the theoretical frameworks as they were applied. The swim narratives were complemented with recordings of the Agile tasks when they were added to backlogs for development.

In summary, this doctoral study discovered a hybrid DBR for Agile software development (hDAS) methodology that inculcates educational theory with DBR and
participant research in requirements-gathering for Agile software development and feedback to the software development process. It also presents two case studies of this process. This methodology is relevant to the production and updating of MUVEs to improve the design and implementation for the purposes of VET. Further research is also recommended.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>3D</td>
<td>Three Dimensional</td>
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<tr>
<td>ADDIE</td>
<td>Analysis Design Development Implement and Evaluate</td>
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<td>AMF</td>
<td>Agile Method Fragment</td>
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<td>BRM</td>
<td>Bridge Resource Management</td>
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<tr>
<td>CA</td>
<td>Computer Architecture</td>
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<tr>
<td>COPTTM</td>
<td>Code of Practice for Temporary Traffic Management</td>
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<td>DBR</td>
<td>Design Based Research</td>
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<td>HCI</td>
<td>Human Computer Interaction</td>
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<tr>
<td>hDAS</td>
<td>hybrid DBR for Agile Software development</td>
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<tr>
<td>IMO</td>
<td>International Maritime Organisation</td>
</tr>
<tr>
<td>IS</td>
<td>Information System</td>
</tr>
<tr>
<td>ISD</td>
<td>Instructional Design</td>
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<tr>
<td>IT</td>
<td>Information Technology</td>
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<td>LPP</td>
<td>Legitimate Peripheral Participation</td>
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<tr>
<td>MMOG</td>
<td>Massively Multiplayers Online Game</td>
</tr>
<tr>
<td>MUVE</td>
<td>Multi-user virtual environment</td>
</tr>
<tr>
<td>SDM</td>
<td>Software Development Method</td>
</tr>
<tr>
<td>SLENZ</td>
<td>Second Life Education in New Zealand</td>
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<td>SMCP</td>
<td>Standard Maritime Communication Phrases</td>
</tr>
<tr>
<td>STMS</td>
<td>Site Traffic Management Supervisor</td>
</tr>
<tr>
<td>TBI</td>
<td>Technology Based Instruction</td>
</tr>
<tr>
<td>TC1</td>
<td>Traffic Controller Level 1</td>
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<tr>
<td>TPACK</td>
<td>Technological and Pedagogical Content Knowledge</td>
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<tr>
<td>TQ</td>
<td>Theory Question</td>
</tr>
<tr>
<td>TTM</td>
<td>Temporary Traffic Management</td>
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<tr>
<td>VET</td>
<td>Vocational Education and Training</td>
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<tr>
<td>VLE</td>
<td>Virtual Learning Environment</td>
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<td>VRLE</td>
<td>Virtual Reality Learning Environment</td>
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<td>VW</td>
<td>Virtual world</td>
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GLOSSARY

Agile software development is software development that conforms to the Manifesto for Agile Development and the principles behind the Agile Manifesto.

Analysis Design Development Implement and Evaluate is a model ISD process.

Avatar is a personalisable representation of the self, used for interaction within a virtual world.

Backlog list is a Product backlog or Sprint backlog list in the Scrum software development method.

Master is the Master of a maritime vessel, i.e. the Captain in charge of the vessel.

MUVE platform is a software system that implements MUVEs.

Participant swim is period of active contribution to a research or development project by a participant.

Product backlog is a list of requirements made up of user stories used in the Scrum software development method.

Scrum is an Agile software development method.

Second Life® is an open sandbox MUVE platform, which is a registered trademark of Linden Lab.

Serious games are games used for training. These are usually implemented on a digital system.

Sprint is a short, time-boxed period when a scrum team works to complete a set amount of work stories used in the Scrum software development method.

Sprint backlog is a list of features to be in a release of software developed in a sprint.

Swim diagram is a diagram in the swim notation that depicts in overview, participation, interaction and development in an hDAS project.

Synthetic environment is a 3D computer simulation with a high level of realism.

User Story is a very high-level definition of a requirement in development of software.

Virtual world is an online environment in which users collaborate and communicate for the purpose of game play or socializing.
PUBLICATIONS ARISING FROM THIS THESIS

Chapter in Book

Paper in Journal

Papers in conference proceedings


Poster presentations

CHAPTER 1
INTRODUCTION

1.1 Introduction

Multi-user virtual environments (MUVEs) or virtual worlds (VWs) and training (VET) have been shown to be valuable for use in education, including the preparation for challenging and hazardous vocational contexts (Gregory, Susan, Gregory, B., Reiners, T., Fardinpour, A., Hillier, M., Lee, M., & others, 2013; Hew & Cheung, 2010). In their review of 205 empirical studies on the use of the Second Life® MUVE education, Mantziou, Papachristos, and Mikropoulos (2018) confirm is the most popular and widely used of the MUVE platforms. MUVEs can recreate hazardous or emergency scenarios and allow participants to practise problem solving and communication skills prior to these being enacted in real situations. An example is developing the particular knowledge, skills and teamwork required among professionals working on the bridge of a ship to ensure the safe navigation of large vessels that can dwarf the ports, in which they dock. Rigorous protocols for language and other practices have evolved for such contexts in order to increase efficiency and safety. It can be very challenging for learners to develop the necessary competencies to join such professions through training in contexts that may be authentic for colleges but not for their chosen profession.

The objective of this study is to develop an effective methodology for the design, development and testing of MUVEs in vocational education, which has received little research attention. The methodology is illustrated through the three-phased design of two MUVEs. One MUVE was designed to simulate the hazardous situation of temporary traffic management (TTM); and the other, the bridge of a maritime ship so that the students, operating though their avatars, can better develop legitimate behaviours and competence in skills that are required of professionals in the field. The research used a multidisciplinary methodology that spans the fields of education and software engineering, and applies this to two vocational contexts (civil engineering and surveying, and maritime studies).
This chapter provides a brief literature review before stating the problem. The research context is highly relevant to the study, in which the researcher takes multiple roles. The chapter ends with an overview of the chapters in the thesis.

1.2 Background literature

VW technology is developing in general use and is predicted to become pervasive. According to Savin-Baden, Falconer, Wimpenny and Callaghan (2017), there are more than 2.6 billion registered users of VWs (mostly children between the ages of 10 and 15), and the number of registered adults in VWs doubled between 2011 and 2015. Hence, they argue that over time more students are becoming familiar with this technology. Kisiel and Smith (2018) predicts that “… virtual worlds designed as augmentations to our physical worlds, will be at the heart of the next extension of a human” (p. xxv) and will be as pervasive as our digital devices are at present.

MUVEs have been shown to be valuable for use in education. For example, de Freitas (2008) identified 80 MUVE applications available for education at that time. The growth of this approach in New Zealand is described by Hearns, Diener and Honey’s (2011) review of teaching and learning through VWs within seven New Zealand tertiary institutions and Gregory et al.’s (2013) expanded review of Australia and New Zealand higher education. The latter researchers concluded that the emergent phase of such an innovation, which is often characterised by hype, was maturing to recognise the many challenges that come with such innovations in education and training.

MUVEs have been shown to be successful in VET and these include a number of simulations. Hudson and Degast-Kennedy (2009) describe a Canadian border simulation in the Second Life® MUVE that was used by students preparing to apply to become border security officers. Simulations developed by Knudsen (2010) on the Second Life® MUVE are used for vocational training in Denmark. The Second Life Education New Zealand (SLENZ) project developed and trialed MUVE-based simulations for midwifery training on the normal birthing process and in a Foundations Studies course, preparing students for job interviews (Winter, 2010). Patel, Aggarwal, Cohen, Taylor, and Darzi (2013) studied a VW-based environment for training surgeons’ assessment of patients in emergency situations using an online
virtual patient simulation. They found that the surgeons who attended the simulated training performed better than those who did not attend. Cooke and Stone (2013) report on the design and initial evaluation of a ship’s bridge training simulation to train the avoidance of ship collisions. It was developed to bridge the gap between the classroom and live training on a vessel, and gained broad acceptance by Royal Navy Junior Warfare Officers. Coco, Cavin and Machmtes (2010) describe training skilled and unskilled workers in an immersive virtual learning environment on road traffic management safety in traffic flagging procedures. They found that adult learners perceived a benefit from this training and indicated heightened concern for safety when working on roads.

There have been a few studies of the design processes of VWs in education. For example, Englund (2017) presents research on how the implementation of VWs in healthcare are influenced by teachers’ approaches to teaching and their conceptions of teaching and learning with educational technology. Jacobson (2017) introduced authenticity in educational immersive media as a key feature of good design, in which he developed a theory of authenticity. Dede, Grotzer, Kamarainen, and Metcalf (2017 b) report on research of a design strategy for blending virtual reality with an immersive curriculum developed in studies of MUVEs in education.

Dede and Richards (2017) present important dimensions of a research agenda for immersive learning:

- A research agenda for immersive learning should focus on applied, collective research; adaptation of learning environments based on what works for whom, in what context; and a balance between design-based studies and evaluations of effectiveness. (p 239)

They concluded that there is a need for further research that understands the implications of immersive technologies to learning and education:

Immersion, particularly VR and MUVEs, by their very nature alter perspective, context, and even the participants’ sense of self, while
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immersion in the form of MR and AR alters our sense of participation in the external environment ... [documenting] the most advanced work completed to date in order to understand the applications of immersive technologies to learning and education ... demonstrates how early stage our current understandings are. We have only scratched the surface of understanding the educational implications of these technologies. (p. 242)

1.3 The problem, research aim and research question

Research on MUVEs used in education rarely present the details of the process of the educational design and software development of a MUVE for a given vocational context. Although a few studies present software architecture designs with testing of the system in educational contexts (e.g. Cooke & Stone, 2013; Dass & Cid, 2018), and describe the effect of educational theory in the design (e.g. Dede et al., 2017 a), none have studied the interplay between educational theory and software engineering of MUVEs in detail. To do so requires a multidisciplinary approach.

The aim of this study was to develop a multidisciplinary methodology for the creation and maintenance of MUVEs in effective vocational education and training (VET). The approach used was to study the development of a methodology for producing carefully designed educational MUVE-based interventions for a particular vocational community of practice (Lave & Wenger, 1991). The vocations selected were civil engineering and surveying, and maritime studies.

The research question was, “How can MUVEs be designed for vocational education and training?”

1.4 The researcher

It is useful to describe my background in order to clarify why I had the expertise and experience to become a participant researcher of a MUVE development. I began the
INTRODUCTION

research with experience in all the roles necessary for creating and testing MUVEs except two. I did not have the required authentic vocational expertise and I was not a graphic artist who could add to the authenticity of a MUVE.

In my role as an Information Technology (IT) lecturer in polytechnics for eleven years, I had previously designed, created and implemented MUVEs to extend my classroom environment for students who could not be physically present. My capacity to create simulations in MUVEs led to my role as a developer on the SLENZ project (Cochrane, Atkins, & Sutcliffe, 2008; Winter, 2010), in which I developed two MUVEs: one for trainee midwives to experience the normal birth process, and another to support Foundation Studies students prepare for job interviews. Through this experience, I identified the following roles in the effective design and development of MUVEs in VET: IT experts, design experts and software developers. I also identified the lack of educational theory and research-informed educational practice being used to inform the process.

The need for students to practise working in geographically distributed teams has been recognised by IT and Software Engineering educators (Nagarajan & Edwards, 2008; Richardson, Milewsk, Mullick, & Keil, 2006; Tabrizi, Collins & Kalamkar, 2009). I had also delivered two degree-level courses using MUVEs: Human Computer Interaction (HCI) and Computer Architecture (CA). In the HCI course, students used the MUVE to develop interactive environments as a software development platform. In the CA course, the MUVE was used to provide students, who could not attend classes, the opportunity to participate in the course, by presenting all lectures and running all tutorials and laboratory sessions in the MUVE (Cochrane, et al., 2008). The MUVE also provided a platform for developing simulations already used in CA tutorials and laboratory sessions. Assessment results of students that used a MUVE in their courses were equivalent to those who attended the same courses in person, without using the MUVEs. That equivalence gave me confidence that the use of MUVEs in the courses was a reasonable risk.

Based on earlier work by other educators, I consider the opportunity of working at a distance is an experience my students should have as they move into the workplace. In
my case, to provide students with the ‘collaboration at a distance experience’, I used a MUVE to allow IT students to collaborate with architecture students and to get feedback from the architecture educator at another institution (Cochrane & Cockeram, 2010). My students acted as consultants for the distance students. The experience through the MUVE went beyond digital voice or text-based communication. It allowed the architecture students to express their 3D designs and it gave the IT students a field trip. The students were able to experience embodied verbal and non-verbal communication in a high fidelity, 3D environment (Dalgarno & Lee, 2010) that presented the client's work and workspace. In this case, the MUVE provided a bridge from the classroom into a real situation where the students' practice had genuine clients with authentic requirements.

The MUVE had the potential to be an environment for IT students to practise meeting with those clients, and possibly in specific cases, it could provide an environment for developing prototypes that could be tried by the clients. This shared presence and experience – where being physically present would have been difficult – enhanced the students' learning experience in two ways: through collaboration between students from different disciplines, and through contact with an educator who would normally not be present. A similar experience was reported by Mennecke et al. (2010) where students and educators were both present in a MUVE. Although the course instructor was not present, a student was able to communicate with an educator, who was present, to acquire suitable guidance and advice. The capacity for MUVEs to provide enhanced shared presence and experience is another personal motivation for undertaking this study.

My knowledge, skills and experience motivated and underpinned the research presented in this thesis. I became a participant researcher with several roles, including the role of educational researcher. As researcher I adopted a critical lens on the processes and practices. The resulting challenges are addressed in the final concluding chapter.

1.5 Overview of the thesis
INTRODUCTION

The thesis consists of six chapters beginning with this introduction. Chapter Two provides the context of the study by examining related literature more deeply, while maintaining the theme that leads to hDAS methodology as it pragmatically emerged during the study. It explores Agile software development methods as an approach to software development that complements DBR and argues that enacting DBR is compatible with a tailored Agile method of software engineering and identifies ways, in which they can be deployed alongside each other.

Chapter Three lays out an hDAS methodology to inform gaps in research on specifying and developing VWs. It brings together software development techniques and DBR and provides a detailed account of this innovative approach to the effective design, development and testing of MUVEs in VET.

Chapter Four presents findings from the first case study in which a MUVE for a TTM training course was created. Findings from enacting phase one of the hDAS process for the first time includes the building blocks used in the design and development of MUVEs in this study. During the development of this first MUVE, a method of inquiry was determined and an Agile software development environment was established. Introduced is a novel Swim analysis model, which then becomes an intrinsic part of the hDAS methodology. Development of the first MUVE provided a valuable source of data on how the DBR process was affected by a framework of educational theory and instruction.

Chapter Five presents the findings from the second case study in which a MUVE-based intervention in the training of standard maritime communication on a ship’s bridge was designed, created and used in a classroom. Phases one and two of the hDAS method are presented. The Agile software development method and the development of instruments, as enacted in the first case, were revisited in this case. Findings from data collected from the Agile software development in this case are summarised and presented as a search for solutions in an artefacts space. The design, development and running of a MUVE as an intervention provided data useful for the formative evaluation of the designed system.
INTRODUCTION

Chapter Six begins by clarifying the originality of this research in which the hDAS methodology is described in detail for the first time. The hDAS methodology and the case studies are then situated within the literature. Challenges and limitations of the research are presented, including the roles of the participant researcher. Future research is recommended. Chapter Six concludes that this DBR research study has discovered a novel DBR Agile methodology for research that answers the research question, “How can MUVEs be designed for vocational education and training?”

The next chapter reviews relevant literature and identifies the theories and frameworks selected for this study.
CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Multi-user virtual environments (MUVEs) or virtual worlds (VWs) have been shown to be valuable for use in education. De Freitas (2008) asserts that MUVEs:

in the future may provide a ‘wrapper’ for sets of educational services including e-portfolios, e-learning materials, assignments and class sessions, course module materials, learning games, tracking and monitoring assignments, communications between tutors and learners and e-assessment. (p. 5)

De Freitas is supported by Kirriemuir’s (2009) report of virtual world activities in UK universities and colleges and by Hearns et al. (2011) in New Zealand and Gregory et al. (2013) in Australasia. Gregory et al. (2013) concluded that the emergent phase of such an innovation, often characterised by hype, was maturing to recognise the many challenges that come with such innovations in education and training.

The first section of this chapter defines the term, MUVE, in vocational education and training (VET) and discusses learning from games and through simulations; the learning affordances of MUVEs and concludes with a definition of MUVE for VET adopted for this study. The second section reviews MUVEs in VET with a discussion of MUVEs that have considered educational theory in their design. In the third section, the application of analysis design development implement and evaluate (ADDIE) in the design of MUVEs for VET is considered and argues for a paradigmatic shift from ADDIE-like instructional design models to using design based research (DBR) to test theory in practice while producing MUVEs suited to VET. Section four describes DBR as it is applied to VET and discusses gaps in the DBR process. The fifth section introduces legitimate peripheral participation (LPP) (Lave & Wenger, 1991) as an authentic situated learning theory suited to VET and the technological and pedagogical content knowledge framework (TPACK) (Mishra & Koehler, 2006) as a theoretical framework for instructional design. Information Systems (IS) design and the application of pragmatism as research of practice theory in DBR and Agile software development is discussed in the sixth section. This is
followed by a discussion of Agile software development in the context of DBR, along with Agile methodologies and Agile method tailoring. A review and discussion of how DBR aligns with software development leads to a hybrid DBR for Agile software development (hDAS) methodology.

2.2 Multi-User Virtual Environments designed for vocational education and training

2.2.1 Definitions

The term, MUVE, is defined in slightly different ways by different educational research teams. Aldritch (2009) cited in Choi & Baek (2011) treats a MUVE as a specialised form of a highly interactive virtual environment in which multiple users can interact synchronously, and Bell (2008) in Choi & Baek (2011) proposes that a common definition of a MUVE is to “induce synchronous interaction among users within a computer-based three dimensional virtual space” (p. 2385). However, more recently Mantziou et al. (2018), who reviewed the technical learning affordances of MUVEs, introduce MUVEs as “online 3D virtual environments that allow many users, being represented by avatars, to simultaneously log in, communicate and interact with each other and with the virtual environment” (p. 1738). Girvan (2018), however, argues that:

> definitions of virtual worlds lack an essential conceptualisation of what a virtual world is. The propensity towards a techno-centric definition has its advantages as it allows for a myriad of user experiences, however it results in confusion between technologies with similar technical features, (p. 1086)

She defines VWs as:

> Shared, simulated spaces, which are inhabited and shaped by their inhabitants who are represented as avatars. These avatars mediate our experience of this space as we move, interact with objects and interact with others, with whom we construct a shared understanding of the world at that time. (p. 1099)

Salt, Atkins, & Blackall (2008) define a MUVE in a manner similar to Bell (2008), as "the term currently used to describe a persistent 3D graphical environment accessed
over the Internet, which allows a large number of simultaneous users to interact synchronously" (p. 11). Warburton (2009) puts an emphasis on the participants' sense of immersion or presence in a VW, by stating that "a virtual world provides an experience set within a technological environment that gives the user a strong sense of being there" (p. 415). Warburton's emphasis on immersion in a VW is based on Shroeder's (2008) definition of virtual reality from 1996:

A computer-generated display that allows or compels the user (or users) to have a sense of being present in an environment other than the one they are actually in, and to interact with that environment. (p. 415)

Not all researchers consider 3D a necessary technical characteristic of MUVEs. For example, de Freitas (2008) considers VWs and hence MUVEs that are immersive environments which are not rendered in 3D, such as, Habbo Hotel (Sulake Corporation, 2009).

De Freitas (2008), Mantziou et al. (2018) and Warburton (2009) identify the use of an avatar for interaction in the VW. De Freitas (2008) attributes the act of creating an avatar to the provision of learner or user control in the environment. Warburton (2009) lists recurrent features of VWs that include the "virtual embodiment in the form of an avatar (a personisable 3-D representation of the self" (p. 415). Virtual embodiment of an avatar in vocational contexts implies that the avatar is designed to reflect vocational practices. Learner control in the environment through a representation of the learner as an avatar provides an opportunity for the learner to consider their identity in the vocational context.

An appropriate definition of the term, MUVE for VET, is found through a genealogy of the meaning of the term, VW, expressed in recent digital culture. A MUVE is considered a VW (Downey, 2014) but the semantic origin of the term, VW, informs the design of MUVEs for VET. The first use of the term, VW, is attributed to Langer (1953) in Evenden (2016). Langer (1953) introduced VW in her discussion of place in the context of works of art:

A place, in this non-geographical sense, is a created thing, an ethnic domain made visible, tangible, sensible. As such it is, of course, an illusion. Like any other plastic symbol, it is
primarily an illusion of self-contained, self-sufficient, perceptual space. But the principle of organization is its own: for it is organized as a functional realm made visible—the center of a virtual world, the “ethnic domain,” and itself a geographical semblance. (p. 180)

Langer (1953) conceived of a VW as an expression of, or viewed through, an ethnic domain or reality. Hence, in this study, the design of MUVEs for VET uses VWs within the cultural reality of a particular vocation.

The terms, VW and MUVE, derive from digital games and lead to an integrated definition of MUVEs for VET where their design includes the ethnic domain (the vocation in which the MUVE is being designed). Treating the design of a MUVE as design in a digital medium with technical learning affordances (Choi & Baek, 2011), the VW of the particular vocation can only be properly expressed by members of that vocation. That is, the MUVE for VET is an expression in the digital medium that comes from that vocation.

Heudin (2004) attributes the term, VW, to Ivan Sutherland (1965), who described the ultimate digital display as "a window through which one beholds a virtual world" (p. 2). This perspective is present in Castronva’s (2005) definition of a digital VW 40 years later. He views it as a:

'practical virtual reality' tool, a way to make decently immersive virtual reality spaces practically available to just about anyone on demand. (In the Kindle version, in the First paragraph under "What is a Synthetic World")

Kisiel and Smith (2018) support Castronva’s (2005) definition, and expect that VWs will become as prevalent for work and as pervasive as digital devices are at present. They assert:

"Synthetic worlds; or virtual worlds designed as augmentations to our physical worlds, will be at the heart of the next extension of a human, and humanity – in much the same way that Alan’s [Alan Kay] Alto-based systems are the center of our computing world today. (p. xxv)

Research into VWs and synthetic environments has been the topic of scientific research for at least twenty years (Durlach and Mavor, 1994). However, Castronova
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(2005) observed that the renewed interest in virtual reality re-emerged with VWs in digital games. For example, Koven (1986) noted that, “the purpose of video game playing is not merely fun; it is a way of learning to survive in the 'virtual' world of high-tech communication and calculation” (p. 115). According to Downey (2014), the development of VWs is based in advances in the technical characteristics of digital games that express VWs, which Langer (1953) views as the world (or the story) of the game in which the player becomes immersed. It is an ethnic domain; the game’s applied narratology (Simons, 2007).

Downey (2014) identifies three generations of VWs from the late 1970s until the present time: 1978 to 1984; 1985 to 1996 and from 1997 to the present. He describes the characteristics of VWs in each generation:

First generation virtual worlds were primarily text-based, small in scale (250 users or less), and set in the realm of fantasy adventure (e.g., Dungeons & Dragons and Middle Earth). Second generation worlds witnessed the growing use of graphical worlds, larger scale systems (1,000 or more users), the introduction of social-oriented worlds, and the development of worlds in which users could create objects and shape their world in real time. Finally, the third (current) generation marks the age of massive systems (10,000+ simultaneous users), visually striking 3D worlds, and a growing array of genres and types of virtual worlds (e.g., MMOGs, MUVEs, MMOLEs; fantasy, science fiction, pseudo-reality) that target adults and children alike. (p. 57)

Downey (2014) presents the following taxonomy of terms describing VWs. The taxonomy, reformatted as a list, includes:

- **Virtual World.** Generic, overarching term used to describe online environments (text or graphical) in which users collaborate communicate for the purpose of gaming and/or socializing.
- **MMO.** Massively Multiplayers Online. A generic term like virtual worlds used to describe a spectrum of worlds.
- **MMOG.** Massively Multiplayers Online Game. A subset of MMOs specifically oriented towards gaming.
- **MMORPG.** Massively Multiplayers Online Role Playing Game. A subset of
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MMOGs specifically oriented towards role playing games such as World of Warcraft.

- MUVE. Multi-User Virtual Environment. A term promoted by Harvard researcher Chris Dede to designate virtual worlds that are social oriented versus gaming oriented. (p. 62)

Some education researchers view MUVEs, such as Second Life®, as a form of MMOG (Delwiche, 2006). In the study reported in this thesis, MMOGs are treated as a subset of VWs in which the purpose is game play (Schroeder, 2008). In the third generation VWs, both MMOGs and MUVEs have similar functional requirements and allow large numbers of simultaneous participants to interact synchronously (Downey, 2014). The main difference between MMOGs and MUVEs is in their purpose. In a MMOG, the user plays a particular game designed for the environment whereas a MUVE for VET is one that meets vocational training needs. Although sandbox game-like environments (Mantziou et al., 2018), are used as platforms for educational MUVEs, being “game-like” does not imply that game play is characteristic of MUVEs for VETs. In the study presented here, while the vocational context implies a design for a specific context, the design of MUVEs is not motivated by design for game play. See Appendix 1 for a review of platforms that support MUVEs.

Authors use the nomenclature above in variable ways.. For example, Downey (2014) defines the acronym MUD as “Multi-User Dungeon” First Generation Worlds (1978–1984) whereas Ritke-Jones (2010) defines MUD as “Multi-User Domain” (p. xi).

MUVEs emerged from the VWs of digital games; they are technically the same as a MMOG without game play. For the study reported in this thesis, a MUVE is also technically a 3D VW that is used to simulate a physical real world environment (discussed in Section 2.4).

2.2.2 Learning from games and through simulations

Boyle et al. (2016) reviewed papers that present positive outcomes of computer games
and serious games in education in the context of outcomes presented by Abu-Taieh and Abutayeh’s (2009) review of simulation systems. The following discussion of Hay’s (2005) review of the effectiveness of instructional games, that leads to the assertion that games in MUVES should only be used in for VET, if it suits the intervention being designed by the vocation for training.

Some research has been undertaken, which examines the effectiveness of games for students’ learning. Hays (2005) reviewed the effectiveness of instructional games. He documents 105 articles on the design, use, and evaluation of games, 48 of which “provided empirical data on the effectiveness of instructional games”, (p. 6). Hays (2005) defines a game as “an artificially constructed, competitive activity with a specific goal, a set of rules and constraints that is located in a specific context” (p. 15). He draws on Caillois' (2001) categorisation of games through their rules, where games form:

- a continuum anchored by the terms paidia and ludus ... Games at the paidia end of the continuum have few or no rules and are played for sheer joy. At the other end of the continuum we find ludus ... refers to games with rules and requirements for play. The more a game is bounded by specific rules, the closer it falls toward the ludus end of the continuum. (p. 11)

This continuum from paidia to ludus is analogous to a continuum from constructivist learning (Bassot, 2012) to classical classroom instruction. The purely constructivist learning environment would provide the content and the opportunity for the learner to make meaning, whereas the classical classroom environment would provide a very structured environment in which learning is undertaken in a very specific sequence. Hence, a constructivist MUVE is characteristic of paidia in the construction of knowledge.

Hays’ (2005) first recommendation is that, “The decision to use a game should be based on a detailed analysis of the learning requirements and an analysis of the tradeoffs among alternate instructional approaches” (p. 53). Although research into using computer games for teaching and learning is ongoing (Bradford, 2010; Kablan, 2010; Pivec, 2009), in the study reported in this thesis, the development of a game in a MUVE would only be undertaken if a game was identified as significant to that
Boyle et al. (2016) reviewed 143 papers published from 2009 to 2014 that present positive outcomes of computer games and serious games (games used for training). They concluded:

*Games for learning have been used to promote knowledge acquisition across a wide range of topics and to a lesser degree skill and social skill acquisition and behaviour change … Despite the intense interest in games, it is important to realise that developing games for learning can be very complex and costly and still provides significant challenges. Future research will benefit from detailed experimental studies that systematically explore which game features are most effective in promoting engagement and supporting learning.*

Although serious games are potentially useful in VET, they have been used less for skills acquisition than for knowledge acquisition. That implies that further research is required into the design of games for skill development, for vocational training.

Abu-Taieh and Abutayeh’s (2009) review of 50 simulation systems found that knowledge transfer from experts to novices was an outcome from simulations for VET. Despite Boyle et al.’s (2016) finding that games are not being used for skill development, I contend that simulations, expressed in learning games for vocational training, do provide opportunities for the acquisition of skills, social skills and behavioural change through simulated practice. For example, Landman et al. (2018) found that when aircraft pilots trained to fly aircraft in simulators the transfer of skills was brittle and according to Hjelmervik, Nazir, and Myhrvold (2018), “[Maritime] Training simulators are largely deployed to provide operators working within complex systems to instill adequate skills to handle normal and abnormal situations” (p. 17). While simulators are not games for learning, a well-designed simulation intrinsic to a game could provide the practice of skills and role-play of social situations to allow participants to develop skills, social skills and undergo behavioural change. Games for learning that include vocationally suited simulations can provide environments for learning. Hence, MUVEs can be designed to provide for practice through simulations and serious games for learning.
The design of a MUVE for VET is guided by the ethnic domain of vocational learning situation. Insights into MUVE-based instruction for VET can be found in Hiller’s (2013) explanations of how of virtual reality learning environments (VRLE), technology-based instruction (TBI) can take place for VET. In the study reported in this thesis, VRLE were considered to be equivalent to MUVEs when they are designed for multiple users.

According to Hillen (2013) VRLE, TBI takes place through the provision of social constructivist learning (Bassot, 2012) and instruction based on shared presence by students and vocational instructors that allows vocational instructors to use a Zone of Proximal Development approach (Vygotskii & Kozulin, 1986 cited in Hillen (2013)) in a didactic structure, that can make use of game and simulation features. Her explanation provides an alternative to the underpinning behaviourist learning perspective present in the ADDIE instructional design model (ISD) (Allen, 2006). see section 2.4 below.

2.2.3 Learning affordances of MUVEs

Mantziou et al. (2018) examined the learning affordances (Dalgarno and Lee, 2010) of 205 empirical studies of MUVEs in educational contexts, using the term as “learning affordances” as proposed by Dalgarno and Lee (2010). They identified five learning affordances and six types of learning activities. The learning affordances included creation, modelling and simulation; free navigation, content presentation and delivery, multichannel communication, and collaboration and cooperation (Table 3, p. 1754). The learning activities included content creation, content exploration and interaction with content, social interaction, gaming, and participation in representations of real-life events and situations (p. 1754). Mantziou et al. found that research into social interaction was the most frequent, followed in turn by content exploration and interaction with content, content creation, participation in representation of real-life events and situations, and then gaming.

In the study reported in this thesis, the MUVEs for VET used participation in
representation of real-life events and situations as the learning activity because it enacted all five learning affordances.

Dalgarno and Lee (2010) propose features and learning affordances for virtual learning environments (VLEs) that are relevant for MUVEs that are multi-user and enable social affordances through a shared presence, to provide a stronger definition of MUVEs. Dalgarno and Lee (2010) consider the technical learning affordances of 3D virtual environments, they quote Hedberg and Alexander’s (1994) assertion that the most important feature is a “transparent interface with which the user directly controls the objects in the context of the virtual world” (Hedberg & Alexander, 1994, p. 215) cited in Dalgarno and Lee (2010, p 12).

Dalgarno and Lee (2010) identify two categories of distinguishing features of 3D virtual learning environments (VLE). The first is “Representational Fidelity” (p. 15), which includes a “Realistic display of Environment, Smooth display of view changes and object motion, Consistency of object behaviour, User representation, Spatial audio and Kinaesthetic and tactile force feedback”, (p. 15). The second is “Learner interaction”, (p. 15), which includes “Embodied actions including view control, navigation and object manipulation, Control of environment attributes and behaviour, and Construction of objects and scripting of objects”, (p. 15). These features and the following associated affordances provide useful human interface affordances, that although they mention avatar in the context of “User representation”, they do not treat social interaction as afforded from multi-user environments as a top-level distinguishing feature. Their top-level analysis is strictly of the single-user experience in a physical sense. Hence, their analysis defines the user experience as it would be for an individual, but also misses aspects of cognition that can be afforded by 3D virtual environments, such as, distributed and external cognition (Preece, Rogers, & Sharp, 2002, Chapter 3) that is afforded by persistence in VWs and through interaction with other users in the virtual environment. They derive five learning affordances of 3D virtual environments from three perspectives. From the first perspective, affordances of “3-D simulations and microworlds”, (p. 18) “can be used to facilitate: , as follows

1. learning tasks that lead to the development of enhanced spatial knowledge
representation of the explored domain.” (p. 18)

2. experiential learning tasks that would be impractical or impossible to undertake in the real world.” (p. 19)

3. learning tasks that lead to increased intrinsic motivation and engagement.” (p. 20)

From the second perspective, “3-D environments as interfaces to learning resources” (p. 20) “can be used to facilitate:

4. learning tasks that lead to improved transfer of knowledge and skills to real situations through contextualisation of learning” (p. 21).

From the third perspective, “3-D multi-user VLEs” (p 21) “can be used to facilitate:

5. tasks that lead to richer and/or more effective collaborative learning than is possible with 2-D alternatives.” (p. 23)

As noted above, de Freitas (2008) and Warburton (2009) attribute MUVEs with a sense of immersion and presence as described by Bronack, Sanders, Cheney, Riedl, Tashner and Matzen, N (2008) presence pedagogy theory (P2). As described by Dalgarno and Lee (2010) the fifth affordance, they describe, is the closest to the provision of a sense of immersion and presence, i.e. tasks in “3-D multi-user VLEs” (p. 22) “can be used to facilitate: tasks that lead to richer and/or more effective collaborative learning than is possible with 2-D alternatives.” (p. 23). However, that does not identify the strength of the effect of a shared presence in learning as described by Hiller (2013) in her explanation of how learning can take place in VLE technology-based instruction and misses the affective nature of participation in designed-for-purpose MUVEs as a VW of a vocation.

In summary, a MUVE is a VW that identifies an ethnic domain (Langer,1953). This perspective guides the design of the MUVE, which by definition represents its own ethnic domain. The perspective purposefully filters the design of MUVEs for VET in practices of the vocation. Emerging from VWs expressed in digital games (Castronova, 2005; Downey, 2014), the MUVE must provide learning by inculcating the practices of that VW. A number of learning affordances for this design were
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derived from literature on serious games (Boyle et al., 2016) and simulation practices for learning (Abu-Taieh & Abutayeh, 2009; Hjelmervik, Nazir, & Myhrvold, 2018; Landman et al., 2018). How VRLE TBI can take place is summarised by MUVEs for VET were also presented as a multi-user VRLE with technology-based instruction (Hillen, 2013). That relationship indicates that Hillen’s (2013) summary is also characteristic of technology-based instruction using MUVEs.

For this study, a MUVE is defined as a VW designed within the ethnic domain of a vocation, and designed for interventions in VET. A MUVE is a third generation VW, which is a persistent and immersive 3D VW accessed through the Internet that allows a large number of participants to simultaneously use avatars to interact synchronously.

This definition of MUVE presents an opportunity to consider how to design MUVEs for VET. The following section discusses MUVEs used in education, mainly sampling literature that has VET characteristics. The section concludes with a review of literature that considers educational theory applied in MUVEs.

2.3 MUVEs in vocational education and training that apply education theory

There is a need for the design of MUVEs in VET to test educational theory. Kirriemuir's (2009) review of VW activities in UK universities and colleges, reports that all but one university has "staff who have developed, or are developing, something in a virtual world" (p. 3) and MUVEs are being used in courses for 18 subject areas over a wide range of disciplines, such as, midwifery, language learning, ICT and digital media, drama and performance, computer science, law, psychology and mental health, and engineering.

The motivations for using MUVEs in education were varied. Kirriemuir (2009, front page) quotes Tim Johnson (Senior Lecturer, IHS, University of Worcester):
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It really is not a matter of choice; nurse and midwife education (and many other healthcare professions) currently have nowhere left to accommodate the needs of students except in virtual worlds.

Tim Johnson reflects the pressure on educators to provide learning experiences for students that may not be possible for a variety of reasons.

MUVEs are used in education to enable learners to participate and practise skills in a course where social, physical or ethical aspects would otherwise constrain them. For example, very few midwifery students are able to experience birthing in the first year of their course. However, Winter (2010) describes the development of a MUVE that is available to trainee midwives where they practise the normal birthing process. In the case of anaesthesia nurse practitioners, Gerald and Antonacci (2009) describe a MUVE simulation where nurses participate in nurse anaesthesia practices in a (simulated) live medical operating room.

The capacity to provide learning experiences through MUVEs has been demonstrated in previous studies. For example, Jarmon, Traphagan, and Mayrath (2008) describe a case where communication studies students were able to reach into a real community using a MUVE as one of their communication tools. The MUVE provided authentic learning situations in which the students collaborated with architects and a real community in the design and implementation of real housing. In that course, the learning experience was made more authentic because the MUVE provided social and visual communication capacity not previously available. Although Jarmon et al. (2008) describe a positive outcome for students, they identify a need for further research on the effective use of MUVEs in communication studies.

Authentic learning experiences have also been provided in vocational training through simulating real-world vocational situations. For example, simulations developed by Knudsen (2010) on the Second Life® MUVE are used for vocational training in Denmark. In one of the environments, students walk their avatars through a simulated building site to undertake a safety inspection of the site. In another simulation, students with English as a second language can practise their English while role-
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playing a number of common scenarios. Hudson and Degast-Kennedy (2009) describe a Canadian border simulation in Second Life® that was created post-9/11 when security restrictions led to limitations on access to the border. This simulation is used by students, who are preparing to apply to become border security officers. Students use the MUVE to practise interviewing travellers crossing the border. Student outcomes were above expectations when compared to previous classes that had not used the MUVE. Students' grades improved and they "left the project with a sense of accomplishment and one of ... participating in a ‘real world’ experience" (p. 10). They also gained confidence in their capacity to interview travellers and saw themselves as having "an advantage in a competitive workplace screening process" (p. 10). Vergara, Caudell, Goldsmith, Panaiotis and Alverson (2009) describe a simulation for medical training, knowledge-based techniques that allowed instructors to target specific concepts and keep track of how effective each student was at diagnosis relating to Mr Toma, a virtual patient. Wheeler (2009) describes Media Zoo, which includes a MUVE, a physical space and a web implementation. It was designed for staff at the University of Leicester, "to experience, interact and understand the potential educational applications of learning technologies" (p. 427). The Media Zoo MUVE simulates a physical and web environment as well as introduces MUVE-specific experiences. However, the Media Zoo MUVE does not simulate a real situation for practice. It reproduces an environment to communicate with educators about learning technologies.

Researchers argue that MUVEs should be used for developing simulations of authentic situations rather than for constructivist learning experiences (Gerald & Antonacci, 2009; Hewitt, Spencer, Mirliss & Twal2009). Broadribb and Carter (2009) describe a course where Second Life® was used to role-play office activities. They surveyed participants before and after the course and found an increase in the capacity of the participants, although they could not attribute this directly to the MUVE. Walker and Rockinson-Szapkiw (2009) describe using Second Life® for education in clinical counselling. They found that problems with the voice-over IP system limited the authenticity of the experience. These studies suggest that authentic simulation is very appropriate and effective for vocational contexts but technological problems can reduce authenticity in the situation.
MUVE-like and VW-like systems are also widely used in military vocational training. For example, in the Royal New Zealand Navy, MUVE environments are used for training ships’ bridge operations. Their system provides a number of simulations of different ships’ bridges that participants can train in (Lordan, 2018; Royal New Zealand Navy, 2019). The live virtual constructive architecture (LVCA) framework described by Bizub, Wallace, and Ceranowicz (2009) is a technical framework that identifies a core set of technical specifications for simulation systems. Knight and Reese (2001) report on the design and implementation of a transportable training system, stating that the “Aviation Combined Arms Tactical Trainer – Aviation Reconfigurable Manned Simulator (AVCATT-A) is further advancing war fighter readiness by facilitating the use of virtual simulators for team and combined arms training” (p. 2). Crane, Benasutti, Proaps and Bliss (2018) describe techniques for dealing with high-resolution in augmented reality systems. Thiele (2014) presented a paper entitled Research Directions For Future Simulation-Based Training Design in Defence. Of particular interest is the recognition of dynamic, situated processes in building novel solutions. He states that, “This dynamic, situated process of building a novel solution is also not easily captured in a written, static, de-contextualised TNA [training needs analysis], especially without a model describing the mechanics of the adaptive process” (p. 6). This reflects the adaptation to a dynamic, situated process that is resolved by the design process discovered for MUVEs in this study.

As introduced in chapter one, there have been a few reports of the design processes of VWs in education. Reeves (2006) describes exemplary DBR projects two of which developed MUVEs: the River City Learning environment and Quest Atlantis. The River City Learning environment (Ketelhut, Dede, Clarke, Nelson, & Bowman, 2007; Ketelhut, Nelson, Clarke, & Dede, 2010) was used as a “pedagogical vehicle, ... exploring how a technology-intensive learning experience that immerses participants in a virtual ‘world’ … can help middle school students learn both deep inquiry skills (scientific processes) and science knowledge” (p. 2). Although the River City learning environment project focused on primary school education, strategies learned in its development were applied in the current study. For example, Clarke and Dede (2009) suggest that the system should be designed so that it has scalability, i.e. it can be scaled up or down for different sized groups. Designing for scalability could influence pedagogy and the selection of software development techniques used in the design of the interventions.
Barab et al. (2005) provide an overview of the design and implementation of Quest Atlantis, a MUVE based environment in which children learn through game play. They consider their approach to instructional design and DBR that evolves as they undertake their research and development, to be at the intersection of entertainment, education and social commitment. Although relevant, there was a gap in the literature regarding the design of a MUVE for specific vocational contexts.

MUVEs have been devised that are based on theoretical underpinnings, to test theories in practice. Davies, Abu and Leigh (2018) consider that their ADELIS model for “Designing Authentic Simulation-based Teaching, Learning and Assessment” as “addressing the simulation design theory-practice gap phenomenon” (p. 4) and recognises the need for theory suited to the instructional design. In Bronack et al. (2008), the AET Zone MUVE includes areas that support their P2 theory, where the P2 tenets are located in specific artefacts of the virtual space. The P2 tenet to “ask questions and correct misperceptions” (p.61 ) is represented by a western movie-style saloon called, the So What? Saloon, which provides a help facility of frequently asked questions in the AET Zone. Prasolova-Førland (2004) describes a collaborative virtual environment MUVE, called Viras, that was based on a theory that social awareness affects a learner's capacity to obtain relevant information. Prasolova-Førland states that:

Social awareness is awareness of the configurations and developments of learning trajectories and the patterns and histories of participations of the learners in the communities and groups. (p. 140)

In Viras, the environment provides seeds for a structure in which members of specific communities are located near to each other. However, a vocational situation is not simulated. Zheng, Young, Wagner, and Brewer (2009) describe analysis of communication in a VW proposing that the concept of negotiation for action provided resources for English language acquisition. Zheng et al. (2009) investigate communication in a VW but do not report on how to use it. The paper analyses communication during the VW experience, with the analyses being used in the resolution of a theory of communication.
As introduced above, the ongoing study that considers how MUVEs can be used in education is the River City learning environment and its descendant, EcoXPT, (Ketelhut, Dede, Clarke, Nelson & Bowman 2007; Ketelhut, Nelson, Clarke & Dede 2010; Dede, 2017) in which, as described by Ketelhut et al. (2007), a MUVE is used as a:

- pedagogical vehicle, ... exploring how a technology-intensive learning experience that immerses
- participants in a virtual 'world' ... can help middle school students learn both deep inquiry skills
- (scientific processes) and science knowledge. (p. 2)

The River City project used research by design (Plomp, 2007) and, although it focused on primary school education, lessons learned in its development can be usefully applied in the current study. For example, Clarke and Dede (2009) suggest the system should be designed for scalability, which could influence pedagogy and the selection of software development techniques used in the design of the interventions. Similarly, a DBR approach within which socially responsive design is identified as a theory is used for the Quest Atlantis project (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005) that provided learning through quests.

MUVEs in education are used for creating planned and intentional simulations of authentic situations and as a communication medium through which learning is experienced. In this study these points of view provide two ends of a spectrum of affordances from MUVEs. DBR, as used in the River City, EcoXPT MUVE (Ketelhut et al., 2007, Dede, 2017) learning environment, has produced useful theories and developed an effective learning environment in a long-term study.

A systematic review of multi-user VWs in healthcare education (Liaw et al., 2018) highlights the current situation in the design of MUVEs in VET. Liaw et al. concluded:

*Despite a growth of studies on the use of MUVE in healthcare education, there is a need for more understanding of the application of theories to inform the learning activities. Therefore, we*
suggest educators to incorporate a theoretical model to explain the learning processes behind

MUVEs. (p. 13).

Most MUVEs are not designed to reflect educational theory; the exceptions are River City and Quest Atlantis.

2.4 Designing MUVEs for instruction using ADDIE

Soto (2013) sought to answer the question of which instructional design models (ISD) are educators using to design virtual world instruction? In his survey of 62 experienced designers, developer, and published researchers of VW, Soto found that about 67% used an ISD model with 75% of them using the ADDIE model (Allen, 2006) and 30% using the text, *The systematic design of instruction* (Dick, Carey & Carey, 2009). About 75% of respondents adjusted or adapted their ISD model to suit the situation. Soto concluded that ISD models are outdated, lack flexibility, do not incorporate game design theory, and the choice of an ISD model depends on the project. He stated:

> Each discipline requires a unique approach for designing instruction in virtual world environments. While many instructional designers may use ID models with which they are familiar, different instructional situations may require the use of a different ID model, as no ID model can satisfy them all. (http://jolt.merlot.org/vol9no3/soto_0913.htm, section: choice of models is dependent on the project)

Soto concludes that, “According to this research, participants in this study believed that merging various ISD models could help create unique processes to address specific learning needs” (http://jolt.merlot.org/vol9no3/soto_0913.htm, section: conclusion).

In their handbook, *Learning in 3D: Adding a New Dimension to Enterprise Learning and Collaboration*, Kapp and O’Driscoll (2009) describe how to design virtual immersive environments (VIEs) and 3D learning environments (3DLEs), using an ADDIE model. 3DLEs and VIEs, as described by Kapp and O’Driscoll, are MUVEs. 3DLEs are MUVEs designed for training and education in enterprises. While they
present detailed steps to follow when using an ADDIE model, they simplify the model by representing ADDIE as a sequence of steps, thus making it a more manageable process for enterprises. Their simplified process follows a generation one-style ADDIE model (Allen, 2006). This approach meets Allen’s (2006) assertion that ADDIE was created for developing ISD tools to meet the “challenge of the low-level of training expertise being required of those functioning as the training organisation” (p. 435). Kapp and O’Driscol (2009) argue that in the development step of ADDIE, there must be close collaboration between the instructional designer, content developer and programmer to realise the vision of the previous step. Furthermore, scripting by the programmer cannot start until the content developer has produced the environment. This feature is missing in the design of 3DLEs.

Given that 75% of respondents in Soto’s (2013) survey, and Kapp and O’Driscol’s (2009) use the ADDIE ISD model, it is useful to describe and discuss the ADDIE model in more detail.

Allen (2006) describes ADDIE as an ISD model developed post-World War II in the 1940s, applied in highly specified jobs for “systematic training within a military context of learning highly specified job tasks by a continuous cadre of homogenous learners” (p. 432). Allen (2006) notes that the military did not use ISD for management training. According to Allen, ADDIE designs are principally applications of behavioural learning theory because the majority of jobs are made up of procedural tasks. For non-procedural tasks, “concepts from cognitive psychology and systems engineering were used” (p. 432). Allen (2006) citing (Gagne et al. 2005). Allen also notes that “50 years after the advent of ADDIE, … [we] still have difficulty verifying participant expertise at the conclusion of training” (p. 440).

Allen (2006) identifies four generations of ADDIE, each made up of a number of phases. In the first generation of ADDIE, five phases were followed mostly in sequence, quality improvements were provided through feedback across all phases, but the ISD had environmental constraints. The first-generation ADDIE model include the following phases:

1. analyse system requirements
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2. define education and training
3. develop objectives and tests
4. plan, develop and validate instructions
5. conduct evaluation.

These phases are then repeated as required. Generations two to four ADDIE resulted from revising each model and building on previous generations. According to Allen (2006) phases of the revised ADDIE models call on designers to:

- “analyse and determine what instruction is needed”
- “design instruction to meet the need”
- “develop instructional materials to support system requirements”
- “implement the instructional system” (p. 435).

Evaluation is integrated in all phases of each model by “gather[ing] feedback data through formative, summative, and operational evaluations to assess system and student performance” (Allen, 2006, p. 435). The second generation ADDIE models adopted systems theory to control and manage more complex instructional development processes. The third generation ADDIE models were developed for flexibility needed outside of the military and phases were considered interactive processes that could be entered into at any point. While generation three ADDIE models were still mainly driven by behavioural learning theory, cognitive theory was applied in their process, e.g. in simulations to gather “cognitive expertise in decision making (Driscoll, 2005)” in Allen (2006, p. 431). Fourth generation ADDIE models use developments in artificial intelligence to handle the complexity of the ADDIE system “with a continuous evaluation and troubleshooting process” Allen (2006) citing (Gagne et al. 2005), pp. 432 to 433). The new “complexity of the ADDIE system” (p. 432) comes from “advancements in understanding how humans learn and educational technology … provided major changes in many of the system variables” (p. 432). The ongoing focus on evaluation appears to be related to an emerging understanding that ADDIE required integration or adjustment to base it on new theory.
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The ADDIE models and systems have developed over time to focus on integrated and continuous evaluation to ensure ongoing enhancement to incorporate new theoretical perspectives.

As summarised in Allen (2006), the evaluation function in ADDIE models “gathers feedback data through formative, summative, and operational evaluations to assess system and student performance” p 435, processes that support that function are not detailed, nor are processes that implement the feedback described. Closing these gaps would potentially provide useful information on the effect of feedback on the overall ADDIE system, and by determining fit-for-purpose processes, the efficiency of introducing feedback into the system may be considered.

The study reported in this thesis acknowledges the gap that ADDIE models invoke by mainly taking a behavioural learning theory approach that meets training in procedural tasks. The perspective taken is that the design of interventions using MUVES must consider all training needs, as determined by procedural and non-procedural vocational tasks. The ADDIE model has been reported as being used by a lot of MUVE designers, but ADDIE itself is under stress to adapt so that it reflects new theoretical perspectives.

The ongoing increase in complexity can be addressed by taking a paradigmatic shift in ISD in which the outcome of the design is also the design process adapted to current theoretical understanding and discipline needs that address how to design MUVEs for VET. That approach is described in more detail in the following section on educational DBR.

2.5 Educational design based research

Using DBR paradigmatically changes the approach to designing MUVEs. DBR tests theory in practice to produce useful artefacts, and design research becomes a foundation through which to develop an understanding of theory in practice while producing vocationally suited MUVEs that are VWs of the vocation. That means that there is no longer the stress where an ISD model has to be adjusted to fit new
education theory; instead the design process reflects the research and development contexts.

DBR is guided by developmental goals. Figure 2.1 illustrates the differences between research conducted with traditional empirical goals and that inspired by developmental goals (Reeves, 2000). In contrast to empirical research, developmental research starts with an analysis of practical problems by researchers and practitioners. Solutions that are developed are underpinned by theoretical frameworks and are evaluated and tested in practice. Design principles are then produced from an analysis of documentation and reflection.

At each stage, the problems, solutions, evaluation and design principles are refined. The derived design principles can feedback into the other process stages in further iterations. While Reeves (2006) later used the term, design research, instead of development research”, in this thesis, the term “development research” is used to distinguish it from educational DBR and IS design research.

In educational DBR, educational theories are enacted in practice and what emerges from that practice is evidence, which can be evaluated. Plomp (2007) identifies three phases in educational DBR to improve the theory base of education:

![Figure 2.1 Comparison of empirical research and development(al) research, from Reeves (Figure 3, 2000, p. 9). Reproduced with permission.](image-url)
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**Preliminary Research:** Needs and content analysis, review of literature, development of a conceptual or theoretical framework for the study.

**Prototyping Phase:** Iterative design phase consisting of iterations, each being a micro-cycle of research with formative evaluation as the most important research activity aimed at improving and refining the intervention.

**Assessment Phase:** (Semi-) Summative evaluation to conclude whether the solution or intervention meets the pre-determined specifications. As also this phase often results in recommendations for improvement of the intervention, we call this phase semi-summative.

Throughout all these activities the researcher or research group will do systematic reflection and documentation to produce the theories or design principles ... as the scientific yield from the research. (p. 17)

Educational theory is a key aspect of DBR and is used to inform the design of educational products and processes, and the evaluation of them. Improvement to educational theory is the most important output or finding.

DBR originates from design experiments (Brown, 1992; Collins, 1992). Brown (1992) describes “classroom life” (p. 141) as:

[S]ynergic: Aspects of it that are often treated independently, such as teacher training, curriculum selection, testing, and so forth actually form part of a systemic whole. Just as it is impossible to change one aspect of the system without creating perturbations in others, so too it is difficult to study any one aspect independently from the whole operating system. (pp. 141–142)

Brown (1992) adopted design experiments in her research in complex classroom situations.

According to Cobb, Confrey, diSessa, Lehrer and Schuble (2003), design experiments on learning processes reach beyond the classroom. They describe the purpose of design experiments as a way to develop theories for the broader context of learning processes:
The purpose of design experimentation is to develop a class of theories about both the process of learning and the means that are designed to support that learning, be it the learning of individual students, of a classroom community, of a professional teaching community, or of a school or school district viewed as an organization. (p. 10)

Cobb et al. (2003) argue that learning is supported by, “the affordances, and constraints of material artifacts, teaching and learning practices, and policy levers … as well as other forms of mediation” (p. 10). In the study reported in this thesis, the vocation drives the scope of investigations of the effect of theory in the design and creation of MUVEs for interventions in VET.

Sandoval and Bell (2004) cite Collins (1992) as putting, “forth a notion of educational research as a ‘design science,’ like aerospace engineering, that required a methodology to systematically test design variants for effectiveness” (p. 2). Collins, Joseph, and Bielaczyc (2004) identify problems with design experiments, such as, “resistance to experimental control” (p. 2) and comparison of designs due to the complexity and unpredictability of real-world situations that tend to produce large volumes of data with combinations of methodologies.

In the study reported in this thesis, findings come from the cases and the DBR process from enacting a DBR methodology, i.e. the outcome is not generalizable. However, since the process is a topic of study, applying the process to test and develop theories can be repeated. We acknowledge these challenges; they are thought of as ongoing. We recognise that the methodology is developed for a specific design that the systematic collection of a large amount of data on the interventions are undertaken in real-world situations. The collection of a large amount of data is seen as a valuable resource that can be subject to subsequent careful analysis.

Easterday, Rees Lewis, and Gerber (2014) reflect on DBR, stating that, “unfortunately, there are many unresolved issues with DBR that arise because we lack a clear definition about what DBR is, how it is conducted, and what it produces” (p. 317). They describe DBR:
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DBR provides educational researchers with a process for use-inspired basic research … where researchers design and study interventions that solve practical problems in order to generate effective interventions and theory that is useful for guiding design. DBR is important because it recognizes that neither theory nor interventions alone are sufficient. (p. 317)

Easterday et al. (2014) argue that uncertainty about the DBR process comes from uncertainty about the phases of DBR processes, and how these are enacted depends on who conducts the DBR. They articulate the following DBR process requirements:

- There needs to be a “clear definition of the phases of DBR” (p 222).
- DBR “differs from other research in that it designs a product while using other methodologies as nested processes (subphases) of design” (p. 222).
- DBR “differs from design practice in that it does not just produce an educational intervention but makes use of nested scientific processes to produce theory” (p. 222).

For them, DBR produces, “gains by deploying the appropriately nested scientific process at a given stage of development” (p. 222). They argue that nested scientific processes ensure DBR is effective. DBR is an umbrella process that encapsulates the application of other research methodologies. Easterday et al. (2017) continue to present a similar definition of DBR:

\[
\text{DBR … does not just produce an educational intervention but makes use of nested scientific processes to produce theory in the form of novel design models of how people learn that do not just promote learning but expand our capacity to promote learning.} \quad \text{(p. 24-25)}
\]

However, according to Dede et al. (2004) the focus of DBR is on how the strengths and limits of a design inform theories of learning (educational theory) rather than the focus presented by Easterday et al. (2014) in which the theoretical focus is in developing, “theory that is useful for guiding design [of a learning situation]” (p 317).

In the study reported in this thesis, theoretical frameworks are used in the design and development of MUVEs in two case studies. The design of instruments for inquiry were considered as embedding a qualitative participant research method within the educational DBR process, which does not necessarily require the nesting of scientific
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methods to be effective in identifying recurrent patterns affected by theoretical frameworks in the development of MUVEs for the selected cases.

To test theory in practice, legitimate peripheral participation (LLP) was selected as an authentic, situated theory that can be tested in the design of MUVEs in the two vocational situations of this study.

2.6 Theories that inform the design of interventions

A theory and theoretical framework were selected to inform the initial development of the interventions. The legitimate peripheral participation (LPP) theory in situated learning (Lave & Wenger, 1991) provides a way to think about the efficacy of interventions. The technological pedagogical content knowledge (TPACK) framework (Mishra & Koehler, 2006) allows us to consider the complex relations that can occur in the development of interventions that use technology in education.

Legitimate Peripheral Participation

LPP is a theoretical perspective that matches the learning environment we want for our students at New Zealand polytechnics. In LPP, learning is couched in the social participation in a recognised community of practice that develops over time and seeks to reproduce itself. Participants move from being novices and on the periphery of the community of practice to being experts at the centre of the community of practice. LPP (or situated learning) leads to a theory of learning and teaching in the context of a journey towards full participation in a community of practice (depicted in Figure 2.2). A person starts at the periphery of the community of practice and moves towards full participation by progressing through a number of stages as a journeyman. Specific artefacts may be used in teaching and learning that are associated with stages in the development of capacity within the discipline. This is analogous to a student moving towards being a participant in a discipline community at workplaces that we want our students to be ready for. Being ready for work is not just a matter of having a specific skill set but also being able to act in the workplace in an authentic manner.
In the study reported in this thesis the LPP theoretical framework informed the development of MUVEs by providing a way to think about the authenticity of the learning for the learner and the community of practice the learner is moving into. By focusing on the legitimacy of the learner’s experience in the context of that, their journey towards being a full participant in that community also informed the design of teaching strategies and pedagogies. From the community's perspective, identifying legitimate activities on the path towards being a participant were the focus when designing teaching strategies and pedagogies, and determining appropriate content for a learner at a given stage in their journey.

Legitimacy can also be identified by artefacts or objects that mark progress within the community of practice. In the Second Life® MUVE, novices have, until recently, been readily identified by the appearance of their avatars; by going through the process of enhancing their appearance implies that trainees have developed in the VW, either independently or through associating with more experienced journeymen. In software development there are also artefacts that mark boundaries. The use of appropriate coding practices, such as, correct indentation and naming conventions, differentiate a person who is new to programming from one who is already practising the craft. Within a course, these boundary artefacts might identify learning goals or features for discussion in formative assessments. LPP practices provide a lens that can focus the approaches to use when designing interventions by ensuring that the intervention is legitimate for both the learner and the community of practice. From this lens, other technology-based theories can be used in learning, and how to assess that technology.
Technological pedagogical content knowledge

Using a MUVE in a vocational context has an effect on the pedagogy selected and on the way course content is conveyed. For example, particular content may be more effectively conveyed through a MUVE, or a particular pedagogical approach may be more effective using a MUVE. Technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006) provides a teaching framework that can be used for designing interventions. Figure 2.3 depicts the interconnections between pedagogy, content and technology.

![Knowledge to consider when using technology in teaching and learning, based on Mishra & Koehler (2006, Figure 4, p 1025)](image)

Pedagogical content knowledge (PCK) presents an opportunity to consider the best way to teach content. Technological pedagogical knowledge (TPK) identifies concerns about the way technology impacts pedagogy and the way pedagogy impacts the use of technology. Technological content knowledge (TCL) identifies concerns with technology in the content of a learning context. TPACK presents an opportunity to consider the synthesis of appropriate teaching and learning solutions using technology, pedagogy and content knowledge. For example, the TPACK framework ensures that what a teacher needs to know about technology is considered in educational design. Development of pedagogy is influenced by content and technology. Effective use of a MUVE may be reduced by poor content and or the needs arising from pedagogy. Hence, TPACK is useful in this study by providing a theoretical framework in the design and development of interventions using MUVEs.
Educational DBR (Plomp, 2007) provides an understanding of how to design and implement educational MUVEs for intervention in VET. Intervention is treated as a case study that identifies and tests theory and design practices that lead to fit-for-purpose MUVEs.

The design of MUVEs can also be informed by IS design. A DBR process matches a practice theory perspective of IS design.

### 2.7 Information systems design research: A practice theory perspective

As digital artefacts, MUVEs are information systems. IS design research is similar to, and informs DBR as it proceeds in this study. Mennecke et al. (2007) introduce IS research in their statement on the scope of VW research in their panel discussion, according to panel members’ expertise and perspectives:

> As an information system, virtual worlds present researchers in information systems, computer science, and information science with numerous opportunities to observe, build, and refine insights into the underlying infrastructure involving distributed computing, scripting, new systems development and project management methodologies, and the creation of middle-ware that links 'virtual world' and 'real world' enterprise applications, (pp. 2-3)

Hence, the development of MUVEs as VWs presents an opportunity to research IS design research.

Rohde, Brödner, Stevens, Betz, and Wulf (2017) introduce IS design research that informs philosophical perspectives taken in the study reported in this thesis. IS design research is concerned with the design of information systems, as “technical artefacts” (Rohde et al., 2017, p. 1), which are subjected to deliberate design policy and formal specifications, which, “need to be socially appropriated for effective and meaningful use in organizational practices” (p. 1). They argue that IS design research considers positivist or interpretivist perspectives, but rarely pragmatist perspectives. According to these authors, positivism reduces the scope of IS socio-technical research to searching for regularities and causal relationships among objects, using methods based on reproducible objective experimental results. Interpretivist-led, socio-technical
investigations, however, take the perspective of intentional social actors, who interpret, create and modify the broader social situation in which change has a historical context and knowledge is socially constructed meaning.

Pragmatism refers to a world that is in a constant state of becoming, where actions effect change and desired changes are through actions that are guided by purpose and knowledge. They think of pragmatism as a practice-theory research perspective. This process of research can be seen as one in which objects are encountered in the world that is becoming, and through “unknown or newly conspicuous objects” (p. 3) are recognised. To recognise these objects, a “specific mode of exploratory action is needed in order to disclose and conceive their potential functionality, and to learn how they can be used intentionally” (p. 3). Concepts of the functions and effects of these objects are formed through their pattern of actions, “action schemes” (p. 3) and recurrent characteristics; patterns in practice that are subsequently useful as others go through similar experiences.

The study reported in this thesis focuses on practical problems for which development is practised. Hence, several perspectives are taken. A pragmatist perspective is the main perspective taken through which development research leads the practical development of solutions within theoretical frameworks. A positivist perspective is taken in the design of the educational DBR process. That artefact is then used in the consideration of regularities and causal relationships in its application through cases. An interpretivist perspective is taken for the case studies and in the design of instruments as required in the enacting of the process in a case.

Hogue’s (2013) view of pragmatism underpinning educational design research, correlates with Rohde et al.’s (2017) description of pragmatism in IS design research as a practice-theory perspective. As described in the following section, Agile software development methods, which focus on adapting to business needs and producing software that work, also have pragmatism in their underpinnings.

2.8 Agile software development
Although Agile software development has become more common, it was purposefully posited as suited to development DBR.

Hoda, Salleh, Grundy and Tee (2017) report that Agile software development has become more prevalent since its formal declaration through the Agile Manifesto in 2001 (Beck et al., 2001a). For example, in their systematic tertiary literature review, they identify twenty-eight systematic literature reviews of Agile software development published from 2008 to 2015, in ten different categories, of those twenty were undertaken in the latter half of the survey period.

The Agile Manifesto (Beck et al., 2001a) induces a formalised definition of Agile software development practice. The first statement in the Agile Manifesto (Beck et al., 2001a) is a declaration of the fundamental behaviour that identifies an Agile software developer. As shown in Table 2.1 the “Manifesto for Agile Software Development”, starts with the phrase “We are uncovering better ways of developing software” (Beck et al., 2001a). That is, the manifesto makes explicit the investigation and undertaking of research and development of ways to develop software, as characteristic of an Agile software developer. The statement concludes, “by doing it and helping others do it” (Beck et al., 2001a), see Table 2.1, asserts that Agile software development is an active process undertaken by practitioners who throughout practice engage in helping others develop software.

*Table 2.1  The Manifesto for Agile Development (Beck et al., 2001a).*

<table>
<thead>
<tr>
<th>Manifesto for Agile Software Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:</td>
</tr>
<tr>
<td>Individuals and interactions over processes and tools</td>
</tr>
<tr>
<td>Working software over comprehensive documentation</td>
</tr>
<tr>
<td>Customer collaboration over contract negotiation</td>
</tr>
<tr>
<td>Responding to change over following a plan</td>
</tr>
<tr>
<td>That is, while there is value in the items on the right, we value the items on the left more.</td>
</tr>
</tbody>
</table>
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Through the manifesto, Agile software developers recognise the value of: “processes and tools”, “comprehensive documentation”, “contract negotiation” and “following a plan” (Beck et al., 2001 a). By valuing “individuals and interactions” over “processes and tools” (Beck et al., 2001 a), Agile software developers, recognise software development as a social activity more than a process guided or “tick box” activity. Agile software developers value “working software” over “comprehensive documentation” recognising the software artefact has precedence (Beck et al., 2001 a). Potentially, producing a working software artefact opens pathways towards understanding requirements that come during the process of development of that software. Software developers are aware of or may have experienced software development projects that meet a contract while not meeting customer expectations. Agile software developers value “customer collaboration” over “contract negotiation” (Beck et al., 2001 a). When customers are collaborators during development, mutual expectations are better understood, and hence development is constrained to meet those. Agile developers adapt to change as the development proceeds (Beck et al., 2001 a). This reflects an understanding that the developed artefact may change as exploration of potential solution spaces is undertaken. Following a plan, while a valued practice, does not take precedence over the development of a suited software artefact.

Table 2.2 Principles behind the Agile Manifesto (Beck et al., 2001 b).

<table>
<thead>
<tr>
<th>Principles behind the Agile Manifesto</th>
</tr>
</thead>
<tbody>
<tr>
<td>We follow these principles:</td>
</tr>
<tr>
<td>Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.</td>
</tr>
<tr>
<td>Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.</td>
</tr>
<tr>
<td>Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.</td>
</tr>
<tr>
<td>Business people and developers must work together daily throughout the project.</td>
</tr>
<tr>
<td>Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.</td>
</tr>
<tr>
<td>The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.</td>
</tr>
<tr>
<td>Working software is the primary measure of progress.</td>
</tr>
<tr>
<td>Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.</td>
</tr>
<tr>
<td>Continuous attention to technical excellence and good design enhances agility.</td>
</tr>
<tr>
<td>Simplicity--the art of maximizing the amount of work not done--is essential.</td>
</tr>
</tbody>
</table>
The best architectures, requirements, and designs emerge from self-organizing teams.
At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

The first four “Principles behind the Agile Manifesto” (Beck et al., 2001 b), as shown in Table 2.2, identify the customer as a central focus in Agile software development. The first starts with the phrase “Our highest priority is to satisfy our customer …” (Beck et al., 2001 b), sets the customer in centre stage. The second principle welcomes changing requirements and even late development to “harness change for the customer’s competitive advantage” (Beck et al., 2001 b). Adapting to change in the solution space to give a customer competitive advantage, ensures the Agile developer becomes familiar with the customer’s business in the context of the software artefact to be developed; they engage in the solution spaces and domains that emerge from the customer’s business need. The third principle is the delivery of working software frequently (Beck et al., 2001 b), that allows the customer to use the software and proceed. The fourth principle, that business people and developers work together daily throughout the project (Beck et al., 2001 b) enhances collaboration with the customer, since the business people would be those who are practicing in the customer’s area of expertise.

The remaining Principles (Beck et al., 2001 b), are in two categories: development practices and team organisation practices. Principles concerned with team organisation practices include “Build projects around motivated individuals …”, “the most efficient … method of conveying information … is face-to-face communication”, “… promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely”, and “At regular intervals the team reflects on how to become more effective …”, all from the web page (Beck et al., 2001 b). Those concerned with development practices include “Working software is the primary measure of progress”, “Continuous attention to technical excellence and good design enhance agility”, “Simplicity – the art of maximizing the amount of work not done – is essential”, “The best architectures, requirements, and designs emerge from self-organizing teams”, all from the web page (Beck et al., 2001 b). The Agile Manifesto and its Principles (Beck et al., 2001 b), as shown in Table 2.2, can be used to guide development of the MUVE as requirements emerge from design for a particular
vocational training situation. During development design research Agile principles that focus on team organisation and software development practices guide the relation of participants and the process of the research. For example, “… sustainable development … to maintain a constant pace indefinitely” identifies the need to manage on-going development sustainably, within DBR in which development is continuously iterative; design based research develops an artefact through which reflection on the theoretic frames being applied in an iteration leads to emergence of proto-theories, which in turn are applied in on-going development in further iterations. The principles, “Working software is the primary measure of progress” coupled with “Simplicity … is essential”, guide development of the MUVE, allowing the developer to reflect on, for example, the level of graphical detail or the level of interactivity provided by the MUVE that would be sufficient in the vocational training situation.

**Agile Method(ologie)s**

This section presents the range of Agile software development methods (SDM), and reflects on SDMs that have Agile characteristics. According to Wufka and Ralph (2015) “agile software development is concerned with how teams, artifacts, process and project environments change and how those changes affect each other” (p. 61). Agile software development is undertaken using a series of related Agile methods within a methodology (Cockburn, 2003, p. 6).

In their systematic review of Agile methods tailoring, Campanelli and Parreiras (2015, p. 86) identify and describe mainstream agile methods: “Extreme Programing (XP), Scrum, Kanban, Lean, Feature-Driven Development (FDD), Dynamic Systems Development Method (DSDM), Adaptive Software Development (ASD), Crystal and Rational Unified Process (RUP)”, see appendix “A2.1 Agile Methods” for brief summaries of these mainstream Agile methods. Highsmith (2002 a) describes and compares Agile methods and methodologies in detail. Each of the methods, represent the conceptualisation by an individual or a practitioner community regarding adaptive “fit for purpose” Agile software development. Most of these methods were established before the Agile Manifesto, and each complies with the manifesto and the principles behind the manifesto in different ways; they “reflect concordance” (Highsmith, 2002 a) in different degrees. For example, to software developers who are XP and Scrum practitioners, RUP, Kanban and Lean may be seen as on the bounds of Agile methods. RUP is a highly prescribed software development process which can been seen as
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process over people, which is contrary to Agile principles. Kanban and Lean come from manufacturing situations, hence their processes would need to be adapted to software development situations.

The Agile manifesto assertion that Agile software development practitioners value “Individuals and interactions over processes and tools”, does not imply that Agile rejects processes and tools. However, a process centred method may be considered less in the spirit of the Agile manifesto. For example, RUP and DSDM are Agile in the sense that their processes are iterative and they aim to provide usable software as frequently as possible. However, RUP (Rational software development company, 1998) is a prescriptive approach to software development that requires detailed defined sequences of process activities within the iterations, that is formalised by the Unified Modelling Language (UML) (OMG, 2019). Similarly, DSDM includes prescribed sequences of process activities, see Highsmith (2002 a). Hence RUP and DSDM that have an emphasis on detailed processes can be perceived as contrary to “Individuals and interactions over processes and tools”. On another bound in the definition of Agile methods, Kanban and its parent Lean (Campanelli & Parreiras, 2015) are techniques that come from manufacturing contexts and hence do not necessarily match software development. For example, as noted by Poppendieck and Poppendieck (2003), “lean production practices—specific guidelines on what to do—cannot be transplanted directly from a manufacturing plant to software development”, p 27. Hence, while following the manufacturing version of Lean in form, Lean software development focuses on software development issues. Poppendieck and Poppendieck (2003, Table 1.1, p. 19) compare “Seven Wastes of Manufacturing” with “Seven Wastes of Software Development”, the manufacturing waste “Inventory” becomes the software development waste “Partially Done Work”, and the manufacturing waste “Over production” becomes the software development waste “Extra features”.

Undertaking Agile development for MUVEs in vocational contexts requires consideration of development in an educational context. For example, when following the principle “Business people and developers must work together daily throughout the project”, it is noted that practitioner tutors and trainers are not business people, consideration needs to be given to who is the educational practice expert in place of business people. Furthermore, “working together daily” is very unlikely to be
manageable in the context developing an educational intervention with active educational practitioners. Hence, in an educational context Agile software development would reflect conformance with the Agile manifesto, while being tailored to an educational design context.

**Agile Method tailoring**

This section presents literature on tailoring of Agile methods, that is undertaken in software development companies, by taking either a “contingency factors” or a “method engineering” approach to the tailoring of software development method both of which could be enhanced by reference to a repository of Agile Method Fragments (Esfahani & Yu, 2010).

Method tailoring is normally undertaken during software development. Dittrich (2016) reports “Qualitative empirical research indicates that software teams balance what is recommend by the method with the specific technical and organizational circumstances of the project”, p 220. Campanelli and Parreiras (2015, p 87) cite Kalus and Kuhrmann, (2013) “No matter the selected method or process, tailoring is normally needed for context adequacy in either organization and project levels”. Esfahani and Yu (2010) observe

> … few software companies adopt a prescribed agile process in its entirety. For many practitioners, agile software development is about picking up fragments from various agile methods, assembling them as a light-weight process, and deploying them in their software projects, p 163.

According to Esfahani and Yu (2010), in a recent survey 60% of companies are not following a particular method, they deploy techniques and tools introduced by different methods. Similarly, Dittrich (2016) cites Fitzgerald(1998), nearly a decade earlier, who Dittrich says “concludes that only 6% of all practitioners apply a formally defined method”, p 220.

Approaches to method tailoring are: “method engineering”, and “contingency factors”. Campanelli and Parreiras (2015) citing Conboy and Fitzgerald (2010) and Fitzgerald, Russo, and O’Kane (2000) identify “contingency factors” and “method engineering” as the mainly classified options to execute method tailoring that have been studied.
Software development organisations taking the “contingency factors” approach, use them to select from a portfolio of complete methods to meet the software development situation. Software development organisations that use “method engineering” create a new method for the situation based on existing method fragments. Campanelli and Parreiras (2015) report that from the papers they reviewed 69% undertook research based on the “method engineering” approach, 8% investigated the “contingency factors” approach and 21% were unclear. Taking a bottom up “method engineering” perspective, Esfahani and Yu (2010) collate Agile techniques and tools that are fragmentary parts of Agile methods. To facilitate method tailoring for Agile software development, they present an Agile Method Fragment (AMF) repository, which for each AMF, describes how the AMF meets project or management situations and indicates the effect of its application in different positive and or negative contexts. Taking a top down “method engineering” perspective, Crystal Agile software development, Cockburn (1999) proposes the design of a “family” of “methodologies” for undertaking Agile development. Crystal (Cockburn, 1999), which conforms to the Agile manifesto, is described as being “… a family of stretch-to-fit, human-powered software development methodologies.” (at the top of the web page), that are derived from understanding human communication and practices and roles taken within a project.

Given “method engineering” is most frequently addressed, it should be noted that “contingency factors” are useful when undertaking “method engineering”. For example, both the tool provided by Esfahani and Yu (2010), and the Crystal family of methodologies (Cockburn, 1999), express consideration of “contingency factors”: Esfahani and Yu (2010) describe the purpose and fit of the AMFs to the method to be undertaken, Crystal (Cockburn, 1999) applies a theory that describes the shape of a methodology to be produced in a given software development situation.

In the study reported in this thesis, method tailoring of an Agile method requires the designed method to affect the way development is undertaken and to provide for the integration of Agile methods in the context of enacting DBR. In the study a “method engineering” approach is taken in which the Agile method is integrated into a design based research methodology. In one sense, the contingency factors that determine a tailored Agile method were determined through the design base research methodology
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in a bottom up manner. In another sense the over-arching design based research methodology drives the Agile development in a top down manner.

2.9 DBR, aligns with Software Development Methods.

This section describes the ways in which software techniques are compatible with DBR because the designed DBR methodology that is seeded by LPP and TPACK integrates software development techniques. The observation by Easterday et al. (2014) that DBR is designed for each study, and each DBR method appears to use a different process, is like Agile method tailoring. Although an overarching process is described by Plomp (2007) – above, each DBR process is discovered during design for the given research study, in a manner that is equivalent to One Method Per Project described by Cockburn (1999) in which the an Agile method is tailored for the project.

Stages in development research described by Reeves (2000), as depicted in Figure 2.1 are: “analysis of practical problems by researchers and practitioners”, “development of solutions with a theoretic framework”, “evaluation and testing of solutions in practice” and “documentation and reflection to produce design principles”. These are similar to stages of a simple interaction design lifecycle model as described by Sharp et al. (2007). These are: identify needs/establish requirements, (re)design, build an interactive version (prototype) and evaluate. The interaction design lifecycle model, described by Sharp et al. (2007), in turn reflects established stages in software development. The stages are: requirements analysis, software design, software implementation and testing followed by software maintenance (Davis, Bersoff & Comer, Figure 1, 1988). Given this similarity between the stages in development research and generic stages in software development, methods and processes used in software development could be applied in the development of interventions. For example, when using an Agile methodology, user stories identify requirements for the system to be developed. As introduced by Cobb (2011):

User stories provide an easy-to-understand and simplified way of stating requirements that is commonly used with many agile methodologies such as Scrum and Extreme Programming. A user story is a very high-level definition of a requirement, containing just enough information so
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that the developers can produce a reasonable estimate of the effort to implement it without a lot of detail. (p. 51-52).

In DBR, design is for and with educational practitioners and learners, their user stories establish the needs and requirements in the on-going design process, and relate analysis of practical problems by researchers and practitioners.

The fourth stage depicted for developmental research in Figure 2.1 is “documentation and reflection to produce design principles”, this is on-going in DBR and expressed in semi-summative analysis at the end of a design cycle. For example, when using and creating interventions, reflection on the rationale in the design of an intervention can lead to design principles for the interventions. In software development, documentation of the on-going process can lead to refinement of software development methods, that come about from review of the software development process when a product is released. A technique used in software development is to express the rationale through the design of a software design pattern language, for example an established pattern language is Tidwell's (1999) Common Ground pattern language that describes patterns in the Human Computer Interaction design where each pattern:

… defines a context of use, a problem the designer needs to solve, a set of “forces” pushing the designer in different directions, and a primary rule -- and sometimes additional secondary rules - on how those forces might be resolved to best solve the problem. (web page).

Design patterns for interventions could be established, the context of use of the pattern would be based on theoretical areas in education, for example ‘when teaching”, “in the development of pedagogy”, and “when learning”.

DBR through its cyclic collaborative and reflective aspect is also compatible with an Agile approach to software development. As described by Nerur (2005), these are characterised by:

short iterative cycles of development driven by product features, periods of reflection and introspection, collaborative decision making, incorporation of rapid feedback and change, and continuous integration of code changes into the system under development, (p. 75)
The term “sprint” is used to describe a short cycle that undertakes the development of a set of required features of the software that are to be in release of the software to the client. Reflection on the features implemented in a sprint identifies the focus of the next sprint.

Iterative development cycles as undertaken in the enactment of Agile software development methods corresponds with the enactment of DBR processes, for example, as in the McKenney and Reeves (2013) process depicted in Figure 3.1 in the next chapter. In the study reported in this thesis, software analysis and design methods were used to refine details in the development of the MUVE-based intervention. The study focused on DBR guided application of a tailored Agile method in the creation of MUVEs by a given vocation. That lead to hybrid Design based research for Agile Software development (hDAS) hDAS methodology.

2.10 In summary - How can MUVEs be designed for vocational education and training?

This chapter presents the scope of the study not only direct from literature but through synthesis of the meaning of MUVE as a VW for vocational education and training as technology for instruction, to allow design of MUVEs that suits a given vocation and that provides for participation in a vocation that is legitimate for the vocation and legitimate for the participant trainee, i.e. that matches the authentic situated theory LPP (Lave & Wenger, 1991). The perspective presented comes from understanding the genealogy of the term VW as it emerged with digital games (Downey, 2014) and the meaning of the term VW as an ethnic domain (Langer, 1953) of a given vocation.

How VWs and MUVEs allow learning when used in TBI is discussed briefly (Hillen, 2013), and reviews of learning affordances (Dalgrano & Lee, 2006; Mantziou et al., 2018) are explored. VWs as they are and have been used are reviewed. It is noted that MUVEs are used for service vocations, for example firefighting and military services.

From a review of the design of MUVEs, gaps found are: they are designed without consideration of educational theory in practice, and without research into how to
translate the design into working MUVEs for use in an educational intervention. First design using ADDIE (Allen, 2006) – that is a common procedural model for instructional design, is discussed, and gaps in ADDIE are presented. A paradigmatic shift to DBR that tests educational theory in practice is presented as an alternative approach that can be taken to understand how to design MUVEs for VET. DBR as development research as it has been used in design of MUVEs for VET, is reviewed.

In this chapter initial education theories that inform design of MUVEs and that can be tested in practice through DBR were introduced. Authentic situated theory LPP (Lave and Wenger, 1991) was selected because it is a theory that matches the mandate of technical institutes that graduates are “work ready”. TPACK (Mishra & Khoeler, 2006) was selected because it guides instruction design through consideration of technology in pedagogical and content knowledge. Combining both in a DBR process, allows for them to be tested in practice.

This chapter explores Agile software development methods as an approach to software development that complements DBR. It proposes that enacting DBR is like Agile method tailoring, and this chapter indicates a need for DBR that includes a tailored Agile method to become a topic in research.

The following chapter presents a methodology that uses a DBR process with a tailored Agile SDM to understand how to design MUVEs for VET. That approach inculcates suited theories selected to be tested in practice and consequently allows for observation of their effect when used to guide design of the MUVE for an intervention in VET situations.
CHAPTER 3
METHODOLOGY

3.1 Introduction

There is little or no research into the process of specifying and developing virtual worlds for vocational education. This chapter lays out a methodology to inform such research, which brings together software development techniques with design based research (DBR). This chapter presents an approach that integrates Agile software design with DBR for the more effective production of multi-user virtual environments (MUVEs) for vocational education. Educational theories are used to inform the design; they provide seeds in the design and development of the interventions. Established Agile software documentation and processes are informed from data collected from practitioners, including user stories, descriptions of tasks, developer and stakeholder comments that become working documents as the system is developed. These, in turn, are one of the sources in the DBR that evaluates educational theories to propose adapted and/or new theories; the data collected is presented as a case that situates adjustments for existing theories generated through proposed proto-theories. Before the early phases of the methodology are illustrated in the development of MUVEs in two vocational education contexts, the complementary approaches are introduced.

Through the enactment of a DBR process to create software for MUVEs in two vocational education contexts, an Agile software development methodology was discovered called the “hybrid design based research for Agile Software development” (hDAS). The hDAS methodology is a hybrid of DBR and Agile software development. hDAS is a phased methodology that is informed by selected theories. A description of the first enactment of phase one of the hDAS processes is presented in Chapter Four (the temporary traffic management (TTM) MUVE case study), while Chapter Five presents a description of the second enactment of phase one and the first enactment of phase two in the context of the ship’s bridge MUVE. The mature hDAS methodology is discussed in Chapter Six. Early versions of this methodology have been published in Cochrane, Davis & Morrow (2013) and Cochrane, Davis & Mackie (2016). This chapter includes sections of those publications.
This chapter begins with a section that describes the DBR process that was enacted in the creation of the software for the first MUVE for TTM. The DBR presented in this chapter provides a process that develops an understanding of the nature of the DBR process as it is enacted in the development of artefacts for vocational education and training (VET) interventions using MUVEs.

### 3.2 Design based research

As introduced in the previous chapter, enacting a DBR presents a paradigmatic shift in the design of MUVEs that allows for educational theoretical perspectives to be tested in practice rather than treating the theoretical perspective as an addition to a prescribed process that is to have an effect on the design.

Based on Reeves’ (2000) development research (Figure 2.1 in the previous chapter), DBR was undertaken in a process that took some structure from the process of the CASCADE-SEA study by McKenney (2001) cited in Plomp (2007). DBR as development research takes a practice turn in which theory is tested through analyses of practical problems, the development of solutions with theoretic underpinnings, evaluations and tests of the solutions, and documentation of reflections to produce further design principles. In this DBR method, the process is a solution for the design of MUVEs in VET.

Figure 3.1 shows the CASCADE-SEA process. There are three phases: needs and content analysis; design, development and formative evaluation and semi-summative evaluation. The process shows an extended design and development phase, with four iterations (or sprints) of prototypes and increased numbers of participants.
In this current study, the three phases of the CASCADE-SEA process were replaced with three phases as shown in Figure 3.2:

1. Phase one identifies and develops a MUVE based intervention in collaboration with practitioners.
2. Phase two implements the intervention and undertakes formative evaluations as the intervention proceeds.
3. Phase three has been adjusted to fit this study.
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For this study, the three-phase process of DBR used educational theory and theoretical frames to identify and refine the following concerns and goals:

- Identify and develop a MUVE based intervention for a course in collaboration with practitioners.
- Implement the intervention for the course, carry out a formative evaluation.
- Undertake a semi-summative evaluation of the design.

The phases were undertaken in sequence, with the sequence potentially repeated over at least two runs of a course. A prototype intervention was developed in collaboration with practitioners and refined using feedback from students and practitioners. During each phase there were developments or adjustments of the intervention. The practices carried out during each phase are specified in the following sections.

Practices during phase one

During the first phase, the researcher and developer work with the practitioners to identify a point in the course where a MUVE based intervention can be used. Students' learning trajectories are considered, to identify and determine details of the intervention to be designed and developed. During this phase, educational theories and frameworks are selected for investigation and applied in the design of the intervention, and the design and development of the MUVE. During this phase, legitimate peripheral participation (LPP) (Lave & Wenger, 1991) and technological pedagogical content knowledge (TPACK) (Mishra & Khoeler, 2006) are incorporated into the design process.

During the first phase, practitioners are involved with the design of the intervention. The interaction with the practitioners is highly iterative, in a series of emergent collaborative sessions over a period of time. While the purpose of the collaboration during the first phase is defined, the level and frequency of the sessions can not be determined before the phase starts. The tailored Agile method (described below) is used during this phase to identify a list of features to be developed determined during collaborative sessions. These are implemented with feedback from the practitioner prior to the next sprint. The sprint iterations are deemed complete when the
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implemented features meet a level that the vocational practitioners consider sufficient for the teaching and learning interventions using the designed MUVE.

Practices during phase two
In the second phase, the MUVE based intervention is tested and integrated into a run of a course. During the second phase, feedback is solicited from the practitioner and trainees, leading to formative adjustments to the intervention and the MUVE. The formative adjustments lead to software development sprints that adjust features for use in the intervention. Between runs of the intervention, formative adjustments are made to the MUVE and the intervention, based on further feedback from the practitioners. During this phase, the effect of educational theories and frameworks on the design of the intervention, and the design and development of the MUVE are observed and recorded. During interventions. Data recordings were then used during phase three as described below. As in phase one the educational theory LPP and TPACK are incorporated into the design and development resulting from the formative evaluation of the MUVE. During the enactment of phases one and two of this DBR process, the number of participants in the ship’s bridge course increased in a manner similar to the second phase in the CASCADE-SEA process depicted in Figure 3.1.

Practices during phase three
During the third phase, semi-summative evaluations are undertaken and presented as cases. Inquiry focuses on how the intervention brings the learner into the vocation and the impact of the technology during the intervention. Feedback is received from a focus group of a self-selected sample of students and the practitioner. Analyses of the development documentation and field notes are used to describe the effect of educational theory during the design and implementation of the intervention.

Case findings presented in the following two chapters are products of phase three of the process. In this study, the development of two MUVE-based interventions was undertaken. During the first case, the development of a MUVE for use in interventions in TTM training, refined and established methods of inquiry and the software environments for classroom based interventions using phase one of the DBR process. In the second case, development of a MUVE-based intervention in ships’ bridge communication training was completed using phase one and phase two of the process.
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This thesis is also considered a product of phase three of the DBR process that led to the discovery of hDAS, which is discussed in Chapter Six.

A tailored Agile method – an atypical Scrum

Iterative development cycles in Agile methods match the approach described for DBR. For example, in this study, prototypes were developed in a series of cycles in Agile sprints (see Figure 3.2). Development of the artefacts generated by the methodology purposefully started with a tailored Agile software development method.

The following describes the rationale that led to the initial tailored Agile software development method for this study in relation to current software development practices. After examining all common Agile software development methods, XP and Scrum were found to be the most commonly practised. The Agile software development community would consider either method to be a good place to start when considering methods for Agile software development. In their systematic review of Agile global software development (GSD), Vallon, da Silva Estácio, Prikladnicki, and Grechenig (2017) note a trend from XP towards the Scrum-based Agile software development method. They reported that, “in 2010–2016 Scrum is in the centre of agile GSD implementations with eight Scrum-based practices in the top ten agile practices used in GSD” (p. 1). Hence, a Scrum-based method was considered to be a good candidate to tailor for the Agile software development method in this study.

There were several reasons that Scrum was chosen for this study. XP (Beck & Andres, 2004) requires paired programming and frequent complete system integration. Similarly, Scrum requires a number of roles in execution and requires integrating and running solutions to be delivered at the end of each sprint. This current study was undertaken with one developer, who could produce an integrated and running solution that is delivered at the end of each sprint. However, while a single person can take on multiple roles in activities, such as, paired programming and can hold daily Scrums with a Scrum Master and a team of developers, the additional process and planning required by the single developer, and would therefore contravene the Agile Manifesto. Scrum was selected as the preferred method because it was compatible with the development situation where paired programming is possible.
Scrum is a non-prescriptive software development method (Harichandan, Panda, & Acharya, 2014) and fitted with the DBR process. The product backlog contains Scrum product backlog cards that describe user stories identified during phases one and two. In turn, from discussion and/or formal interviews with practitioners, a sprint backlog produced tasks for a given sprint. Demonstration, review and sprint retrospectives are undertaken prior to, during and after an intervention that used the developed MUVE.

As discussed above, pragmatic observation leads to tailoring a Scrum-based software development method, as shown in Figure 3.3. For the tailored method, software development takes place when the researcher/developer is able to do that development. The daily scrum becomes a reflection on working notes and planning focused on the set of tasks in the development of features of the MUVE that is undertaken at the start of a work period. Determined by the time available to the researcher as a developer, sprints are not necessarily in contiguous blocks of time.

In summary, the Agile method tailoring in this study removed the daily scrum and retained the following agile method fragments (AMFs) (Esfahani & Yu, 2010): product backlog; sprint backlog; sprint planning meetings; tasks generated for sprints; sprints and demonstrations with sprint reviews. Participant roles during development are determined during the enactment of the educational DBR process.
Throughout this study, the progress of the Agile product backlog and sprint backlog tasks undertaken during the development of the MUVEs were recorded using software tools. A purpose-built online Agile software development service, AgileBuddy, (Allen, 2019) was selected to record progress in the Agile process. Over the course of the study, AgileBuddy was shutdown. The shutdown process provided for exporting the recordings with the service in text based CSV format files. Trello (2015) was then used to record progress of the Agile process. The Trello board system provided an export of the recorded progress, in JSON format, which in turn was manipulated into CSV file format. AgileBuddy (Allen, 2019) and Trello (2015) provided records that were used for analysis.

The following section presents the two cases used to enact the emerging hDAS process used to design and implement MUVEs for training interventions in two vocational contexts.

3.3 Case studies in the development of MUVEs using the DBR process

The development of two MUVEs was undertaken at different New Zealand polytechnic technical institutes. At the first institute, the study started with the development of a MUVE for training in TTM. The study continued at the second institute with the development of a MUVE for training in ship’s bridge communication. For convenience, the technical institutes are given the pseudonyms, Technical Institute One (TI1) and Technical Institute Two (TI2). At TI1, the design and development of a MUVE for TTM was taken to the point where a prototype was tested by a tutor and a small group of students. Described in detail in Chapter Four, this work was then treated as a study of the building blocks for designing and developing a MUVE, using LPP and TPACK as theoretical frameworks. Described in Chapter Five, the development environment and theory-incorporated interviews designed and refined in the first case study formed the foundation for phase one of the method undertaken at TI2 in the design and development of the MUVE for training ship’s bridge communication.

According to Yin (2009), in an exploratory study, the case study is an appropriate
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research strategy when the exploratory study considers “how” and “why” research questions, requires no control over behavioural events and focuses on contemporary events. DBR with an emphasis on development and design is research into “how”. Reflection on the effect of theory in the learning and teaching within a DBR process aligns the research with “why”. DBR does not require control over behavioural events and focuses on contemporary events during the research process.

Like the case study method depicted by Yin (2009), the DBR process in this study (depicted in Figure 3.2) started with the selection of theoretical frameworks that filter the development of the interventions. Using a pragmatist perspective, the DBR process was applied for exploratory and revelatory purposes, through the development of two MUVEs, in two different educational contexts. When the DBR process is treated as a case study protocol as described by Yin (2009, p. 79), design and development of each MUVE is a separate case, through which the overall DBR process is under investigation, giving the study the appearance of a holistic multiple-case, “Type 3” design (Yin, 2009).

Undertaken at TI1, the first MUVE was developed for TTM training by enacting phase one of the DBR process. A method of inquiry was determined and an Agile software development environment was established. Development of the first MUVE provided a valuable source of data on how the DBR process was affected by LPP and TPACK during development of the MUVEs. The second case undertook phases one and two of the DBR process at TI2, in which the second MUVE was designed, developed and used in classroom interventions in ship’s bridge communication. The tools of inquiry and development environment established in the first case were made more generic to allow them to be applied in the second case.

Easterday et al. (2014, 2017) specified a requirement for nested “scientific methods” to provide scientific rigour. In this current study, the proposed case studies were initially thought of as being embedded within the DBR process to provide scientific rigour. However, the teaching and learning interventions implemented during this project were the subject of holistic case studies (Scholz & Tietje, 2002; Yin 1998) that investigated the effective use of MUVEs in live and real teaching and learning in
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vocational courses in New Zealand polytechnics.

As the DBR proceeded, the effect of theoretical frameworks on the design research practice was identified and supported by a body of evidence collected for each intervention. Those bodies of evidence became the sources of the two case studies (Scholz & Tietje, 2002). The characteristics of the case studies for this study include a holistic design, the motivation for undertaking case studies, and its epistemological status (Scholtz & Tietje, 2002).

- The design is holistic where the case is studied through its phenomenology. In this study careful attention was given to the how each case extends the classroom into a community of practice (the vocational discipline) through MUVEs. MUVEs are used to provide access to practices of that vocation that may not be available in a particular organisation and to engage teachers in the provision of authentic learning experiences for their students.

- The motivation for using case studies was to study the cases themselves to determine their particular attributes and properties. The cases were instrumental in testing how to develop MUVEs for the specified vocational contexts using LPP and TPACK as theoretical frameworks. Hence, the case studies were instrumental in the DBR process.

- Epistemological status. The case studies were exploratory and revelatory with the purposes of documenting outcomes from the research by design process and to act as sources of design rules and to reflect on the incorporation of educational theory in subsequent iterations.

The case studies were structured by the design process articulated by Scholz and Tietje (2002): “the case team has to structure the case and formulate a specific perspective or theoretical framework” (p. 13). The format of the case studies is "ground breaking" (p. 13) because:

- the studies undertook a DBR process informed by educational theory in the development of MUVEs in specific vocational contexts, for which DBR has not previously been undertaken.

- Agile software development was explicitly integrated into the DBR process.

- Participant perspectives were presented in terms of their engagement with the
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study. As described in the following chapter, the participation of each participant is described as a series of “swims” during the DBR process. The participants’ swims provided the focus for reflection and analysis of the participant perspectives and their engagement with the study.

Data collection in both case studies was designed to gather multiple sources of evidence providing triangulation, through audio and video recordings, and field notes taken during the interventions, semi-structured interviews with participant practitioners and focus group discussions. Documentation of the Agile process was also used as a source of evidence on reflections of the DBR process and the interventions that were undertaken. As described in the following chapter, the design of an instrument of inquiry was part of the DBR process.

In both cases, the researcher was a participant, as a developer, technician and designer of the MUVEs. The design of the MUVEs for the interventions to be undertaken was established through strong participation by trainers who were practitioners in the vocational situations, i.e. trainers of TTM and ship’s bridge communication courses. In each case, vocational trainees provided feedback into the interventions and the design of the MUVEs.

3.4 Ethical approval process, letters and consent

In this study, the design of ethical approval forms and gaining ethical approval based on those forms was a necessary prerequisite. As new groups of participants emerged during the research, further ethical approval was obtained as required. That meant the ethical consent forms and letters that were written at the outset of the project had to be revised to suit the later invitation of new groups of participants as they emerged (see samples in Appendix A3). Advice on approval for that variation was sought from the chair of the University Ethics Committee who acknowledged that the variation was within the approval already given by the committee.

Approval to undertake the study was also required from each of the institutes. Given participation in the study by tutor practitioners, student trainees, and the institutes,
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consent was required from students, tutor practitioners, the tutors’ managers, and the chief executives (CE) of the institutes. For each of these participant types, suitable letters and consent forms were designed to invite them to participate. The letters and forms were presented to potential participants who became participants after reading their invitation letters and signing their consent forms. The request to allow the study to proceed was presented to the CE before asking for permission from managers and asking their tutor/practitioners and students if they would like to participate. The CE of the TI1 noted that the study seemed to be asking for permission to use resources allocated for teaching and learning, and required clarification of the cost to the institute. After clarification, the study received consent from the CE to proceed. The CE of TI2 reviewed the ethical approval as given by the University of Canterbury and TI1, and gave consent to proceed based on that review. At TI2, a different type of participant, “expert practitioners” who were not tutors was identified. Permission to add these participant types to the study was solicited and approved by the University and TI2.

3.6 Summary

This chapter has provided a detailed account of an innovative approach to the effective design, development and testing of MUVEs in VET. The application of DBR was seeded with educational frameworks and theories that were found to be relevant to vocational education in the hazardous situation of temporary traffic management and the formal English required for navigation on a maritime ship’s bridge. LPP was used as a filter to inform design thinking for specific vocational contexts because moving towards being work ready increases the student's legitimate practices in these industry contexts. TPACK provided a framework to link content and pedagogy with the MUVE technology, and integrate industry standards into the curriculum with an increase in the authenticity in which they are studied. Agile software development was compatible and blended well with DBR, although logistical challenges were identified due to the need to access sophisticated computer laboratories in the college.

The hDAS methodology worked at two levels. At the higher level, the proposed educational DBR methodological process that developed into hDAS was the topical artefact that was designed and developed through this research. At the lower level, the
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artefacts produced were the MUVEs that were developed for interventions designed using the proposed educational DBR methodology.

By enacting the educational DBR methodology, the design research produced MUVE prototypes that can be and were used in classroom based interventions, such as, the ship’s bridge communication case. Each case provided for reflection and further development and design of the proposed methodology.

The next chapter presents the first case, in which phase one of the DBR process was enacted for TTM, and provided the building blocks for the design and application of the tools of inquiry, a MUVE development environment and a MUVE for TTM training.
CHAPTER FOUR
A MUVE FOR TEMPORARY TRAFFIC MANAGEMENT

4.1 Introduction

This chapter presents the building blocks in the design and development of a MUVE for a Temporary Traffic Management (TTM) training course at TII, and reports on the process of developing semi-structured interview guides to gather the required specifications informed by theoretic frames. It proposes the elements of a model that depicts the design and development process using a novel “participant swim” notation. The swimming notation is used to describe in-depth the design and development of the MUVE intervention for TTM.

The design and development of the TTM MUVE used Agile principles and practices, and was informed by an iterative series of semi-structured interviews between the researcher/developer and the TTM trainer/practitioners. This involved a process intended to:

1. Design interview guides, framed by LPP and TPACK, to discuss and elicit information about:
   a. students’ learning trajectories (Cobb, Confrey, diSessa, Lehrer & Schauble 2003; Hunter, 2006) and characteristics of the class in which the intervention was to be used;
   b. the location of the MUVE within the TTM course; and
   c. the necessary networked hardware and software systems for supporting a MUVE.

2. Design a model to depict the DBR process in this context, which enables analysis and reflection on the data and processes using the notion of a series of swims in an Agile development pool.
Section 4.2 places the TTM course within the disciplinary contexts and courses offered at TII that draw on the knowledge and skills covered in TTM.

Section 4.3 describes the process of developing the semi-structured interview guides that were used to identify the requirements for designing and developing the intervention in TTM. LPP and TPACK perspectives were used in this process. Agile drilling down identified learning pathways and how they related to potential learning trajectories for TTM trainees. The section presents details of the interview process that was undertaken in designing and developing the MUVE intervention. This included how LPP and TPACK influenced the process.

Section 4.4 introduces a novel “swim” notation to analyse and reflect on the DBR process and the roles that participants played in it. The perspectives of participants (TTM tutors and students) and their roles are represented as swims in a swimming lane.

Section 4.5 details participant swims as they were involved in the design and development of the MUVE. The effects of participants’ swims were considered in terms of LPP, TPACK and their outcome on the development process.

**4.2 Temporary Traffic Management course**

At TII, TTM instruction was integrated into other curricula because TTM is a necessary part of work on public roads in New Zealand. TTM is used in intrinsically hazardous situations, such as, when work is undertaken on active roads. The *Code of Practice for Temporary Traffic Management* (COPTTM) (NZ Transport Agency, 2010) is the standard reference for all temporary traffic management on state highways and local roads in New Zealand. The supplement, *Temporary Traffic Management for Local Roads* (New Zealand Transport Agency, 2009) specified technical operations and was used in discussions about TTM regulations and local road layouts.
There are three levels of qualification in TTM: a person warranted to place traffic management delineators on the road; a person being responsible for the work site; and the regional traffic controller, who is responsible for TTM in a specific region.

TTM practices were also required in other disciplines. At TII, the Bachelor of Engineering Technology and the New Zealand Diploma in Engineering (Civil) include courses with TTM instruction: Traffic and Highway Engineering (year 1), Road Design and Maintenance (year 2), Traffic Engineering (year 2), Land Surveying (year 1), Engineering Surveying (year 2) and Construction Practices (year 2). Therefore, while TTM is its own discipline, it is also taught in at least other two disciplines, engineering and surveying.

4.3 Designing interview guides

Interviews were found to be an important part of the method of the DBR process described in Chapter Two. The design of a semi-structured interview guide took place after preliminary discussions with TTM tutor/practitioners and after a virtual world (VW) environment for supporting the MUVE had been implemented. The approach taken was pragmatic, and informed by the concept of taking an “interpretative turn”. Yanow and Schwartz-Shea (2006) define taking an interpretive turn as being:

... closely even intimately, empirical and concerned with the problems of meaning, conceived of and analyzed hermeneutically or otherwise that bear an action as well as understanding, ... that the central focus on much empirical social science should be problems of meaning.” p. xii

Hence, the selection and design of instruments of inquiry was purposefully delayed until they could be considered in a contextually suited situation within the DBR method as it was being enacted.

4.3.1 The role of LPP and TPACK in designing the interview guides

In this study, the theoretic frames, LPP and TPACK, were used to affect the design of the
semi-structured interview guide. Therefore, the first step in developing the guide involved revisiting how these theories or perspectives had already influenced the development of the guide.

Through LPP, an individual becomes fully participant in a community of practice within a discipline through identified artefacts that indicate their status within the discipline (Lave & Wenger, 1991). Status within the discipline may be indicated by an actual physical license or office awarded by the discipline or the actual level of skills and practices demonstrated from the perspective of the community of practice. Both kinds of artefacts are gathered in a journey from the periphery to full participation in the discipline.

The place of an individual in the discipline (LPP) determines (i) the context for teaching and learning, and (ii) the intervention that could be developed. Interviews were used to answer the question, “Where is the participant in their journey towards becoming fully participant?” To answer this, it was necessary to understand where participation in the discipline started and where the participants were with respect to that. Determining the boundary of a system under development is common practice at the start of analysis and design cycles in the development of information systems. If the boundary is not identified then the scope of the information system design (Dennis & Wixom, 2009) and development of that system can become unmanageable (Shmueli & Ronen, 2017).

Taking an LPP perspective to determine the requirements of the intervention can be constrained by a participant’s legitimate journey towards becoming fully participant in the discipline. That journey is made up of the pathways participants can take towards achieving recognition by the discipline. The pathways represent the learning trajectories that the participant must take.

From an information systems development perspective, the periphery of the discipline identified “scope boundaries” in an “emergent outcome control” (Harris, Hevner, & Collins, 2006, p. 3) of the system under development. During the development of the system, identifying, designing and developing learning trajectories within legitimate
pathways provide an “ongoing feedback” mechanism (Harris, Hevner, & Collins, 2006, p. 3) through which emerges control of outcomes. Hence, LPP mediates the feedback within emergent control of the system being developed.

The TPACK framework was used as a guide for soliciting the requirements to be developed for the intervention. This was achieved by asking questions related to the learning situation that induced a discussion of technology, pedagogy, pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge (Mishra & Koehler, 2006). TPACK identifies the need to address the cross-pollination of concerns that influence the design. Hence it assists the designer in the design of an intervention using technology. For example, pedagogical concerns are influenced by both technological and content knowledge. However, both technological concerns and content knowledge are also useful in their own right. Consequently, requirements analysis using TPACK would need to include a reconciliation of concerns across the foci that could be guided by a culture applied in the development of the system.

Therefore, the application of TPACK aimed to induce an emergent outcome as a control on the development of the system. Its component concerns can be treated as a set of constraints that indicate “scope boundaries” for the system to be developed, while at the same time providing contexts for feedback throughout the development. To achieve this, TPACK requires a cultural effect to reconcile requirements that are guided by reflection on LPP for the vocation and in further software development Agile principles. Hence, inculcating TPACK into the interview guide has an effect, affecting a “clan control mechanism” (p. 3) as described by Harris, Hevner, and Collins (2006) in the ongoing design and development of the system. Here TPACK, in turn, determines the culture that affects the outcomes.

Using theoretical frameworks as lenses in the design of the interview guides affected meaning making. In the case of LPP, the discipline periphery and the pathways towards full participation in the discipline identify suitable topics for investigation. In a manner
orthogonal to LPP, TPACK was used to provide a set of foci that need to be reconciled and require a cultural effect that came from LPP. These determine actions and understandings in the design of the interview guide that lead to meaning making (understanding and actions).

4.3.2 Interview guides for designing the TTM intervention

In this study a semi-structured interview guide was designed to solicit requirements for the development of the TTM MUVE intervention. A second guide was used to generate the Agile development method described in the methodology chapter.

Identifying the requirements for the TTM MUVE intervention

Wengraf (2001) presents a “pyramid model” to inform the design of interviews guides that are informed by theoretical perspectives. As depicted in Figure 4.1, research purposes identify central research questions that, in turn, lead to the identification of theory questions. A theory question is expressed through interview questions that solicit responses influenced by that theory.

Theory questions are not asked directly in an interview (Wengraf, 2001). Rather, theory is treated as a guide or filter for the interview questions that are asked. The theory questions for developing the TTM interview guides are listed in Table 4.1 under the heading...
“Theoretic Guide”. Interviewer questions were formulated to solicit information guided by LPP and TPACK theories. Hence, the interview determined the relationship between the described practice and these theoretic frames.

Table 4.1 lists the theoretic focus and the corresponding interview questions with TTM viewed as part of the surveying and engineering disciplines and as its own discipline. Each question (influenced by its theoretic focus) prompted open discussion with the interviewees.

**Table 4.1  The TTM practitioner interview guide using LPP and TPACK**

<table>
<thead>
<tr>
<th>Focus</th>
<th>Interview questions/prompts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content knowledge (CK) LPP</td>
<td>In TTM what do our engineers and surveyors need to know?</td>
</tr>
<tr>
<td></td>
<td>Is TTM couched within other disciplines?</td>
</tr>
<tr>
<td></td>
<td>Discuss ‘levels’ (artefacts are considered) within the discipline here.</td>
</tr>
<tr>
<td>Technological knowledge (TK)</td>
<td>Let’s talk about TTM knowledge and technology that is used, for example equipment that makes up TTM.</td>
</tr>
<tr>
<td>Technological content knowledge (TCK)</td>
<td>Is there any equipment needed from (for?) TTM?</td>
</tr>
<tr>
<td></td>
<td>Are there existing resources that help when talking about TTM? (National standards documentation)</td>
</tr>
<tr>
<td>Pedagogical knowledge (PK)</td>
<td>When running a course, what approaches are taken?</td>
</tr>
<tr>
<td>Technological pedagogical knowledge (TPK)</td>
<td>Equipment and resources to enable teaching approaches (make it easier).</td>
</tr>
<tr>
<td></td>
<td>Teaching environment resources (make it harder).</td>
</tr>
<tr>
<td></td>
<td>Teaching approach requires?</td>
</tr>
<tr>
<td>Pedagogical content knowledge (PCK)</td>
<td>When teaching about TTM is there anything about TTM that determines the approach you take?</td>
</tr>
<tr>
<td>Technological pedagogical content knowledge (TPCK) LPP</td>
<td>Given you have a way to teach TTM, is there a set of concerns or ‘got yas’ in that teaching?</td>
</tr>
<tr>
<td></td>
<td>Resources?</td>
</tr>
<tr>
<td></td>
<td>What <em>needs</em> to be covered?</td>
</tr>
<tr>
<td></td>
<td>Does this change depending on the discipline (i.e. engineering, surveying)?</td>
</tr>
</tbody>
</table>

4.4 Inducting an Agile process by drilling into details – follow-up interviews

Further interviews of the same participant were used to drill down and determine details of the proposed intervention and MUVE development that were led by LPP and TPACK concerns. As recommended by a participant, *The Local Road Supplement of the COPTTM* (NZ Transport Agency, 2010) was used to identify and discuss TTM layouts that may be used during the intervention to help with trainee learning trajectories. These were accompanied by discussions and reflections on interaction metaphors (Sharp, Rogers, &
Preece, 2007) that would enhance learning and potentially be used as guides in the selection of affordances to be developed or used within the MUVE. An example of a second interview guide is presented in Table 4.2. The title of the interview is “Inducting a backlog list” to identify that the interview was leading to developing the intervention using an Agile development process.

Table 4.2  Inducting a backlog list – drilling for more details

<table>
<thead>
<tr>
<th>Section</th>
<th>Prompts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting the Agile development process</td>
<td>The purpose of this meeting is to discuss the features we are to develop for a class that is using the MUVE</td>
</tr>
<tr>
<td>Features on the backlog list</td>
<td>Then from that list of features we will identify those that can be developed in the next short period of time – giving features [a relative] priority. That list of features then becomes the “backlog list” for development of the system.</td>
</tr>
<tr>
<td>Learning pathways</td>
<td>I’d like to get us started by identifying students’ learning pathways, and discuss metaphors that can be used to help students use the system. Learning pathways are the ways a person moves through a subject as they learn. Each person will learn in different ways. However, your teaching pattern will provide a way through the subject’s material.</td>
</tr>
<tr>
<td>[Interaction] Metaphors</td>
<td>Let’s also consider metaphors that might be useful for students and staff when working with TTM in the MUVE.</td>
</tr>
</tbody>
</table>

These reflections on requirements fed into the induction of software development processes as discussed in section 4.5.

Interview Design

The theory-seeded and inculcated interview guides identified teaching and learning approaches that led to the design of a MUVE intervention. Using LPP and TPACK in the design of these interviews affected the focus of the design and induced an ongoing subtext in the development process.

Interview – participants and procedures
Two expert teaching practitioners volunteered to work with the designer/researcher in the design and development of the MUVE for TTM instruction. Both had over 10 years’ experience in teaching TTM. One was a surveyor and tutor (ST); the other was a civil engineer and the programme coordinator for Civil Engineering (PC). The first interview was conducted with the surveying tutor, for whom the intervention was being designed. The second interview was conducted with the programme co-ordinator, who described the courses in which TTM was situated and provided an overview of TTM as a discipline. A preliminary analysis of the audio-recorded interviews identified the context in which TTM was taught as a necessary part of the engineering curriculum. A second interview with each of these participants were conducted to provide more detail about a suitable intervention.

The interviews revealed that: the constraints on the time and place TTM instruction could take place; details about TTM's vocational structure; and the three levels of qualification in TTM – a person warranted to place traffic management delineators on the road, a person being responsible for the work site, and the regional traffic controller who is responsible for TTM in a specific region.

The first interview was conducted with the surveyor tutor/practitioner (ST) in order to gain more detail about how a TTM class was currently conducted and how it could be conducted with a MUVE. A mock-up of a TTM workspace MUVE was produced, based on layout information from the COPTTM (see Figure 4.5). The interview also identified where, and in what way, the MUVE might be used in the course. The interview introduced a discussion of learning trajectories (Cobb, 2000; Hunter, 2006) which led to identifying a set of features for the MUVE. These features became the focus in the induction of a backlog for an Agile development “sprint”.

The second interview indicated that TPACK and LPP could be used to guide the design of interview guides. The collected data was useful in setting the context of the research. A more in-depth application of the theories also guided subsequent foci of the research, such as, how using simulation related to pedagogy in TPACK.
4.6 Design based research represented as swims in swimming lanes – the Swim Model

Participants joined the design and development process for periods of time as and when they were available. Their participation in the project influenced and led to modifications in the process. This activity can be likened to taking a “swim” in the project “pool” of activities that take place over time. Over time a participant may return to the pool for more than one swim. Hence, analysis of, and reflection on, the DBR is presented in terms of participant swims in the project.

Models of processes using “swim lanes” and “pools” are well known. For example, the Business Process Model and Notation (OMG, 2011) includes notations for concepts, such as, pool and swim lane. and UML sequence diagrams (Ambler, 2014) depict sequential interactions of instances of object-oriented classes using vertical tracks and swim lane notations. (See Appendix A4. UML Sequence diagrams have Swim lanes) A less well known, user-centred interaction design that is integrated with Agile processes has been represented as parallel developer and designer tracks, in which separate developer and design cycles affect each other over time (Sharp, Rogers & Preece, 2007).

As shown in Figure 4.2, the design and development over time is depicted as separate horizontal parallel tracks that influence each other. In that notation, the designer track leads to work in the developer track that is depicted by an arc ending in an arrow that
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touches a rectangle depicting work in a given cycle for the developer. In turn, the developer track leads to work for the designer track, which is depicted by an arc ending in an arrowhead that ends on a rectangle depicting work in a given cycle for the designer.

**Components of the swim model**

Influenced by information systems models of process, the “swim model”, as a notational model of participant activities in the project, was developed to present an overview of the DBR process of design and development as it unfolded. Figure 4.3 presents the elements of the swim model developed for representing in overview the DBR process in TTM using swim notation in relation to time, swims, tracks, participant interaction while gathering data, and participation in events.

![Diagram depicting time, stages, swims, tracks and length](image)

Figure 4.3  Diagram depicting time, stages, swims, tracks and length

Each element is interpreted as follows:

- **Time** starts on the left of the diagram (March 2011) and moves to the right (December 2012).

- **Stages** There were two stages: “Preparing for the educational context and MUVE development” and “Prototype implementation”.

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• *Swims* depict sequential and parallel participation in the development of the MUVE as horizontal rectangular strips. Swims by the same participant, for example, are depicted in the same horizontal line, such as, the three strips labelled “Tutor Surveyor”.

• *Track* identifies three components of the process: participants, events, and artefacts and services. A strip that represents a period of activity or participation in the swim lane is thought of as a swim in the respective track. The length of a swim indicates the duration of that swim. While the swim is depicted as continuous over a period of time, the actual time spent might have been brief (e.g. for a meeting or a review session). It is represented as continuous so that the swim can be labelled.

• *Length* The length of the strip also expresses informal work and ongoing engagement in the development process. Comparing lengths of strips provides a visual comparison of swims by participants and the swim’s potential effect on the overall development process. The placement and length of a swim indicates the sequence of occurrence, contiguous participation and a relative visualisation of scale in terms of time rather than a precise period of time.

**Transfer and communication between swims**

Once the basic elements of the model were established, the model was developed further by adding lines to depict connections and interactions between different elements. Figure 4.4 depicts the design and development of the TTM MUVE using the swim notation.
Lines connecting swims depict data gathering and design interactions of swims and the subsequent activity emerging from the interaction. That interaction may have led to an Agile sprint by the developer, which was followed by a review by the domain experts – the tutors and the designer. Three types of connecting lines are used in the swim notation:

1. **Dashed line arrows** (at the beginning and/or at the end of the line)
   These arrows show interactions between participants towards the development of the MUVE during their respective swims. These directed dashed-line arrows, sloped from left to right and upward or downward, between swims or from an event or an artefact or service, depict a transfer of required information through an arranged discussion, interview or meeting.

2. **Dotted line arrows**
   These lines show participation in preparations and discussions prior to the development of an artefact used in the research. There were two situations where they were used. The first indicates participations in the decision to undertake the development in a MUVE. The second situation indicates the start of the development of the interview guides used in the research. Dotted-line arrows attach a participant to a ‘circle’ as described below.
3. *Double-ended broad arrows*

These arrows depict developmental or design interactions at a significant event, which involved several participants and included or made use of an artefact or service. They also indicate that data and further formative or semi-summative design work was being undertaken that involved and affected the participants, artefacts and services.

Circles are used to depict the connections between a decision (e.g. to develop a MUVE intervention) and participant initiators (those involved in making that decision). A circle represents the iterative nature of the beginning of a development rather than a defined point in time. There are five ‘starts’ that can be seen at beginning of the swims:

1. Virtual World Server service
2. TTM MUVE (Mock up 1)
3. TTM MUVE (Mock up 2)
4. TTM MUVE (Prototype)
5. Research instruments.

### 4.7 Swimming to develop the TTM MUVE

Taking a DBR perspective, the main artefact developed was a prototype of the TTM MUVE. The prototype was demonstrated twice during semi-structured interviews to identify any further requirements. These are depicted in the events swim lane track as a ‘preview demo’ and ‘short demo’ (Figure 4.4). These events led to further refinement of the MUVE and further refinement of the research instruments. The research instruments were a set of artefacts being developed as identified in the ‘research instruments’ swim, depicted in the ‘artefacts and services’ swim lane track. A virtual world (VW) server that included its own building and scripting system was selected, implemented and used throughout the development.

Thirteen participant swims took place during the development. These included those who were formal participants in the project and those who were not:
1. The researcher, designer and developer (six swims);

2. An expert VW builder and an IT student who tested the VW server (two swims);

3. The survey tutor and the course co-ordinator, who provided feedback about the design and development process (four swims); and

4. Student testers who provided feedback during a ‘short demo’ (one swim).

A civil engineer/tutor, (not depicted in Figure 4.4 and not formally a participant in the project), confirmed that the TTM layout selected for an intervention was used to test civil engineering students’ TTM knowledge at a different institute. Table 4.3 summarises the participants and their participation during the DBR process.

Table 4.3. Participants and their participation during the DBR process

<table>
<thead>
<tr>
<th>Participant</th>
<th>Participation</th>
<th>Method requirements were gathered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil engineer/ Programme coordinator (PC)</td>
<td>Interview 2 (IA2)</td>
<td>Audio recording interview 2</td>
</tr>
<tr>
<td></td>
<td>Planning for an intervention.</td>
<td>COPTTM local roads supplement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field notes</td>
</tr>
<tr>
<td>Tutor surveyor (TS)</td>
<td>Interview 1 (IA1)</td>
<td>Audio recording of Interview 1</td>
</tr>
<tr>
<td></td>
<td>Interview 3 (IA3)</td>
<td>Audio recording of the preview demo event</td>
</tr>
<tr>
<td></td>
<td>TS participated in demo interview 4 (IN4)</td>
<td>Analysis of Interview 4 in a field note</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COPTTM local roads supplement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field notes</td>
</tr>
</tbody>
</table>
The TTM MUVE was composed of six significant parts that were developed through sub-
task swims for the six starts described above. ‘Toy Town’ (for TTM) was designed and
developed first, followed by ‘Avatars (for TTM)’. Both continued throughout the process.
The development of ‘Road Cones’ and a ‘Heads Up display’ (HUD) followed. The
development of the Road Cones continued as part of the development of ‘Road Cones &
Signs’. However, it was decided to discontinue the development of the HUD interface
because it was decided that using a HUD metaphor could potentially distract from
immersion in the VW, in which the main interaction metaphor is that of an avatar acting in
the virtual world, as described in the following. A HUD metaphor potentially puts control
of the interface in front of the VW display giving the sense that the VW is behind a screen
and controlled through ‘buttons’ display on that screen, and not directly through the action
of the avatar. The ‘TTM Work Truck and Cars for town’ development during the
prototype development stage added authenticity to the learner experience by providing
scenarios where the trainee would be able to ‘drive to the work site’, rather than ‘walking’
an avatar around Toy Town.

Taking place prior to ‘preview demo’, the event ‘Virtual World server test’ successfully
provided confidence that the public, when given a login and an avatar, could access and
use the VW. The VW expert developed two islands into a small cityscape as part of TTM
MUVE (Mock up 1) that was used during the ‘preview demo’ session. Both the
programme co-ordinator and the surveying tutor participated in the ‘planning for
intervention’ events that are depicted as a single event in Figure 4.4. This event was not

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<table>
<thead>
<tr>
<th>Role</th>
<th>Participation Details</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher, designer, developer (RDD)</td>
<td>Participated in all events</td>
<td>Agile board (sprints)</td>
</tr>
<tr>
<td>VW expert</td>
<td>PREVIEW session</td>
<td>Field notes</td>
</tr>
<tr>
<td>Student testers</td>
<td>Participated in demo</td>
<td>Field notes</td>
</tr>
</tbody>
</table>
discussed in participant swims below. The planning for intervention was ongoing and challenging; for example, times organised for the intervention were difficult to arrange and complete because staff would plan for the event then a work-related obligation would require the planned date to be moved.

![Mock up of MUVE](image)

**Figure 4.5** Screen shot of the mock up as used in interview three. Traffic management diagram TMD30 2nd Edition of the Local Roads Supplement to NZTA COPTTM (NZ Transport Agency, 2002, p. 30)

### Participant swims

Seven participants were involved in the design and development of the MUVE. The effects of participants’ swims were considered in terms of LPP, TPACK and their outcome on the development process. Participation by the VW expert has already been described above. Students’ participation is described in the swims undertaken by the TS.

The following sections present the most influential swims by participants on the design and development of the MUVE.

**Civil engineer programme coordinator swims**

The civil engineer programme coordinator (PC) acted as a project champion and participated in interview two (I2A) (See Appendix 4.I2A Interview Two.) PC also participated in the start of the ‘TTM MUVE (mock up)’ and the ‘TTM MUVE (prototype)’ artefact development swims. Interview two provided a description of TTM and its practice, and the educational context of TTM training. PC provided a description of TTM practice as required by engineers and surveyors:
They need to be conversant with the Code of Practice of TTM [pause] to a degree that it, allows them capability to design organise and test a TTM site under varying conditions. [pause] And by conditions, I mean the appropriate level of TTM support particular ... um [volume] of traffic for that road they are working on. They need to test the system that they've been working on for compliance before they order the TTM system. Alternatively they may have to audit their worksite site for compliance, so that entails a full and precise knowledge of the signage the procedures the cone tapers, the speed limits, the limitation signs, and any other traffic management devices that are used. PC (I2A, 02:20-03:41)

Thus, the first LPP-inculated question, as shown in Table 4.1, led to a description of the level at which engineers and surveyors undertake TTM practice. The requirements meeting about TPACK concerning content knowledge (CK) are identified by the reference to the COPTTM (New Zealand Transport Agency, 2010). By asking for the PC’s definition of TTM, the interview identified the periphery of TTM practice and further CK concerns, as shown in Table 4.6. For example:

... temporary traffic management is the process whereby public safety and workplace safety is ensured for people who are transiting an area of road on which work is [in progress] and which requires some kind of health and safety regimen to ensure that safety. Fundamentally it's a protective mechanism. PC (I2A, 04:54)

**Table 4.4  Excerpt from interview two [I2A], LPP and Content Knowledge**

<table>
<thead>
<tr>
<th>Who</th>
<th>Prompt IQ/II</th>
<th>Time</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>I notice that I didn’t actually ask you about what TTM actually is in general, … if you could</td>
<td>04:19</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>… TTM has a fairly explicit definition, as laid down in the Code of Practice, which is most often referred to as COPTTM or Code of Practice for TTM, which I might add is actually under review at this point in time.</td>
<td>04:28</td>
<td>COPTTM (2012) being reviewed; Interview was in 2011. TTM were using COPTTM (2010)</td>
</tr>
<tr>
<td>Researcher</td>
<td>Oh that’s right. I remember you mentioned they’re in the process of doing that.</td>
<td>04:49</td>
<td>Researcher talks over the interviewee</td>
</tr>
<tr>
<td>PC</td>
<td>But, to go back to the original thing, TTM is the process whereby public safety and workplace safety is ensured for people who are transiting an area of road on which work is</td>
<td>04:54</td>
<td></td>
</tr>
</tbody>
</table>
A MUVE FOR TEMPORARY TRAFFIC MANAGEMENT

Responses from interview questions often produced more than the intended theory question (TQ), providing a rich source of information regarding TTM. For example, the question posed (I2A, 07:30), as shown in Table 4.5, had an LPP focus (TQ). However, in responding to the question, PC had to describe technological aspects of TTM that determine pathways in the TTM discipline; the road system hierarchy, as described, relates to the structure of TTM as a discipline and the qualification of personnel who install traffic management. These identified technological concerns led to a discussion about whether high volume roads would need to be included in the design of simulated roads that are part of the Toy Town simulation. From discussions with PC and TS about the proposed intervention, it was decided that low volume roads would be sufficient. In this way an interview question with an LPP (TQ) focus, produced information regarding technology used in TTM that led to a discussion about TCK and its potential application from a TPK perspective.

Table 4.5 Excerpt from interview two [I2A], LPP and Technological Knowledge

<table>
<thead>
<tr>
<th>Who</th>
<th>Prompt IQ/I1</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>Is there a progression within TTM? I notice you mentioned the number of cars, the volume of traffic.</td>
<td>07:30</td>
</tr>
<tr>
<td>PC</td>
<td>The system of highways is organised into a hierarchy of … at the bottom end moving from low volume roads though to extremely high volume roads … the traffic volume is determined by something called the [calculated daily volume of traffic] and the number of lanes as well, and the licensing of the Traffic Controllers and what is known as SMTS or Site Traffic Management Supervisors is hierarchal. So you start at level one controller, then essentially can work on that level of road and then moved right up the hierarchy to specialised or better qualified Traffic Managers who are able to install Traffic Management.</td>
<td>07:48</td>
</tr>
</tbody>
</table>
The technology used by TTM was investigated by using TPACK, thereby providing more details regarding TCK concerns. For example, Table 4.6 shows that TTM requires equipment that ranges from traffic management vehicles through to road cones.

<table>
<thead>
<tr>
<th>Who</th>
<th>Prompt IQ/II</th>
<th>Time</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>When you think about TTM, you mentioned a whole lot of equipment earlier, for e.g. [standard] document [COPTTM], the national document that describes the categories of information that need to be covered and there is also obviously equipment to run as well.</td>
<td>10:51</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>Yeah, there is a standard, a standardised list of approved equipment that can range from the simple devices as a cone and to different sizes of cones relating to, essentially different site distances for notice on operating the roads at different speeds, right through to the other end of the spectrum where they are using attenuator trucks to provide advance warning for a merging traffic management situation where the job place is moving, … yeah, so there is a hierarchy; there is a range of levels of complexity of machinery that is required or devices that are required as you go through the different [levels].</td>
<td>11:27</td>
<td>This discussion may identify cost or expense as a reason for simulation-based training.</td>
</tr>
<tr>
<td>Researcher</td>
<td>These are required by the companies who are doing the job and they …</td>
<td>12:28</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>Yeah, it is very expensive, the investment in equipment is very very large indeed. You know, an attenuator truck would probably cost you $2,000 or $3,000, or a cone can cost you as little as $20.00. And then there is … the personnel who, are an additional cost, but there is definitely a vast range of equipment we can’t afford to buy.</td>
<td>12:32</td>
<td></td>
</tr>
</tbody>
</table>

Larger more complex TTM equipment was left for later development. Table 4.6 shows that the prompt relating to the equipment used in TTM (I2A, 10:51) produced the expected TQ focus and supported the previously described decision to model low volume local roads because developing models of more complex equipment would take more time and potentially not be used when training the students in TTM.

Table 4.7 indicates that the prompt by the researcher (I2A, 09:00) was intended to gather further information about the process through which a person becomes a qualified TTM practitioner. The response described the organisations involved with TTM training and where TTM training would be found in Polytechnic and University courses. PC identified
that the courses at the Institute would allow trainees who completed the course to undertake a TTM qualification at an organisation that has a license to issue TTM qualifications.

Table 4.7  Excerpt from interview two [I2A]: LPP pathways heading towards pedagogical content knowledge

<table>
<thead>
<tr>
<th>Who</th>
<th>Prompt IQ/II</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>Is it on the job training that gets them to the level …</td>
<td>09:00</td>
</tr>
<tr>
<td>PC</td>
<td>Ah</td>
<td>09:04</td>
</tr>
<tr>
<td>Researcher</td>
<td>How does that work?</td>
<td>09:09</td>
</tr>
</tbody>
</table>

PC  No, there is a formal training process. There are a number of training providers that are from private companies through PTE, such as, NZ Institute Highway Technology and some in-house training schemes by companies like Fulton Hogan. However, there is a requirement of the Polytechnic or University to, I suspect, at least be University level [???] across a number of courses, construction management, construction practices. I guess to a lesser extent contract administration through to Traffic Management and design, say an inner city worksite or multi-story building, and roadside maintenance, traffic engineering and traffic and highway engineering which, all have components of the Traffic Management System taught, although we don’t issue a TTM qualification per say because we are not qualified or licensed to do that.

Researcher   So prepare people in a way that they could be aware of the requirements, [???] licence

PC  Once they have left our courses they should be able to walk straight in to a [TTM] test. They are taught to, a standard that would allow them to do that.

Details relating to TPK, and leading to PCK, were prompted by the researcher as shown in Table 4.8 and Table 4.9. In response to the prompt regarding resources used in TTM training (I2A, 13:00), as shown in Table 4.8, PC indicates that there are ‘virtually’ no resources other than the COPTTM (New Zealand Transport Agency, 2010).

Table 4.8  Excerpt from Interview 2 [I2A], Technological Pedagogical Knowledge, Pedagogical Content Knowledge

<table>
<thead>
<tr>
<th>Who</th>
<th>Prompt IQ/II</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>You mentioned the national standards document that you have referred to and that is an existing resource. Are there any other resources that, in your…</td>
<td>13:00</td>
</tr>
<tr>
<td>PC</td>
<td>Virtually none.</td>
<td>13:15</td>
</tr>
<tr>
<td>Researcher</td>
<td>I noticed that you have presented a CD which, I think your student created that one.</td>
<td>13:17</td>
</tr>
<tr>
<td>PC</td>
<td>Yeah, that was part of a project that students were required to do. That particular student was extremely knowledgeable and he works in traffic management and is an auditor, so and he works for a consultant in [REMOVED], and he produced this CD …</td>
<td>13:23</td>
</tr>
<tr>
<td>Researcher</td>
<td>What would be an example of a resource that you can use to help with your teaching? Are there any other resources or virtually nothing?</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>Virtually none, no, and I think that is where the usefulness of your proposed project might, um, might lay.</td>
<td>13:57</td>
</tr>
</tbody>
</table>
Table 4.9 shows that the prompt that asks if there is anything that might make TTM training more difficult (I2A, 14:08) led to responses that suggested a need for authentic situated learning, while identifying that training TTM directly on the roads would have safety concerns for the public as well as the TTM students.

That led to a more detailed discussion later in the interview (I2A, 16:30, 22:58) in which PC described using physical toy models to simulate TTM situations in the classroom. Students tended not to take them seriously and the PC stated that the toy models did not convey the serious nature of the TTM, especially for adult learners. This suggests that the name, Toy Town, needed to be changed for a simulated TTM training town. Although the simulation used authentic materials and a carefully constructed road system, when the simulation is being tested for use in an intervention it would be necessary to determine the reaction of students to a game-like environment.

The approach to TTM training taken by the PC, and potentially all trainers, is classroom based, Table 4.9 from PC (I2A, 16:30), in which description of TTM situations and producing their corresponding layouts according the COPTTM (New Zealand Transport Agency, 2010) are the goals for the learners. As described by PC, “it tends to be really rather old school teaching, like ‘here is the book, this is what the standard test you must do, you must learn that and you must be able to apply that in real life’, so it is not an ideal way of learning” (I2A, 16:30), in Table 4.9.

<table>
<thead>
<tr>
<th>Who</th>
<th>Prompt IQ/II</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>Within the current teaching environment, is there anything that might make it a bit more difficult, in terms of the resources, in terms of the technology?</td>
<td>14:08</td>
</tr>
<tr>
<td>PC</td>
<td>The difficulty is that we can’t really take students, you know live students, out on a live road and do real things with them. Obviously for safety reasons, we would have to put up TTM ourselves in order to be able to take a class onto the road, and have some disruption to the public. They don’t tend to appreciate that very much and it is not a particularly easily controlled situation because students can [muck] things up at times and you cannot forsake the whole notion of having a standardised … practice to avoid errors and which is on a learning situation …</td>
<td>14:18</td>
</tr>
<tr>
<td>PC</td>
<td>There is a real[ly] strong concern [for the] safety both for the students and for the public when you take them onto the road. It is not a situation that you can manage adequately as something …</td>
<td>15:14</td>
</tr>
</tbody>
</table>
Struggling to teach if there are 30–35 students running around

Yeah, it is [a serious] problem and a multi-factorial problem that is complicated by any students who perhaps don’t follow instructions particularly well. So they tend to believe, perhaps, that if they have the right answer and being in a live situation is not the time to find out that it is wrong.

What approaches are taken when you are teaching?

It is very much a paper-based exercise, as much as we try to get as much of the fundamental idea of TTM across and I think this is true for all trainers …. They take this classroom approach now – you can get a plastic place mat with the little road makers and the toy cars and the toy cones and you can teach them using a model [of] the physical model. Some students react quite well to that; some don’t. … with various learning styles that presents them their own difficulties or advantages and otherwise it tends to be really rather old-school teaching; like here is the book, this is the standard test you must do, you must learn that and you must be able to apply that in real life. So it is not an ideal way of learning. I have tried a sort of 2D model.

Yeah… I think you will find that sometimes adult students … tend to find it a little weird to play with toy cars on a plastic mat and so they tend not to take the model very seriously and it doesn’t work or transmit the idea of the enormity, of a poorly managed worksite. It is okay to have model cars sort of crashing and it doesn’t actually convey the true problem if they get it wrong.

The following excerpt continues the thread regarding using toy models

Revisiting LPP, the PC was asked if there was a particular order or pattern that would be followed when training for TTM (I2A, 17:51). The PC indicated that training usually starts with Level 1 (low volume roads) and simple ‘dig out’ scenarios that need TTM. It is through these that TTM trainees would be taught the fundamentals of how to lay out a site and perhaps model or ‘role play it’. The PC indicated that role-playing was difficult due to the lack of TTM resources, such as, TTM signs. An environment in which a TTM trainee can role-play the laying out of TTM for specified scenarios was identified as a requirement for the TTM MUVE.

An inquiry about assessment was added to the interview, to understand more about the pathways towards becoming TTM qualified. Assessment was undertaken by providing the trainees with TTM scenarios for which they were required to produce correct TTM layouts. The PC indicated that the assessment could be iterative, “you know just simply assess them in their design TTM system, and if a student got something wrong, then we need to go back and revisit the reasons why they got it wrong, and then try and sort of teach them the correct method” (I2A, 18:51).
This iterative approach went from simple to more complex TTM scenarios, as described by the PC, “As you increase the degree of complexity they get to control quite quickly, and so the complex situations are not always that well thought out, and a good example of that is when a student has an absolutely brilliant, perfect TTM system prepared for [an approach] from one direction but they have actually forgotten that traffic comes [from] the other way as well” (I2A, 18:51).

The PC identified the amount of information in the COPTTM as a barrier for TTM trainees (I2A, 24:19). He also mentioned that most local bodies and some contracting companies had developed a much smaller document that covers the usual range of TTM compliance in their region. The trainers did not cover the whole of the COPTTM because they did not have time in their courses to do so. This led to the possibility that a subset of the COPTTM could be covered in a classroom intervention using a MUVE designed for TTM.

The TPCK TQ was prompted by an IQ that was close in form to TPCK (I2A, 33:39). The PC also identified issues with equipment, resources and students with different learning styles. According to him, TTM is kinaesthetic by nature, and classroom-based lessons with book and paper were not matched to TTM activities. He compared TTM training with cardio-pulmonary resuscitation (CPR) training, where CPR is best undertaken through physical training. The ideal TTM training situation would be a large field that is safe for the public and the trainees, in which the tutor and the trainees could layout TTM for road situations and have the trainees drive through the TTM layouts. This ideal situation influenced the selection of features to be implemented during development of the TTM MUVE.

Interview two with the PC produced a rich context for the development of the MUVE. LPP and TPACK concerns incorporated into the semi-structured interview guide in Table 4.1 affected responses gathered. Those responses facilitated requirements solicitation by providing a reference source that could be used in subsequent development. For example,
when starting an Agile development using a backlog, stories on the backlog list need to cover discipline requirements. The LPP and TPACK incorporated interview provided a way to check and discuss and reflect on how these requirements were met.

*Tutor/surveyor (TS) swims*

The TS participated in interviews one (I1A), three (I3A) and four (I4N), and events, ‘preview demo’ and ‘demo’. He also participated in the start of the ‘TTM MUVE (Mock up)’ and ‘TTM MUVE (prototype)’ artefact development swims.

*Interview one*

I1A was guided by the same semi-structured interview guide as I2A set out in Table 4.2. During I1A, TS referred to a TTM booklet, the local roads supplement, *Temporary traffic management for local roads*, that was used in TTM training. Responses from the TS focused on practical experiences as a TTM trainer, going into details on how to run TTM training classes. During I1A, the TS confirmed requirements identified by the PC and his responses were more concise. Inculcated LPP and TPACK had the same effect as they did in interview two. For example, in response to the first LPP TQ, TS described TTM:

> *Temporary Traffic Management is just for, obviously if you are working on the road it’s just temporary ... the job may go on for several years but it is temporary because it is not a permanent, fixed solution to your traffic contro., So your signage is all temporary and the management of your traffic is just supposed to go on for a finite period of time ... you have to provide all of your correct cone tapers, signs etc. to keep the motorists safe, and also to keep the workers on the site safe, so that is pretty much what it comes down to.* (TS, I1A, 3:42.

The TS confirmed that TTM was about safety of motorists and workers on the site. In response to an inquiry about what engineers and surveyors needed to know for TTM (the TPACK CK concern), he responded from the perspective of a surveyor/tutor:

> ... we just give them the basic sort of overview of TTM because, once they are out working for a firm, if they are involved in this area they will do their Level 1 or further qualification anyway.... Here, really we are just introducing them to the...
subject and making sure that they know it is required [for] particular sorts of work and how they can keep themselves safe if they’re working on the roads.... Surveyors need to know how to protect themselves and what they should be doing. They should have a generic traffic plan, generally that local authorities may have already approved, and they should stick to that to make sure they can. (TS, I1A, 2:39, 5:56).

The TS described the TTM training at the Institute undertaken by surveyors as an overview of TTM and indicated that the trainees would take a further qualification. By reflecting on the content of the course and indicating that the trainees would take further TTM qualifications when they completed their training at TI1, the TS presented a CK concern.

TS confirmed that the style of teaching and learning was classroom-based and that those classes followed the pattern described by the PC. However, with the TS, trainees worked in groups to draw solutions onto a TTM traffic management diagram (TMD), using a standard diagrammatic notation (TS, I1A, 14:27-15:05); he was identifying PCK and TPK concerns. The TS reflected a need for a more physical approach to training, using model TTM equipment, thereby considering a TPK concern; I thought [that] if I had lots of time, [I would] make my own little mini signs and cones and all that sort of thing … but of course, that’s something we never really get time for. So, yeah that is why this [TTM MUVE] is looking forward. To seeing your ideas on this as something they can actually do themselves would be excellent. (I1A, 15:06–15:20).

From a TPK perspective, the TS identified a need for resources. When he sees real TTM layouts of interest, he stops and takes photographs of the layouts (TS, I1A, 16:01–16:50). The photographs were used by the TS to show real scenarios to the trainees. Identifying this activity related to PCK and TPK concerns as practised by the TS. Therefore, the project designer took images of a TTM scenario as a reference. See Figure 4.6. While not identical to the ‘TMD 30’ (Figure 4.6) used in ‘Preview demo’ (Figure 4.2), these photographs can be used to judge authenticity in the MUVE. Figure 4.6 can be compared with scenes in the MUVE shown in Figure 4.7.
The TS was prompted to discuss TPCK and LPP concerns (Table 4.2, I1A, 21:31). He discussed issues with how drivers see the TTM; drivers who drive between cones rather than treating them as a guide. The hierarchy of qualification in traffic control warrants discussed confirmed information provided by the PC. TS described requirements for engineers undertaking TTM training, unfolding a description of training for Level 1 traffic controller certification (TC1). The certified training organisations provide this through a one-day course that may use a local road supplement booklet that includes exercises and questions to convey TTM. The TS introduced the role of the Level 1 Site Traffic Management Supervisor (STMS), who audits TTM worksites and may be an employee of a city council responsible for traffic control in that area. From an LPP perspective, the TS described progression within the New Zealand traffic management community of practice in which the warrants and qualifications identify the level of participation in that community.

The LPP- and TPACK-inculcated interview guide used during I1A produced a different
type of information from that gathered during I2A. The TS focused on classroom practices that could be used for a classroom-based intervention using a TTM MUVE. He saw the MUVE as a way to provide more authentic experiences for the TTM trainees. The interview provided for the gathering of requirements for use in the design and development of that MUVE.

*Interview three – Preview demo*

Interview three (I3A) included a preview of the VW and TTM MUVE (Mock up) artefacts, which are depicted in the ‘preview demo’ event in Figure 4.5. I3A was undertaken as an open discussion in which the designer/developer demonstrated the following: login to and moving around a VW; a small city called the Toy Land; the MUVE; avatars designed for use by trainees and tutors; and road cones. During the interview, the designer solicited feedback from the TS. Connecting and logging him into the VW services was not successful, and a lot of time was spent making sure the TS had access to the VW. Once the system was set up, the designer moved an avatar around the VW to show aspects that had been developed and a mock-up TTM site in the proposed TTM MUVE. The interview included a review of TTM scenarios depicted as TMD in a copy of the local roads supplement that might be used in an intervention. I3A was undertaken during the preview demo event swim as depicted in Figure 4.3.

Two environments were visited in the VW to gain feedback about how to proceed. The small city developed by the VW expert provided an example of how the TTM MUVE might proceed. Figure 4.8 shows that this example city was a static mock up, and included static vehicles, narrow roads and alleys, as well as the expected. Similarly, Figure 4.5 shows the a mock up of the Toy Town MUVE based on a TMD. An IT student, who had developed a third environment for their Bachelor of IT project walked it through during the preview demonstration.
The TS demonstrated being ‘present’ in the MUVE to ensure that the MUVE was authentic for the trainees. Feedback was provided on the scale of roads and road markings in the Toy Town MUVE. The TS provided advice on how wide the roads should be and confirmed the standard size and nature of the road cones. For example, road cones are reflective and visible at night as shown in Figure 4.9.

The TS noted that there were no street lamps in the MUVE. The shape and clothing of avatars for use by trainees and tutors was also shown (see Figure 4.10) as well as the selection of male and female trainee avatars.
The running of a subsequent demonstration that included students was discussed. Results from the interview led to development of the MUVE.

*Interview four*

The goal of this interview was to induct a backlog list for use in Agile development. It was undertaken after the analysis of the previous interview and further discussions on running a classroom intervention using the MUVE, and scenarios of TTM layouts using standard TMDs. This led to the design of roads in Toy Town to allow the trainees to produce the selected TTM layouts (see Figure 4.11).

The TS also outlined a two-hour class session he ran as follows:
1. Mind maps were used to introduce TTM terms and lead conversations.

2. Run overview. ‘Why have TTM?’ TTM Principles and the reason TTM is undertaken. This was a conversational lesson, in which responses from students were used to determine their knowledge.

3. Described the generic layout of a worksite. Introduced TTM terms, such as, 'work zone' and the protection that is required. This was done with a TTM card showing the layout.

4. Zones of a worksite. Students became familiar with TTM worksite zones. Two diagrams were used; one with labels and one without labels.

5. A discussion of the way the distances of the zones change according to speed. Made trainees aware that TTM goes both ways. The visual effect of speed on the distance between cones so that they look like you cannot drive through them. Videos were shown.

6. TMD for TTM layouts of scenarios found in the local roads supplement were shown with pictures of real equipment.

7. A series of TMDs were discussed. Students became familiar with plans that matched common TTM situations; TMD 21, 22, 30, 31, 32 and 39 from the local roads supplement.

8. Trainees practised TTMs using empty plans and examples.

9. Reflection and summary. Reviewed by asking questions. The serious nature of TTM was checked.

For the first intervention, it was intended that the MUVE would be used in place of sections six and seven of the course plan. I4A was recorded with field notes and reflection after the interview.

**Short demo**

Based on review and reflection on fields notes. The TS and students were given a short demonstration of the MUVE. They logged into the MUVE, used their avatars to go to a worksite, and practised laying out cones. The demonstration included having One avatar drove the TTM work truck to the worksite while the other students sat in the truck. As would happen from time to time during the demonstration, communication on the
Institute’s network became very slow. The slow network on the VW server slowed down the interactions in network communications. This is called ‘lag’ by computer gamers. The slow network led to a slow log in and communication with VW server system during the demonstration. In this ‘laggy’ environment, interaction through the avatar was slow. The demonstration proceeded with the designer showing how cones could be placed and removed, the signage and how to drive the truck. These are depicted in Figures 4.7, 4.9, 4.11 and 4.12. Students were not impressed with the environment. Comments from students included: “Don’t do much”, “we’re into it”, “One wanted to be out on the road”, “Demonstration not good – negative immersion”, “Games”.

Figure 4.12  Screenshot of an avatar at the driving seat of a truck, parked at the worksite

Summary

TS swims affected the development of the MUVE. Responses by the TS to LPP and TPACK prompts in the first interview were based on his classroom practices. I3A provided a context for taking reflective notes that led to a discussion in I4A about lessons that could be used in an intervention. While TTM training for engineers was more detailed than that required by surveyors, details of a potential classroom intervention took form through the swims undertaken by the TS.

Researcher, designer and developer swims

The designer determined the overall design direction and authenticity. During the developer swims, an Agile process was used to build objects, code scripts and implement support services. The researcher enacted phase one of the method in the TTM case towards
developing a classroom-based intervention using a TTM MUVE, as described here. The researcher, designer and developer (RDD) participated in all events.

The research artefacts developed by the RDD through enacting this phase for the TTM case were the LPP and TPACK inculcated research instruments as described above. These were expressed in the broader scope of the three-phase DBR methodology that was being developed in this thesis.

The RDD designed, developed and implemented four artefacts or supporting services for the MUVE: a VW server, simulation areas for TTM MUVE (Mock up 1), TTM MUVE (Mock up 2), and TTM MUVE (prototype). TTM MUVE development included: Toy Town (for TTM), Avatars (for TTM), Road cones, signs, TTM signage, the HUD, and drivable TTM work truck and cars for the town. The RDD participated in the VW server test, the preview demo, the short demo, and the planning for intervention swims. As a researcher, the RDD designed and organised the four interviews described above. As a researcher and designer, he analysed records from the interviews were and determined the requirements for the design of the MUVE. Those requirements were then developed and implemented by the RDD taking a developer role.

Working with the TS, an Agile development process was inducted during I4A, with refinement informed by I2A and brief feedback meetings during development using the Agile process. The tool selected to was Agile Buddy, a free Agile, SCRUM-based software development management system was used to manage the process. The RDD recorded and tracked changes in the status of user stories and features until Agile Buddy was shut down. At that point, the Agile Buddy group provided an online interface for downloading the record of the Agile process (See Appendix A4. Agile Buddy Record Summary).

The RDD set up and deployed the VW server software used to host the TTM MUVE the server’s supporting computer hosts and database system, and organised access to the Internet Protocol (IP) ports required to operate the server. Details of this process are
described in Appendix A4. 3DVW server set up.

*Virtual world server testing (Creating accounts for the VW service – avatars and users)*

Figure 4.4 depicts a test undertaken to provide confidence in accessing and using the system by people other than the RDD. The VW expert and the IT student were given eser accounts and avatars. A command interface was provided for managing the running OpenSimulator VW (OpenSimulator, 2018). User accounts and their corresponding avatars were created with the same command in OpenSimulator. After logging in for the first time, a default avatar is presented (see the image on the left of Figure 4.13). The default avatar body shape, hair and clothing can be changed using the editor provided in the viewer.

![Figure 4.13 On the left, a default avatar. On the right, selecting a new look for a TTM trainee’s avatar](image)

An alternative way to change the look of the avatar from the default one was through the selection of pre-made body shapes, clothes and hair. This approach was provided for users in the TTM MUVE. Working through their avatar, the user could touch one of two cubes, that then presented the option to copy its contents to their inventory (see Figure 4.13). The contents in their inventory were organised into a folder. The user could then select the folder using a context menu, on which there was an option to ‘wear’ the contents of the folder. Executing this action, the viewer presented the option to replace the existing look or add the contents of the folder to the existing look of the avatar. See TTM trainee avatars in Figure 4.10.

The VW server test took place over a few weeks. The VW expert logged in from a distance, and built and imported their stack-simulated city. He practised adjusting avatars and buildings. The IT student logged in using a workstation on the Institute’s campus network and implemented aspects of a BIT Capstone project on a simulated island. Observation of this student building in this environment provided some more testing.
because she was making and testing scripts specific to this VW. Thus, a series of interactive scripts that were implemented under the supervision of the RDD on the VW allocated to her by RDD. On her island, she a created and scripted a MUVE practising the assembly of scaffolding during the training of staff working for a scaffolding company. For that build, this student produced a number of interface interactions using scripts.

**Developer Scripts**

It is interesting to know more detail about developer scripts because they are an essential core activity when designing any VW. As a developer, the RDD undertook all building and all interaction scripting of the VW TTM MUVE and implemented the Agile development process that produced the artefacts. In this case, the main development environment was the Phoenix Firestorm Viewer (The Phoenix Firestorm Project Inc., 2018). As with all open source viewers that view Second Life and subsequently view OpenSimulator VWs (OpenSimulator, 2018) this viewer included object building and script editing. OpenSimulator provided two scripting languages; Linden Scripting Language (LSL) and C#. The OpenSimulator VW server was set up with LSL as the only scripting language. The LSL editor (van der Heijden, Kudra, Archer, & Thoy, 2018) as an LSL syntax-highlighting text-based editor that includes offline debugging was tried during development. Offline debugging was not successful because the offline system did not match the memory configuration of the online VW server. Therefore, in the latter part of the development of the TTM MUVE, scripts were written by direct editing within the VW server. In keeping with good coding practice, scripts were labelled with appropriate version numbers and frequent archives were kept of the VW MUVE. Essential scripts were placed inside VW objects that were kept in a developer area – a sky box set aside for inworld development.

**4.8 Summary and conclusion**

Taking a pragmatic and interpretive approach to developing tools of inquiry led to the design of semi-structured interview guides framed by LPP and TPACK. This original approach provided evidence that these were useful in soliciting requirements during the design process. This was done with the intention that LPP and TPACK would impact the process. Reflecting on the control of IS development processes, LPP and TPACK were
considered in terms of their affective influence on the DBR in this case. It was found that both LPP and TPACK required resolution through the cultural oversight of the particular vocation of TTM and hence, the process control of this Agile DBR could be characterised as being through emergent “clan controls” (Harris, Hevner & Collins, 2006, p. 1). Since both are treated orthogonally, it became clear that LPP could provide cultural guidance that complements TPACK.

The innovative technique of the swim model provided an overarching perspective as well as an analytical tool for the DBR process, which emerged from enacting phase one of the DBR Agile methodology. This enactment developed theory-seeded instruments in the form of semi-structured interviews, which were used successfully for soliciting requirements for design and development. These requirements were managed through a tailored Agile process and implemented in the MUVE used as a classroom-based intervention.

The following chapter presents findings for the development of a MUVE for training ship’s bridge personnel in standard maritime communication practices on the bridge of a large vessel. Therefore, the following chapter describes further development of the phase one and proceeds into phase two design processes in a different vocational context.
CHAPTER FIVE
A MUVE FOR COMMUNICATION ON A SHIP’S BRIDGE

5.1 Introduction

This chapter presents findings from enacting phases one and two of the hDAS methodology to design, develop and use a second vocational MUVE-based intervention. The Agile software development approach and the development of instruments as enacted in TTM were revisited in this case. The swim model notation was used to express participation in both phases one and two of the DBR methodology.

In this case, a MUVE-based intervention in the training of standard maritime communication on a ship’s bridge was designed and used in a classroom. This authentic vocational teaching and learning situation allowed for further consideration of LPP and TPACK as theoretical frameworks in the design and development a MUVE-based intervention. In this case, LPP and TPACK were also used as frameworks of reference in the analysis of data recorded during the intervention. To achieve this, data recordings of the intervention were used to identify authentic situations using an LPP perspective as they occurred during the intervention. TPACK provided further perspectives from which to structure the analysis. For example, to extent to which the pedagogy used during the intervention matched the content knowledge and to extent to which the technology affected the authenticity of the teaching and learning situation.

Findings from phase one and phase two of the methodology are presented as follows:

- Phase one presents the selection and development of a MUVE-based intervention to be used in a course taken by trainee mariners.

- Phase two presents findings from the implementation of the intervention in a laboratory classroom in which mariners were undertaking certification to be become ship’s Mates.

The following sections re-introduce details proposed for these phases in the methodology so that they can be used to reflect on the extent to which the method suited the
5.2 Phase one: Selection and development of the MUVE-based intervention

As described in Chapter 3, during the first phase, work with a practitioner identifies a point in the course where a MUVE-based intervention can be used. The method includes the following:

- Students' learning trajectories are used to identify and determine details of the intervention that is to be designed and developed.
- TPACK is applied to the design of the intervention. Issues in the use of the technology, content and the content knowledge are investigated and a hypothetical set of trajectories for the intervention are developed.
- LPP is applied in the design of the intervention.

These are then used to develop requirements for a software development process and in the development of the intervention.

5.3 The context of the intervention identified in phase one

A MUVE-based teaching and learning intervention was developed in collaboration with maritime tutors, trainee mariners at a technical institute and mariners in their place of work. LPP and TPACK were used in the design of data collection interviews during phase one and used as the source of requirements in the development of the MUVE-based intervention. These were expressed as stories in an Agile software development process.

The data collection included:

- Voice recordings of semi-structured interviews and open discussions with tutoring staff and the programme manager at the Institute
- Reflective field notes made of:
  - interviews with tutoring staff and the programme manager
A MUVE FOR COMMUNICATION ON A SHIP’S BRIDGE

- a visit to the vessel that included open discussions with the Master of the vessel on which the ship’s bridge MUVE was based, and with the Harbour Master of the port where the vessel was docked
- In-world video recording of a test intervention and focus group discussion with trainees
- Images taken on the bridge of the vessel
- Agile process documentation.

Participants in phase one were Institute tutors and trainees, a designer, a developer, a graphics builder, a Harbour Master and the Master of a large vessel in port. All Institute staff were certified bridge personnel and three of the staff were certified to be a Master of large vessels. Data was also collected from field notes of conversations with the ship’s Master and the Harbour Master during a visit to a ship’s bridge.

Open discussions and semi-structured interviews with Institute tutors and domain experts determined the educational context for the MUVE-based intervention. The ship’s bridge resource management (BRM), which included training in communication and team work, became the proposed context for the development of the intervention and continued as the overarching context throughout the case. This context was clarified by a maritime tutor (Tutor 1) from the first interview:

Originally I thought Bridge Resource Management, which is actually a course run by a number of people.... Management issues related to different ethnicities, different cultural values and the way they mix on the bridge of a ship in a command situation these day.. [In the past], a lot of the ships had a single nationality on them but now they get the United Nations;, it might be an Indian captain, might be a German first mate, stuff like that. All these things are quite interesting mixes because there are lots of cultural things in it. It’s not only the culture of the ship; it's the culture of the countries ... There are some quite well documented cases [for example] when a container ship ran aground in the straits of Singapore, and that
was all due to cultural issues with one not wanting to talk to the other. (Tutor 1, AT11 2013 28:31)

The need to consider communication issues within the BRM is supported by mariners, as demonstrated in the article, “All @ Sea” (Ward, 2014), which quotes mariners’ messages to the Nautical Institute’s online forum for discussion about BRM. For example:

‘To oblige all team members to SPEAK UP if they are uncertain of the situation, or of another’s actions. I have observed the progress of BRM to be a slow cultural change, that has been evolving for 20+ years. We still have a long way to go’.
Captain William Skahan

‘Despite emphasising it frequently, I have never had my decisions challenged by an officer. However, I was pleasantly surprised and saved by one helmsman who detected a mistake by the OOW operating the Engine Order Telegraph and spoke up.’ Manjit Handa

‘Team members each have their own different tasks, training and culture that can make speaking up an extremely challenging task’. Captain Peter Dann, MNI.
(Ward, 2014, p. 3)

According to Tutors 1 and 2, maritime communication training on a ship’s bridge at the Institute was integrated into other training. For example, during real-time navigation exercises held in simulators, the supervising tutor intervenes in trainee communication as required.

The Ship simulator and bridge teamwork: model course developed under the IMO-Norwegian programme (International Maritime Organization, 2003) was suggested as a source from which to develop an intervention. While the course provided a complete framework for teaching and learning about BRM, it did not provide a detailed description of communication as required on a vessel. Tutor 1 suggested the International Maritime Organisation’s (IMO) Standard Maritime Communication Phrases (SMCP) (Claudia & Alexandru-Florin, 2013; International Maritime Organisation, 2005) for communication
training on a ship’s bridge as a source of detailed communication as required on a vessel. Teaching and learning scenarios based on parts of the SMCP were then discussed as potential training topics for the proposed intervention.

5.4 Two scenarios

Discussion with tutors and the maritime programme manager on how MUVE-based interventions could be used for training using the SMCP led to the development of two scenarios that occur on the ship’s bridge. The first scenario was “handing over the watch” (IMO, 2005, p. 73), in which the officer of the watch would practise phrases required as the watch was transferred from the current officer of the watch to the next officer of the watch. The second scenario was “standard wheel orders” (IMO, 2005, p. 61), which the tutors described as helm orders. This scenario was selected because using helm orders represents the closed loop communication required by all personnel on the vessel, and because all Mates are trained as a helmsman (Tutor 1, Tutor 2, Programme Manager). In closed loop communication all orders from the Master of the vessel are repeated back to the Master, then when the order has been carried out, the person at the helm indicates that status with an appropriate phrase, which in turn is acknowledged by the Master of the vessel with an appropriate phrase (IMO, 2005, p. 61,).

5.5 Development of a ship’s bridge MUVE-based intervention

Development of the MUVE-based intervention for each scenario was sequential. Work towards the ‘Handing over of the watch’ scenario was undertaken first, followed by the ‘Standard wheel orders’ scenario. Artefacts developed for the first scenario were used in the development of the second scenario. The main artefact was a MUVE that provided avatar-based human computer interaction that included human-to-human voice communication on a simulated ship’s bridge. An OpenSim (OpenSimulator, 2014) virtual world (VW) server and a voice service were implemented to support the running of the MUVE.

A non-player character (NPC) was designed to provide automated voice-enabled human
computer interaction, a ‘voice bot’, while developing the MUVE for the Standard wheel orders scenario. The voice bot provided a low quality voice and required several stage set ups that would use too much of the time available for running the interventions. Given that it was already difficult to set up the classroom to provide sufficient quality of the sound for voice communication in the MUVE for the tutor and the trainees to use, it was decided that a voice bot would not be developed further for this case.

Development of the MUVE in overview

Figure 5.1 presents an overview of the development of the MUVE-based intervention from March 2013 to August 2016 using the swim notation described in Chapter Four.

Swim lanes for participation, events and artefact development tracks

In Figure 5.1 the development of the MUVE is separated into tracks for participation, significant events and the development of artefacts and services, over time and in parallel. Participation in the development track is depicted in the first row, a track of significant events are depicted in the second row, and the development track, producing artefacts and services, is depicted in the third row. Depiction of development for the first scenario is
bounded by a grey box with the label ‘Handing over the watch’ on the top of that box. Depiction of the development towards the second scenario is bounded by a grey box with the label ‘Standard wheel orders’.

**Swims by participants, for events and for artefact development**

In the first row of Figure 5.1, Tutor 1 had two swims in development towards both scenarios, whereas there was one swim that depicted the participation of Tutor 2, which continued all the way through to the point at which the ship’s bridge MUVE was used for the intervention in phase two. When both Tutor 1 and Tutor 2 participated at the same time the corresponding participant swims were parallel.

Similarly, swims depict significant events in the development of the MUVE-based intervention, and the development of the artefacts with their supporting services. For example, the development of the ship’s bridge MUVE is depicted by two swim strips. Each of these represents the development of the MUVE for a given scenario.

**Starting development towards a scenario**

The decision to undertake development towards a MUVE for a scenario was in collaboration with domain experts. In Figure 5.1, this is depicted as a circle that receives connecting arrow lines from the main participants in that decision. The circle represents that starting the development towards a scenario was iterative and collaborative in nature, rather than completely defined at one point in time.

**Depiction of data gathering and design work followed by development and review**

As depicted in Figure 5.1, the designer first met Tutor 1 for a semi-structured interview. During that meeting, requirements were gathered by the designer, who in turn worked with the developer of the ship’s bridge MUVE. That interaction is depicted as dashed arrow headed lines between the swims: the first is from the swim indicating participation by the designer with Tutor 1; the next is back from Tutor 1 to the designer, which is followed by a dashed line from the designer to the developer, and a line from the developer to the swim that depicts development on the ship’s bridge MUVE artefact.
The double-ended arrows in Figure 5.1 depict developmental or design interactions at a significant event, which involves several participants. For example, the designer, the graphics builder, the Harbour Master, and the vessel Master participated in the ship’s visit event. Double-ended arrows between the swim of the ship’s bridge MUVE and an event swim depicts that it was used during that event. The ship’s visit was followed by work between the designer and the graphics builder, as depicted by dashed arrow-headed lines.

**Searching the problem space for an artefact through participants and events**

As depicted in the first row of Figure 5.1, recruitment of participants occurred over time rather than at the start of the case. Progressive recruitment of participants fitted the second principle of the Agile manifesto to “Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage” (Beck, et al., 2001 b).

The recruitment of participants over time allowed for gathering requirements for the development as they emerged. Identification and development of the MUVE for use in the intervention can be thought of as a search for a designed solution to a set of requirements. As the set of requirements was more clearly understood, the search for the solution in design was made narrower or wider depending on the nature of the requirement.

That search can be thought of a search through a problem space (Simon & Newell, 1971) in which locations that meet the requirements are found. The goal in development is to meet requirements that lead to the desired artefact. The second principle of the Agile manifesto is compatible with the search in the sense that ‘search’ implies a potential adjustment in the pathway towards the solution that may yet be revealed.

In this case, development proceeded towards the ‘Handing over the watch’ scenario, then changed to development towards the ‘Steering at the wheel’ scenario. While the development process may appear to be linear, the process was in fact more like a search that moved through the problem space as the requirements were gathered and the focus of the development was determined, as depicted in Figure 5.2.
Figure 5.2 presents an abstraction of the search over time using a tree-like notion that starts at the bottom of the column and proceeds upwards. A branch in the tree, depicted by a black circle, represents development activities that may have split or have been added as requirements were gathered and refined. The middle disk represents the selection of development pathways that led to a part of the required artefact. The top disk in Figure 5.2 represents the projections of the development pathways onto the required solution space. As depicted on the top disk development activities towards the development of an artefact for ‘Handing over the watch’ scenario, were useful in the development towards an artefact for the other scenario.

![Figure 5.2 Development towards a required artefact as a search of a problem space using development activities](image)

An online tool was used to keep track of the sprints undertaken towards developing the MUVE. Over fifteen sprints were undertaken towards development of at least 70 tasks or stories on cards, on which over 500 actions were recorded. Thirty-seven checklists were included with the stories on the card. Each of the checklists, in turn, included a number of conditions to check for completion. There was evidence of ‘pruning’ during the development process. For example, ‘6 An NPC (robot) who talks’ was left in the ‘doing’ list, and ‘Put SMCP study stations in the boardroom’ is left in the ‘To do’ list that may indicate pruning or suspension of that development tree.
The initial analysis, presented in Figure 5.3, shows the order a card was added and the date of the last activity on the card during the development process. It shows that the last activity on a card was not strictly in order of creation and hence was not linear. This may indicate that work towards completion of the task or story on the card may have been suspended and returned to at a later time. This, in turn, may show continuation of other tasks while work on that task is suspended, or that the task requires more time to complete.
How the gathering of requirements was influenced by LPP and TPACK

Table 5.1 shows that requirements were gathered during participant swims using LPP and TPACK lenses. The main instrument used to solicit requirements was a guide for a semi-structured interview about the course that the learners attended and was designed using LPP and TPACK perspectives. While it was used for interviews, it was also applied to the ongoing directing behaviour of the designer and developer when interacting with other participants. The original guide for the semi-structured interviews is shown in Table 5.2.

Table 5.1 Gathering development requirements from participants during their swims for ship’s bridge communication

<table>
<thead>
<tr>
<th>Participant</th>
<th>Description of participation</th>
<th>Method used to gather requirements¹</th>
</tr>
</thead>
</table>
| Tutor 1     | Maritime tutor, communications officer. | Semi-structured interview, audio recordings [AT11, AT11.1]  
Swim 1. Principal practitioner contact, identified bridge resource management as the main educational context. | Discussion of scenarios, audio recording [AT12, AT13]  
Swim 2. Participated in the test intervention. | Researcher notes, audio recording after attending a live training session for mariners training in three maritime bridge simulators [AT14]  
| Tutor 2     | Maritime tutor, vessel Master, Blue Ocean-going. | Images of the maritime bridge simulation spaces  
Swim 1. Principal practitioner contact re Standard wheel orders scenario, invited trainee mariners to the test intervention and final intervention, ran the intervention as the tutor role-playing the vessel Master. | Labelled image of the maritime bridge  
|             |                                           | Test run of prototype one in the laboratory, audio recording [AT15]  
|             |                                           | Attended test intervention using with prototype one test intervention [ATestIntervention, VTestIntervention (1–3)] |

¹ Includes both audio and visual recordings.
### A MUVE FOR COMMUNICATION ON A SHIP’S BRIDGE

<table>
<thead>
<tr>
<th>Role</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tutor 3</td>
<td>Maritime tutor, military communications vessel bridge experience.</td>
</tr>
<tr>
<td>Swim 1.</td>
<td>Participated as a vessel Master testing prototype 2.</td>
</tr>
<tr>
<td>Programme Manager</td>
<td>Maritime studies programme manager (PM). Vessel Master, Blue Ocean-going. Participated in early discussions allowing staff to participate.</td>
</tr>
<tr>
<td>Swim 1.</td>
<td>Participated as a practitioner advising on the selection of a scenario.</td>
</tr>
<tr>
<td>Swim 2.</td>
<td>Participated as a vessel Master testing prototype 2.</td>
</tr>
</tbody>
</table>
| Researcher, designer, technician | I took these roles:  
Researcher. Data collection and present work.  
Designer. Determined the overall direction and authenticity  
Technician. Set up laboratories and assisted during a run of the intervention |
| Developer | I took the developer role, In the Developer Swim, scripts were coded and support services were implemented, |
| | Agile board (Sprints) |
| Graphics builder | An experienced builder of environments in virtual worlds. Provided implementation of the virtual environment as specified by the designer, making the environment look more authentic |
| | Agile board |
| Trainee mariners | Took part in the test intervention, followed by the focus group discussion. |
| | Test intervention [ATestIntervention]  
Focus group [at end of ATestIntervention] |
| Harbour Master | Facilitated a visit to the bridge of the real vessel for the designer, graphics builder and developer |
| | Field notes |
| Real vessel Master | Was present on the real vessel, discussed the MUVE and communication on a vessel |
| | Field notes  
Mention in newspaper article |

1 A = audio, V = video

For particular interviews, the sections and topics were maintained but the wording and order taken for the discussion sections were adjusted to match the situation. The discussion was led in such a way as to unfold relevant threads of information, keeping in mind the
current topic and the necessary influence from LPP and TPACK.

<table>
<thead>
<tr>
<th>Table 5.2</th>
<th>Guide for semi-structured interviews influenced by LPP and TPACK</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Section</strong></td>
<td><strong>Topic</strong></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Context</td>
<td>Course position within the vocational context.</td>
</tr>
<tr>
<td></td>
<td>What are the expected outcomes? Can you describe the course as</td>
</tr>
<tr>
<td></td>
<td>it sits in the vocation?</td>
</tr>
<tr>
<td></td>
<td>Discuss the stages or levels a person progresses through the</td>
</tr>
<tr>
<td></td>
<td>course from a vocational perspective.</td>
</tr>
<tr>
<td></td>
<td>At what point in their vocational development do the learners</td>
</tr>
<tr>
<td></td>
<td>come onto the course?</td>
</tr>
<tr>
<td>Course Run</td>
<td>Discussion in overview of a student’s progress or phases in the</td>
</tr>
<tr>
<td></td>
<td>course.</td>
</tr>
<tr>
<td></td>
<td>Discuss the course descriptor or outline.</td>
</tr>
<tr>
<td>Teaching</td>
<td>What is the teaching and learning approach taken?</td>
</tr>
<tr>
<td></td>
<td>Give examples of lessons in the course.</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Does the content of the course affect or influence the way the</td>
</tr>
<tr>
<td></td>
<td>course is presented (taught)?</td>
</tr>
<tr>
<td>Technologies</td>
<td>Are there any technologies used in the course?</td>
</tr>
<tr>
<td></td>
<td>Are they intrinsic to the course?</td>
</tr>
<tr>
<td></td>
<td>How do they enhance/facilitate or make the course effective?</td>
</tr>
<tr>
<td></td>
<td>Is any technology used in the courses as part of the approach to</td>
</tr>
<tr>
<td></td>
<td>teaching?</td>
</tr>
<tr>
<td></td>
<td>Does the course require specific technology?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment</td>
<td>Discuss assessment</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Course</td>
<td>How is the course likely to change in future?</td>
</tr>
<tr>
<td>future</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How might the programme change?</td>
</tr>
<tr>
<td></td>
<td>What do you recommend?</td>
</tr>
</tbody>
</table>

1 LPP progress from periphery, legitimate for vocation and learner

**Tutor 1 participant swims**

Tutor 1 participated in the design and development towards both scenarios, as depicted in Figure 5.1. During his second swim, Tutor 1 attended the test intervention as an observer and contributed to the development of the Steering at the wheel scenario by identifying the
SMCP as a source of maritime phrases to be used with marine vessels.

Tutor 1 was the practitioner that led development towards the ‘Handing over the watch’ scenario. Requirements were gathered during the start of development as depicted by the circle at the start of the artefact swim towards development of the ship’s bridge MUVE prototype 1, as depicted in Figure 5.1. The first interview identified BRM as the context for the intervention. Further discussion led to the development of a Change of watch-based scenario for the MUVE-based intervention (AT12 and AT13).

Tutor 1 organised three teams of maritime trainees to attend a live training session of a simulated crossing of Cook Strait (see Figure 5.4). A tutor controlled the simulation from a control room and each team was in their own ship’s bridge simulator room. While all three of the bridge simulation rooms contained authentic navigation and control instruments, such as, a real radio and real radar devices, only one of the three simulator rooms contained a visual simulation of the view out of the bridge.

As noted in AT14 and discussed further in AT13, attendance at the simulation session helped develop an understanding of learning situations presented to the trainees. Trainees were required to prepare a plan and communication, and respond with appropriate communication and adjustments in control of their simulated vessels as the tutor introduced simulations of low flying aircraft and other vessels near to their simulated vessels. At the end of the simulated crossing, the teams had a debriefing session in which
the tutor discussed their responses in the simulation. During the simulation, the tutor may adjust the trainees’ communication through real radio communication.

![Figure 5.5](image1.png)

*Figure 5.5  Images from a real vessel’s bridge that were used as a model for the ship’s bridge MUVE simulation early in the development of prototype 1.*

Observation of the trainees and their tutor confirmed they had a shared presence and communication amongst them as requirements for the MUVE. Authentic ships’ controls were also identified as requirements. Despite two of the simulated ship’s bridges not having a visual simulation of the view from the ship’s bridge, it was confirmed that a visual simulation of the view out of the bridge was preferred. A briefing room was also identified as a requirement for the MUVE.

![Figure 5.6](image2.png)

*Figure 5.6  Labelled images of the vessel controls (Tutor 1).*

Interaction between the designer and Tutor 1 led to the development of a MUVE to be used in a communication-centred scenario. Tutor 1 provided images from the target vessel
(Figure 5.5) and labelled images of the vessel controls (Figure 5.6). That led to implementation of an early version of the Ship’s Bridge prototype 1 for use in a Handing over of the watch scenario to be tested by Tutor 1, as recorded in AT15.

The requirements that were identified for the ‘Handing over the watch’ scenario came from authentic learning situations presented in simulated environments. Maritime personnel had actually attended training in the simulators to gain certification in their discipline that would allow them to run a crossing of the Cook Strait. The levels of certification that trainee Mates undertake allows them to progress from the Mate, to an Officer of the Watch, and then, to a Master of a vessel. The LPP lens provided a way to develop an intervention that met the discipline requirements.

Work towards the ‘Handing over the watch’ scenario included an investigation into the phrases used and a discussion of the role-play that the trainees would undertake in their training. In the process of developing the MUVE, learning trajectories in relation to TPACK were considered. LPP informed the underlying situated authentic learning perspective and the pedagogy was to provide learning situations that were as authentic as possible. The content knowledge was to be presented as a list of phrases from the SMCP that covered the required exchange of information when the bridge Officer of the Watch changed from one officer to the next (Tutor 1). The TPACK was to bring together a shared presence, voice communication within a simulation environment that was as real as possible using the MUVE, and to undertake authentic practices during the change of the watch.

**Tutor 2 participant swim**

Tutor 2 undertook a single swim for most of phase one. He started during the development of the Handing over of the watch scenario and continued as the main practitioner in the development of the Steering at the wheel scenario. Tutor 2 participated in the change of direction from development towards the first scenario to the development towards, and initiation of, the second scenario.

Tutor 2 is a qualified vessel Master, who has operated large vessels and had recently been
an Officer of the Watch on many Cook Strait crossings. Tutor 2 identified the need for careful communication of the status of the vessel during the ‘Handing over the watch’ scenario. Tutor 2 presented well-formed and considered orders on the vessel and introduced the culture of an authentic Master of a vessel into the development of the MUVE.

Tutor 2 worked with maritime trainees and mariners, who were taking courses for certification to become higher qualified mariners. During phase one, Tutor 2 invited the trainees to participate in the test intervention. During phase two, he invited the mariners to participate in the intervention. Tutor 2 acted as a vessel Master and tutor for the test intervention (VTestIntervention, extracted from ATestIntervention).

Tutor 2 confirmed the progression of mariners as they developed in the discipline (AT21) from deck hands, to higher ratings, to Mate and then Master of a vessel. He introduced the need for closed-loop communication for orders on the vessel. While maintaining the utility of SMCPs, Tutor 2 also introduced genuine communication as it was on the bridge of a large vessel, in which the main mode of communication is closed loop. He explained that the number of personnel on the bridge would vary from one to five depending on the situation of the vessel. For example, in the middle of the Cook Strait there would be one of the ship’s personnel on the bridge, whereas at the entrance to Wellington harbour, several personnel would be present. Although the SMCPs were not strictly enforced on a vessel but acted as a standard to be encouraged, it was important that all personnel operating the bridge were aware of the current situation of the vessel, especially when there was little margin for error as is the case when entering Wellington harbour.

According to Tutor 2, when a Master works with an experienced Mate or helm personnel, the communication may be less frequent and the orders are of the style that allows a Mate at the helm to bring the vessel into a given navigational situation base. For example, if the vessel is heading north (compass 360°), the Master of the vessel may say “Port, steer One Eight Two” to order that the vessel be turned around to the port and travelled in compass direction 182°. He would not order, “Port Twenty” followed by, “Steady as she goes”
when the vessel has reached compass direction 182°.

Discussion with Tutor 2 identified the potential need for automated avatars (NPCs) that talk. The NPCs would provide for situations where trainees could use the MUVE to practise SMCPs for Steering at the wheel, by listening and responding to either an NPC acting as a Master of the vessel or taking the role of the Master and listening for the response from an NPC acting as a Mate at the helm. Phrases extracted from AT22 in preparation for the development of an NPC that acted as a Master were in folder AT2. These were used in tests of voice for the voice-bot NPC.

Following the decision not to use the NPC in the intervention, Tutor 2 guided the development of the intervention towards providing a scenario in which trainees could experience being both a Mate at the wheel and Master of the vessel. He identified the need for working navigation and control displays on the simulated bridge, and a ship’s wheel that operated in a manner similar to the wheel of large vessels, as tested and recorded in AT22.

As a qualified Master of a vessel, Tutor 2’s practice in training was aligned with the LPP theoretical framework, taking care to ensure that learning was legitimate for the discipline and expressed in a way that was legitimate for the trainees. Different learning trajectories for the trainees were facilitated by Tutor 2 in ways that were legitimate for them. For example, a young trainee from a fishing vessel was becoming familiar with the bridge as well as the helm orders. Tutor 2 adjusted the learning situation to match the learner; the young trainee was introduced to the style of communication on a large vessel in a way that allowed him to progress in the acquisition of the required SMCP-like vocabulary in the context of phrases used on a fishing vessel. On the other hand, when working with a mariner, who had experience on large vessels, Tutor 2 elevated the mariner’s role in the learning situation, encouraging the mariner to present examples of good practice and to take the Master role. In both cases, Tutor 2’s practice matches the LPP theoretic frame, by moving both trainees into the discipline in a way that is both legitimate for the trainees and in the maritime discipline.
Programme manager participant swims

The programme manager (PM) encouraged the development of an intervention in which training in closed loop communication would be added to the maritime studies training programme. PM also identified standard wheel orders as the topic of an intervention that would be useful for a wide range of trainee mariners. The PM indicated that trainees at other levels, for example deck hands, could take part in the Steering at the wheel scenario to provide training in closed loop communication. The PM also indicated a need for practising closed loop communication in other scenarios on the vessel, such as, the engine room or cargo decks of the vessel.

The PM tested the MUVE to be used in a classroom intervention. During that test session, the PM was interviewed as a vessel Master. The PM described an encouraging culture for trainee mariners, in which trainees were invited to practise helm control while at sea, where the purpose of helm control was to keep the vessel on a given heading. He identified the need to show the trail of the vessel as it moved through water, which could show the mariner how steady their helm control was, because the trail indicates changes in direction of the vessel as a curved path through the water.

Taking an LPP perspective, participation by the PM identified the way the maritime discipline provided progress from the periphery to becoming a Master mariner. He presented a broader picture across the discipline that included recognising the learning trajectories for all mariners. Taking a TPACK perspective, the pedagogical direction of the course could be influenced by the PM in prospective use of the intervention that was being developed. His feedback about the proposed use of technology for the intervention was positive, reiterating that the situation be as authentic as possible.

Tutor 3 participant swim

Tutor 3 participated in a short swim as a vessel Master to test the MUVE (AT3 and VT3). His main contribution came from his previous role as a military Naval mariner.

Tutor 3 noted that the avatar uniforms should be tidier and pointed out that different styles would be worn by different mariners depending on their position. The quality of the audio
communication was compared to communication on an aircraft. While this could be considered useful, the implication was that audio communication in the MUVE was not as authentic as it should be. Tutor 3 also noted that the rudder control indicator needed to be more accurate. His general impression was that the environment was authentic but that further development of details would improve the experience.

Tutor 3 indicated that the SMCP were not used on military naval vessels; the military language was different. However, he confirmed that closed-loop communication was necessary. He felt that the culture of training in military naval situations was very similar to the merchant culture, as were the learning trajectories and pedagogical approaches (AT2). Tutor 3 confirmed that all bridge personnel received early training in steering at the wheel.

The nature of training in military naval situations seemed to be different than in the merchant situation. Tutor 3 stated that development of the MUVE would be different for a military naval situation, and that the current MUVE would be less authentic for military situations. This would result in different development pathways being followed.

**Designer, developer, technician and graphics builder participant swims**

During development of the MUVE, I took the roles of designer, developer and technician. The designer coordinated and guided the design of the MUVE, and determined the form, scale and detail required to meet sufficient authenticity and usability of the MUVE. An interaction error was introduced when a design rule was applied that in order to meet the requirement that the MUVE be authentic, the simulation should be to scale. Hence, all aspects of the MUVE should be exactly to the same scale in all dimensions as they were in the real vessel. However, the default viewpoint when using avatar interactions in simulation software is from above and behind the avatar’s head. That viewpoint could be hidden by part of the MUVE. For example, the avatar’s head could hide controls on the simulated bridge. The view would then need to be adjusted by the person operating the avatar, which in turn would require training on how to use the MUVE.

The developer role is presented as a separate swim in Figure 5.1. The developer and
designer determined software development concerns; referred to as ‘stories’ in an Agile development process. The developer/designer worked with the graphics builder in the construction of the MUVE and in determining development sprints. Feedback from the tests and demonstrations, and the change in focus led to further stories and subsequent development sprints undertaken by both the developer and the graphics builder.

The technician role was ancillary and ongoing. Prior to, and during tests and demonstrations of the MUVE, the technician assisted during tests and demonstrations, as well as setting up and maintaining the servers required for the MUVE.

The graphics builder participated in the development of the ship’s bridge simulation in the MUVE, making the simulated space look as authentic as possible by building a much more realistic version of the simulated ship’s bridge within a detailed model of the vessel. The graphics builder also participated in the visit to a ship’s bridge by taking images of the real bridge, which were then used to ensure greater authenticity.

Three significant events

During the development of the MUVE there were three significant events: the ship’s bridge visit; the test intervention and the focus group. These are depicted as swim lanes in the second row of Figure 5.1. These events took place over a short period of time when compared with the ongoing development of the MUVE.

Participant swims – The visit to a ship’s bridge

The designer and graphics builder visited the actual vessel, gathered images of the vessel’s bridge and discussed development of the MUVE with the Harbour Master and Master of the vessel. The visit to the ship’s bridge improved authenticity by exposing the designer and the graphics builder to the real environment. Both the designer and the graphics builder noted that, after having spent time developing a digital simulation of the bridge, the actual bridge looked and felt familiar to them.

Harbour Master and Vessel Master participant swims

Although, the Harbour Master and vessel Master were not formal participants in the research, their contribution to the design and development of the MUVE was significant because they facilitated and took part in the visit to a real ship’s bridge. The vessel Master
confirmed the utility of simulation environments for training personnel and the need for communication training throughout the vessel. The Master was able to indicate the purpose of controls and demonstrated high precision manoeuvring of the vessel with thruster controls. A reporter and photographer from the local newspaper also attended the visit. Discussions between the Master and the reporter identified the corporate environment in which the merchant vessel was operated. It was important that images of the corporate logo were not to be published in the newspaper article.

**Participant swims – the test intervention then the focus group**

The test intervention using the MUVE was treated as a real classroom intervention in which mariners training to be officers on super-yachts volunteered to experience and feed into the development of the MUVE (ATestIntervention, VTestIntervention). This was the first enactment of a phase two intervention. A focus group of most of the trainees took place during the same allocated class time, immediately after the test intervention. During the test intervention, Tutor 2 participated as the trainer, Tutor 1 participated as an observer along with me as researcher, designer and technician. All new participants were inducted as participants in the research in the normal manner. As the designer, I gathered feedback regarding the operation of the MUVE. As the researcher, I guided the focus group discussion based on the semi-structured interview described in Table 5.2.

**Trainee mariners participant swims**

Enacting a phase two intervention with super-yacht officer trainees during phase one led to a much more stable MUVE when that was used in a subsequent enactment of phase two. Before the test intervention, trainees were made aware that they were the first users of the MUVE in a classroom setting. During the intervention, Tutor 2 took the role of Master of the vessel in the MUVE. In the laboratory, the Master sat at an allocated workstation and the trainees sat at a set of trainee workstations. The technician made sure the Master’s system was operating and then visited each trainee to check that their system was operating. The trainees explored the MUVE and changed the look of their avatars.

As vessel Master, Tutor 2 then invited a trainee to sit their avatar at the helm and the training started. Each trainee spent time at the helm with the Master. Other trainees were meant to observe and listen to the communication at the helm. However, instead the trainees practised moving their avatars and communicating with each other through the
A MUVE FOR COMMUNICATION ON A SHIP’S BRIDGE

voice communication system. Echoes in the digital voice communication system, due to latency in network communication with the voice server, made it difficult to hear what was being said in the MUVE.

Tutor 2 persisted with his lesson plan and continued to undertake steering at the wheel training with each participant in turn. During the session, the simulated wheel turned upside down and stopped working; resulting in some trainees not being able to practise turning the vessel. The technician had to adjust the position of the wheel so that the class could continue. The outcome from the practical part of the test intervention was that the MUVE failed to provide practice at the wheel.

Most of the trainees in the class also participated in a focus group discussion. The focus group session provided feedback on how the wheel should operate and suggested alternative ways to interact with the simulated wheel. For example, one trainee suggested that the keyboard keys, ASWD, should be used because they are used in games, while another trainee suggested a more natural ‘drag’ over the simulated wheel to change its direction.

The trainee super-yacht officers also suggested that information about the direction of the vessel should be easier to view by using a heads-up display approach. The trainees considered the MUVE useful for training and thought it would be a good addition to their training. As the designer, I noted the suggested changes, which were subsequently recorded in the online tracking software.

LPP and TPACK during development

Technology, content knowledge and pedagogical concerns were brought together by focusing on the development of a ship’s bridge MUVE and the authentic learning by the trainees. The training of all personnel reflected a culture that had grown from ensuring the safe and careful operation of both merchant and military vessels. In this culture, the Master and all personnel communicate in a well-judged manner, while operating the vessel to ensure safe voyages. The simulated bridge and appropriately authentic interaction with the simulated controls were intrinsic to the learning situation. Content knowledge was guided
by SMCP and the actual Master of the vessel. The pedagogy was influenced by the culture of the discipline and its situation, in which the Master of a vessel is the leader, who takes responsibility for running that vessel.

5.6 Phase two: A classroom intervention using the Ship’s Bridge MUVE in communication training for trainee Mates

This intervention took place during phase two of the ship’s bridge case. Tutor 2 ran a class for six self-selected maritime trainee Mates, treating the MUVE as an authentic ship’s bridge. The tutor determined the class pedagogy and structure. Data collection on the class was designed to provide several points of view: the ‘in-world point of view through audio and video recordings of the Vessel Master and the Mate avatars at the wheel in the MUVE; a classroom viewpoint through the audio recording of the class; audio recording of the trainee focus group feedback; and feedback from audio recordings of tutor interviews and data provided by field notes. However, the in-world video recording failed. Therefore, the following analysis was based on:

- A reflective transcript of the classroom audio recording.
- Focus group and tutor interviews audio recorded immediately after the class, from which separate conversations in the classroom of the tutor and trainees were gathered into their threads.
- The researcher’s reflective field notes.

To make as much of the classroom as audible as possible, the audio recordings were enhanced through digital normalisation, followed by amplification of the whole recording using free audio editing software. Normalisation moved quieter and louder audio into a standard volume range.

Normalised audio across the whole recording was not achieved by simply applying a normalisation function to the audio recording. When the audio file was normalised in that way, normalisation mapping was set to bring the higher-volume parts of the recording into a normal volume range, with the effect that the lower-volume parts of the recording
were also mapped into a relatively lower volume. To achieve a standard volume throughout the recoding, normalisation was applied separately to higher-volume parts and lower-volume parts of the recoding, leaving the audio recording at the expected standard base level throughout the recording. When the normalised audio was subsequently amplified, all audio in the recording was amplified from the same volume level. This provided an audio that was amplified to the same level over the duration of the audio recording.

Having all the audio at same level provided the researcher with the ability to transcribe and annotate conversations from as many locations in the classroom as possible. For example, if a conversation was further away from the microphone in the raw audio recording then that conversation was quieter than one that was closer to the microphone. When the audio is normalised across the whole recording and then amplified, the audio originally further away from the microphone was more likely to be audible because the volume was the same, irrespective of the distance from the microphone. Hence, the following analysis was based on annotated transcripts of enhanced audio recordings of different conversations at different locations in the classroom.
Figure 5.7 depicts the findings as a series of episodes that reflected the following: the activities prior to being in the classroom, while in the classroom prior to class and during the class; the focus group discussion and the tutor interviews. Further analyses of the transcript and audio recordings considered the authenticity of situations in the MUVE during the class, and considered TPACK. Findings are presented as swims by participants in each of the episodes.

5.7 Prior to being in the classroom

Figure 5.7 depicts swims of the designer/developer/technician prior to being in the classroom. After the TI, feedback from the tutor and the trainees, and reflection by the designer/developer identified deficiencies in the MUVE that had a significant impact on the intervention. During the designer/developer swims, the following aspects of the MUVE were identified as having a significant impact: turning the wheel; voice communication and viewing the compass direction indicator. The following adjustments were made to the MUVE to address these issues in a series of Agile sprints prior to the second intervention:

- Simulated turning of the helm wheel was changed from ‘clicking on the wheel handles to turn’ to ‘dragging over the wheel to turn’, which proved to not be completely satisfactory. The detail on how this was implemented within the constraints of the VW viewing software is described in Appendix A5.1.

- The digital compass direction indicator was changed from a static graphic to an operating indicator, with digits that were larger than they were on the original vessel.

- A working digital compass direction indicator was added to the helm where trainees using an avatar could see it. Compasses in the bridge wings as well as the main compass on the helm indicated direction like real compasses.

- Improved voice communication was achieved by setting the voice volume of other avatars in the simulation to a level that was audible in each of the running VW viewing programs as described in the following episode.

During this episode, the technician swim transferred the MUVE to the server and created
avatar accounts for trainees to use in the intervention.

5.8 While in the classroom prior to class

The VW expert and the technician participated in the classroom prior to class. As depicted in Figure 5.7, for the event, ‘sound and station set up’, they visited the classroom the day before the intervention to check the laboratory computer workstations were set up as required for the class and to upload and check that a new version of the MUVE would work on the laboratory computer workstations in their current configuration. A check of the class environment should be prior to the intervention with sufficient time after the check to allow for computers to be reconfigured and to allow for the intervention to be reconsidered and changed to meet a potentially new set up.

The event, ‘sound and station set up,’ shown in Figure 5.7 also related to the technician swim to set up the classroom. A class set of headsets was borrowed from the IT Services office and taken to the laboratory. At this point, the access card to the laboratory no longer worked. Hence, the card was renewed immediately by visiting the on-campus access card renewal service. Logging in on the tutor’s workstation was tested successfully. The tutor headset was plugged in and inward audio from the headset’s microphone and audio from the workstation were tested by using the workstation’s audio settings. The VW viewer (Phoenix Firestorm) was opened and log in was undertaken to ensure that it worked, as depicted by the event, ‘log in avatars,’ in Figure 5.7.

The day before the intervention, the VW expert was consulted about the layout of the workstations. He suggested that the helm workstation should be placed as far as possible from the vessel Master’s workstation and the trainees should talk as quietly as possible.

5.9 During the class

Figure 5.7 shows that Tutor 2, the trainees and the technician/researcher participated during the class. The researcher inducted the trainees into the research and set up audio and video recording for the class.
During the class, participant trainees were trained in closed-loop communication using standard maritime communication phrases (SMCP) for steering a vessel. Five participant, labelled PA, PB, PC, PD and PE took turns as vessel Master and Mate at the wheel.

Tutor 2 ran an example session, during which he took the role of vessel Master and PA took the role of Mate at the wheel. As depicted by the swims of PA, PB, PC, PD and PE, during the class the participant, who was Mate at the wheel then took the vessel Master role and another participant took the role as Mate at the wheel. Tutor 2 monitored each participant as they specialize each role and intervened in the role-play by rephrasing the communication or pausing the role-play to describe the correct style of communication in a given context. This sequence (where participants took a role as Mate at the wheel then as vessel Master) was directed by the tutor until most of the participants had specialize the Mate at the wheel role. Other participants explored a duplicate of the ship’s bridge MUVE for practice while they waited to take a role in the training MUVE. Since practice time was unstructured, there was a lot of noise in the room from participants on the practice MUVE.

Throughout the session, Tutor 2 changed roles from vessel Master to tutor as situations arose, providing both training and genuine examples of communication by a Master (see Table 5.3).

Table 5.3  Excerpt from the annotated transcript of the audio recording of the intervention when, the tutor presents authentic communication by taking the role of Master

<table>
<thead>
<tr>
<th>Comment</th>
<th>Time</th>
<th>Participant role</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Yup, that’s about right”</td>
<td>19:06</td>
<td>Tutor 2 as tutor</td>
</tr>
<tr>
<td>“Steady up on zero nine zero.”</td>
<td>19:09</td>
<td>Tutor 2 as vessel Master</td>
</tr>
<tr>
<td>Researcher note: Tutor 2 is guiding PE at the workstation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Steady up on zero nine zero.”</td>
<td>19:12</td>
<td>PE as vessel Master</td>
</tr>
<tr>
<td>“Steady up on zero nine zero.”</td>
<td>19:18</td>
<td>PD as Helmsman</td>
</tr>
<tr>
<td>Tutor 2 gives some advice to PE, then says, “Once he gets there, he’s not there yet.”</td>
<td></td>
<td>Tutor 2 as tutor</td>
</tr>
</tbody>
</table>
Table 5.3 also demonstrates an effect from the technology. Tutor 2 had to take on an unplanned technical role to guide PE at the workstation. Table 5.4 demonstrates further effects of the technology on the session. In this excerpt, the need for the vessel to be seen to be moving was identified. Steering was also found to be more difficult in the MUVE used for training than in the practice MUVE.

Table 5.4  Excerpt from the annotated transcript of the audio recording of the intervention when a participant and Tutor 1 discuss the effect of the technology on the session

<table>
<thead>
<tr>
<th>Comment</th>
<th>Time</th>
<th>Participant role</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Does the boat not actually move?”</td>
<td>20:12</td>
<td>Pet with Tutor 2</td>
</tr>
<tr>
<td>“No.”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Changed, spin round”</td>
<td>20:19</td>
<td>Tutor 2 to PE</td>
</tr>
<tr>
<td>Researcher note: PE changed the position of the Master avatar, Tutor 2 is helping, technician comes over to help, puts the Master avatar back into position. T This happens while PD says the following</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“It was very easy to control on the other.”</td>
<td>20:45</td>
<td>PD as Helmsman</td>
</tr>
<tr>
<td>“It was quite easy to control from the other unit”</td>
<td>20:53</td>
<td>PD as Helmsman</td>
</tr>
</tbody>
</table>

Overall, the number of exchanges that involved training in communication was much higher than a few incidences, in which the technology interfered with the training as shown in Table 5.5.

Table 5.5  Excerpt from an annotated transcript of the audio recording of the intervention when participants mainly practise closed-loop communication

<table>
<thead>
<tr>
<th>Comment</th>
<th>Time</th>
<th>Participant role</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Right, Port ten, altering to One-a Five Zero”</td>
<td>27:04</td>
<td>PD as vessel Master</td>
</tr>
<tr>
<td>Researcher Note: Participant D uses a “command style” of voice, from here.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Could you repeat …”</td>
<td></td>
<td>PE at Helm</td>
</tr>
<tr>
<td>“Altering to One Five Zero, Steady at One Five Zero.”</td>
<td>27:24</td>
<td>PD as vessel Master</td>
</tr>
<tr>
<td>“She’s touchy.”</td>
<td></td>
<td>PE at Helm</td>
</tr>
<tr>
<td>“Yeah, she’s a touchy one, that’s good. Steer One Five Three, that’s fine.”</td>
<td>27:36</td>
<td>PD as vessel Master</td>
</tr>
</tbody>
</table>
The pedagogy followed the LPP-based filter, focusing on authentic communication. However, putting participants in a separate practice MUVE created an ongoing background chatter during the intervention that caused some interference in the learning. For example, “Oh look, you can fly through the deck” (Table 5.5).

Communication on the practice MUVE reflected a playful situation as participants became accustomed to using the VW viewer. This practice helped them to navigate around the training MUVE. However, little practice was at the helm; only one of the trainee participants actually specialized at the helm before undertaking training.
Participant trainee swims were distributed over the two MUVEs and time in the practice MUVE was not structured. This meant that participants enjoyed the session but spent a lot of time playing. Trainees, who were not at the helm, should be provided with the opportunity to specialize in a structured way that would enhance their experience. Alternative arrangements of the MUVE could provide MUVEs for each pair of trainees, so that they could specialize throughout the session.

5.10 The focus group

Trainees self-selected to take part in the focus group that was also attended by Tutor 2 and the designer/researcher. In summary, the trainees, who were from fishing vessels, indicated that other scenarios would be more appropriate for them in their vessels, such as, a scenario that involved the operation of the winches on the vessel. One trainee commented, “For a 16-year-old cadet. In a large vessel … operating machines, such as, a winch [is] dangerous to cadet”.

The trainees confirmed that the environment provided a training opportunity for bridges on large vessels. They also mentioned that such training was available “in Auckland”. The implication was that better simulators were already available. However, when it was suggested that the training could be at distance and online, the trainees were very enthusiastic.

5.11 Tutor feedback

Tutor 2 and the designer/researcher took part in the tutor feedback session. Tutor 2 was enthusiastic about the improvements that had been made in the MUVE and indicated that the learning that had taken place was much improved, giving trainees a genuine experience of training in closed-loop communication at the Wheel. He identified that the controls were not perfect and could be improved.

5.12 Findings summary and conclusions

Using theoretical frameworks in the design and development of an intervention was not
completely transparent or straightforward. Ensuring the theoretical framework had an effect required constant and sustained adherence to the theoretical form in situations where the process, in which it was applied, could overwhelm the effect. In this case, development processes and the situation, in which the intervention took place, has mediated the influence of the theoretical frameworks.

Constraints in the development could have also watered down the desired effect. Applying principles in the Agile manifesto led to an environment that sufficiently met the theoretical bounds. For example, attempting to develop a ‘hyperreal’ interaction in MUVE, i.e. being able to hold the virtual ship’s wheel to steer the vessel, would have enhanced authenticity for an authentic learning situation. However, providing hyperreal interaction of this sort would have required development of new technology for interacting in the MUVE, leading to testing prototypes of the technology and other large-scale development work that would delay, and possibly through failure, prevent timely use of the MUVE in an intervention. Using the interaction technology that was already available may be sufficient to meet the need for authentic interaction for the proposed intervention.

The current MUVE that could be used in authentic learning situations was developed through persistent application of LPP as a design framework. Although TPACK was applied in preparation of the intervention, preparation was mainly guided by LPP. Tutor training would have been needed for TPACK to be applied by the tutor in preparation of the intervention, that training would have intervened in the tutor’s authentic practice, which in turn causes as effect in the authentic situation. Focusing on LPP and authenticity potentially distracted from considering pedagogical concerns for the intervention. More careful application of both theoretical frameworks would lead to a better learning situation for the trainees.

Overall, the design, development of a MUVE and running of an intervention with the MUVE provided a depth of data, from which the value of the designed system could be formatively evaluated. The process of design and development, using an Agile approach, produced a working system. However, the system could have been improved by less
constrained development.
CHAPTER 6
DISCUSSION AND RECOMMENDATIONS

6.1 Introduction

This chapter begins with a summary of the discoveries in this thesis, which centre on the hybrid DBR Agile software development (hDAS) methodology and its deployment to produce and pilot two MUVEs to enhance vocational education. This is the first time that the whole process of MUVE design through to implementation has been described systematically. The swim technique within hDAS is particularly novel.

These findings are then discussed in relation to the literature. As a hybrid approach, the hDAS methodology is different from the processes that have been hybridised. This difference is clarified in relation to both design based research (DBR) and Agile. The originality of this research is also discussed in relation to three categories of instructional design (ISD).

The same theory and theoretical framework were chosen for both MUVE case studies: TTM in civil engineering and surveying vocations and Ship’s bridge communication in the merchant navy maritime vocation. The theory underpinning the MUVEs were Legitimate Peripheral Participation (LPP) and the theoretical framework was Technological Pedagogical Content Knowledge (TPACK). This is the first time they have been applied together to design software for education in these vocations. Their effectiveness is discussed.

In addition to considering the limitations of the study, the chapter makes some recommendations for future research and further application in similar contexts.

6.2 Discoveries

The main discovery of this doctoral study is hybrid DBR Agile Software development
(hDAS) methodology that, when enacted, produced multi-user virtual environments (MUVEs) based on theory, and tested theory in practice. Discoveries, as described in this section, emerged from the enactment of the hDAS process for the TTM and Ship’s bridge cases.

This section presents a summary of the phased hDAS methodology for the first time. It introduces continuous Agile method tailoring as a characteristic of hDAS and describes an hDAS methodological process, with details of its Scrum-based Agile practices. The summary is followed by discoveries found when enacting the hDAS methodology, which included discoveries about the data collection methods, discovery of the swim and discoveries about software development.

**Figure 6.1**  The relationships of key components of hybrid design based research for Agile software development (hDAS) methodology

**The hDAS methodology in overview**

The purpose of the hDAS methodology was to produce a MUVE-based intervention for a particular vocational context, and in the process, test educational theory in the effective design of MUVEs as interventions in vocational education and training (VET). The hDAS methodology deployed professionals from at least three disciplines to develop a MUVE: software engineering; education and the selected vocational discipline. Figure 6.1 depicts the relationships of key components of hDAS methodology.
hDAS methodology in phases determines the tailored hDAS method. Enacting the hDAS method then leads to discoveries for and from method and methodology, which leads to further tailoring of the method. hDAS methodology is enacted in three phases. Phase two is depicted at centre stage because the goal is to implement an intervention using the MUVE for VET. Phase three builds on the other two phases with ongoing feedback and evaluation of design in research practices. Phase one is depicted between Phase three and Phase two to represent the origins of design and development between research design evaluation and running an intervention.

The hDAS methodology is enacted by participants that take roles from three disciplines; education, software engineering and the selected vocation. The terminology used in hDAS is mainly that of the disciplines of education and software engineering (see Table 6.1). Therefore, at least three participants are required: an educational researcher, a vocational practitioner and a software developer. Participants from the vocation include an instructor, who is expert in the vocation, and students of the vocation. Development roles are further divided into software development, graphic design and technical support. Participants take part in enacting hDAS according to their role, which determines the phases they participate in. That participation is identified as a swim during enactment of a phase.

**Table 6.1  Key hDAS roles by discipline and phase**

<table>
<thead>
<tr>
<th>Role</th>
<th>Discipline</th>
<th>Brief description</th>
<th>Phase/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developer</td>
<td>Software engineering, Computer graphics design</td>
<td>A developer designs and develops digital artefacts i.e. a software developer, or a graphics designer. A technician provides technical support for the development and during the run of an intervention</td>
<td>One and Two</td>
</tr>
<tr>
<td>Educational researcher</td>
<td>Education</td>
<td>The educational researcher directs MUVE development according to the research design, collects and analyses the data in research on theory in practice. At least one educational researcher is required.</td>
<td>One and Three</td>
</tr>
<tr>
<td>Vocational practitioner</td>
<td>Selected vocation</td>
<td>A vocational practitioner is an expert member of the selected vocation. A teaching practitioner is preferred. Students of the vocation participate as trainees in practices of the vocation.</td>
<td>One and Two</td>
</tr>
</tbody>
</table>
Throughout the enactment of the methodology, DBR hybridisation with Agile software development tailors the Agile method, because the design research pragmatically determines new and required objects, including those that provide guidance of the design for the vocation. For example, the vocation has specific, legitimate practices that are used for the initial tailoring of the Agile method mandatory for the design and development to proceed. As more is learned about the professional practice, the Agile method is refined (re-tailored or re-factored in software engineering terms) to implement an improved understanding of the requirements, while still conforming with the Agile principles. Each time the hDAS Agile tailored method is enacted, all documentation and tracking of the Agile software development method as it is enacted is archived by the software developer for use in phase three.

As in Agile Scrum software development (Harichandan, Panda, & Acharya, 2014) MUVE-based intervention development proceeds through sprints, also see Figure 3.3. User stories are written in collaboration with researchers, developers and vocational practitioners. Features on the product backlog list are selected through discussions between expert practitioners, trainees, and design and development participants, and then used by the development team for a sprint of graphic design and software coding. These are moved to a sprint backlog list. The priority (or order) of features to be developed is adjusted as an understanding of the requirements comes from interaction between participants in the sprint and from reviews.

As depicted in Figure 6.1, the hDAS methodology has three phases, in which participants take part. Over time, participation in the MUVE development is analysed through swims.

**hDAS phase one**

At the start of phase one, the educational researcher in collaboration with the vocational practitioners selects a vocation in which to test at least one educational theory to apply in the design and development of a MUVE-based intervention. As the DBR is tailored and hybridised within hDAS, this selection of educational theory is revisited for its fit within
the disciplines and the particular vocational context. The educational researcher also
designs the data gathering methods to be used throughout the process suited to the
vocational context. The software engineer produces prototypes to test the most significant
aspects of the MUVE, which the team collaboratively draws from the product backlog list
for each sprint. Towards the end of the prototyping phase, a few student participants are
recruited to contribute their views in a focus group discussion of one or more prototypes.
The decision to move to phase two is made during the review following a sprint.

**hDAS phase two**

During phase two, the team pilots the MUVE-based intervention in a teaching and learning
situation. More students are recruited for piloting the intervention in one of their courses,
along with technical support. Each intervention provides an opportunity to gather evidence
that informs software design requirements and the development of educational theory.

Feedback from running the interventions may lead to features that are added to the product
backlog list, potentially leading to further development sprints between the runs of
interventions. It was discovered that since the features needed for running an intervention
are mostly identified and development is complete in phase two, the backlog list should be
moving into a recognisable ‘burn-down’ that shows developed artefacts are becoming
more stable. At the point where the Agile process becomes more stable, the hDAS process
has produced a suitably stable Agile software development method. The Agile process
continues to be recorded and the researcher continues to collect and analyse data through
swims.

**hDAS phase three**

As depicted in Figure 6.1, phase three is ongoing. Three semi-summative analyses and
evaluations of the design are undertaken using swim model-based analysis. The analysis
reflects on the educational theories applied in design. At the end of an hDAS cycle, phase
three activities focus on the effect of the theories applied in the design and development in
the context of deploying hDAS in that cycle to provide a semi-summative evaluation of
the design. Any rules that have been recognised or proto-theories that emerge inform
tailoring of the next hDAS method tailoring in the next iteration that deploys hDAS.
Enacting hDAS methodology does not require the phases to be carried out strictly in order. For example, after establishing the theory to be tested in phase one and some initial design and development, phase two could be enacted. If the theories chosen were problematic, the development would return to phase one where an alternative theory may be selected to be tested. During or after enacting phases one and two, Phase three is enacted to undertake analysis and reflect on theory as it was tested. Therefore, phase three can be repeatedly entered from phases one and two.

**Discoveries from the case studies**

A number of discoveries were made enacting the hDAS methodology in this study. Enacting an hDAS method induces and continuously tailors an Agile software development method (Highsmith, 2002 a) using educational DBR to apply the educational theory in tailoring the method in process. As the hDAS methodology is enacted, using a suitable hDAS method that produces MUVEs suited to and fit-for-purpose for a vocation in their vocational education and training (VET) situations. Vocational suitability is achieved by working with, and for, the vocation in DBR, and by adapting or tailoring the ongoing hDAS method. Theory seeding (Cochrane, Davis, & Morrow, 2013) enables the inculcation of educational theory into an hDAS process (see Figure 6.1). Participants in an hDAS process take roles as required by the circumstances (see participant swims in Figure 6.1).

**Data collection methods**

The TTM case enacted phase one of the methodology to establish the approach to be used throughout this study. It was discovered that the design of data collection methods has to be left until the context for the MUVE is well understood. As the understanding develops, suitable semi-structured interviews provide opportunities to gather requirements for the MUVE being designed. This allows features to become part of the design by pragmatism, where “unknown or newly conspicuous objects” (Rohde et al., 2017, p. 3) are recognised. Furthermore, the structure in the interview provides an opportunity to seed requirement-gathering with theory. Data collection methods that do not provide opportunities to unfold and discuss details directly and in context with vocational practitioners are considered unsuitable for hDAS. For the MUVE to be ‘of’ and ‘by’ the vocation, it must be informed and clarified by ongoing multi-disciplinary communication. Recording less formal
communications can be suited to hDAS, although inculcation of theory cannot be easily managed without a formal structure. Enacting the semi-structured interviews leads to features being developed from the influence of gathering the seeded-theory requirements.

The semi-structured interviews established in the TTM case were modified to make them more generic and place more emphasis on understanding the context of vocational instruction from the perspective of the profession. This modified semi-structured interviews was used in phase one of the Ship’s bridge communication case. The Ship’s bridge communication study was also a test of LPP and TPACK in practice. It was discovered that the design of the MUVE for the intervention was successfully guided by deploying hDAS, as it had been for TTM. However, there were many more participants who contributed to the design and development of the MUVE for instruction of the Ship’s bridge communication intervention. For example, the naval officer provided valuable information about the differences between military and merchant communication; the military use their own standard phrases in place of the IMO SMCP (IMO, 2005). An increase in the number of participant vocational practitioners and trainees added opportunities for collecting data to produce a richer context for the analysis that tested theory in practice, and refined the design of the MUVE and the intervention that used the MUVE.

The discovery of swims
The contribution of participants in the hybrid DBR-tailored Agile methodology as a process was informed by the derivation of a novel swim model (swim) introduced in Chapter 4 (see Figure 6.1). The swim provides an overview of the process while also enabling a focus on each participant and their interaction in a particular MUVE session. The use of swim lanes is novel in its use for designing and specializ the complex interactions between participants, the environments and the artefacts that are produced by the software engineer. For example, although Sharp, Rogers and Preece (2007) (see Figure 4.2) present interactions between designers and software engineers, indicating that turn-taking is essential. This study indicates that Sharp et al.’s view is over simplistic. The technique of analysis developed with swim lanes is important to track the complex interaction patterns during the process that went far beyond turn taking. Participant swims become units of inquiry through which to reflect on the theoretical seeding using LPP and
An intrinsic component of the hDAS methodology is that the design experiment is reproducible (see Figure 6.1). A detailed description of a design and development process through swims reproduces the analysis of the process and facilitates further review and reflection.

**Running interventions**

The first enactment of an hDAS, phase two intervention using the developed MUVE was undertaken with students training to be officers on super-yachts. A second intervention was with fishermen training to become qualified to work on the bridge of large vessels, such as a large ferry crossing the Cook Strait. It was discovered that these two sets of trainees presented different perspectives; the super-yacht students had more experience with game environments and gave advice on their expectations in terms of interaction with the MUVE, whereas the fishermen trainees presented applications of the MUVE-based technology in other learning situations. For example, they suggested a MUVE for deckhands of fishing vessels to learn how to operate winches.

It was discovered that enacting phase two for the Ship’s bridge case added to the understanding of how the theory-seeded, semi-structured interviews had an effect on the design process in several respects. It provided the opportunity to record data on the MUVE-based intervention as it was used in practice, analyse educational theory in practice through swims and research the software development process.

**Discoveries from software development**

There was correspondence between DBR and software development practices. Adaptation of DBR methods appeared very similar to the software development technique described for Agile methods, called Agile method tailoring, in which the Agile software development method was adapted to suit the project. Given that hDAS is a hybrid DBR Agile methodology, an interesting outcome was that it is purposefully adapted the Agile method to suit the design context. Previous studies of DBR for developing MUVEs for education have not reported on how the design gets implemented through a software
development process. As discovered in this study, hDAS provides a way to research the software development process in the context of educational theories.

Enacting phase one of the hDAS methodology in the Ship’s bridge case led to discoveries that came from the development of software to support artefacts in the MUVE. It was discovered that, when the selected intervention changed from training in the handing over of the watch to training of standard maritime communication at the helm on the ship’s bridge, some intended aspects of the design were not constructed and other aspects, such as, the first mock up of a bridge, continued to be developed for use in the final MUVE, while the design and development of simulated ship-to-shore communication was given a low priority.

It was also discovered that some programming scripts transferred from the first case to the second case, such as, the uniform changing scripts, see Appendix A6.1. On the other hand, scripts that were necessary for the development of the MUVE in the first case were not necessary in the second MUVE. For example, the first MUVE required a system that propagated the signage script to every piece of road to allow interaction for displaying TTM signage; this software was not required by the Ship’s bridge MUVE.

It was also discovered In the Ship’s bridge MUVE that the design and development of features for the MUVE can lead to a dead end. For example, the design and testing of a voice bot for an artificial Master and development problems with the voice bot were resolved by applying principles of the Agile Manifesto (Beck et al., 2000). However the voice bot was abandoned because, when it was tested in the teaching laboratory, the quality of the sound was very poor.

It was also discovered that improvements required for user interface interaction on the simulated ship’s bridge could be more easily implemented using other development platforms. For example, at the helm, a turn of the wheel produced a simulated turn of the vessel that was too slow. Although the slow response to a turn of the wheel was at first due to the researcher/developer not understanding what was required, it was also found to be a
consequence of using the OpenSim environment (Opensimulator, 2014) that restricted the timing of its reaction, producing an untimely response. However, using a 3D development environment, such as, Unity3D (Unity3D company, 2019) or Unreal Engine (Epic Games Inc., 2019) might facilitate the development of interaction that is more immediate.

The hDAS methodology discovered in this study is described in this section answers the question, “How can MUVEs be designed for vocational education and training?”. It was found that the hDAS methodology proposed in chapter three improved after tools for design and analysis were reviewed and applied in phase three of the project. It was discovered that, for these two authentic, situated contexts, LPP and TPACK were theoretical frameworks that progressed the design and development of interventions using MUVEs. When inculcated into an hDAS method, the theories help us understand how MUVEs can be designed for VET.

6.3 Discussion

This section discusses and relates hDAS methodology to educational design research and practice theory, and describes how hDAS meets challenges found in enacting design research. It reiterates the scope of research in hDAS methodology that is a topic of research itself. It also discusses the concerns in DBR that participants have an effect that steers the design in a different direction and the implementation is different from the design, which is alleviated by swim. This section considers hDAS methodology in the context of three types of systems for instructional design (ISD) that have been presented in the literature on the design of MUVEs, presents the relationship of the hDAS method to Agile methods and shows how hDAS undertakes research that fills gaps in DBR using MUVEs through detailed research into the whole process from design to development and evaluation. The section finishes with a brief review of the inculcation of LPP and TPACK in the context of the present enactment of hDAS.

This study was informed by educational DBR. The DBR approach presented here is development research; research in practice (Reeves, 2000). The research-in-practice approach was a response to work by Brown (1992), Cobb, et al. (2003), and Collins (1992)
as cited by Collins, et al. (2004) as early practitioners of research in design. Practitioners of DBR include Dede, et al. (2004) and Easterday, et al. (2017). The significant difference in this project was that it focused on the whole process of how to design MUVEs, including the development of the software. This was an consistent theme throughout the project. The approach has been to fully hybridise the DBR with an appropriately tailored DBR Agile software development method. In this hybrid process, the design research produced suited MUVEs for a specific vocation. It was intended that the research approach would consider educational theory and then select a suitable vocation. However, it is noted that the context can influence the choice of educational theory. In this study, though authentic and situated learning theory was considered through LPP as an authentic situated learning theory and the relationship with a community of practice.

This study was instantiated through the design of a DBR methodology that guided and manipulated a DBR method supported by development of digital artefacts using an Agile software development method. Enacting the DBR method led to the emergence of hDAS. In this thesis, hDAS is an enactment of development research (Reeves, 2000). How that relates to educational design research is worth discussing with reference to processes enacted in this study.

Reeves (2000) argues that design experiments and design research strategies can be applied to enhance educational technology research as “use-inspired basic research” (p. 8), in which basic research is closer to pure science for discovery than applied research. He cites Stokes’s (1997) presentation of Pasteur’s vaccine research as an example of use-inspired basic research, which Stokes calls Pasteur’s Quadrant. The study reported in this thesis can be regarded as use-inspired basic research that is immersed in deriving and understanding practice in the design of MUVEs for VET. The study was motivated by Brown’s (1992) design experiments, in which she designed interventions for live classroom teaching and learning situations. Her perspective provided a guide for the approaches taken in this research, which sought to discover and produce useful artefacts through research in practice, in and for live educational situations.
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How were to be conducted was introduced by Cobb et al. (2003) described the primary goal of design experiments were, “to improve the initial design by testing and revising conjectures as informed by ongoing analysis of both the students’ reasoning and the learning environment” (p. 11). In an analogous manner, the DBR process initially designed in this study became hDAS through the ongoing analysis of the design and development with vocational practitioners and students. The testing and revision were motivated by seeking to situate the learning in authentic VET using MUVEs.

Through observing the enactment of design experiments in education, Collins (2004) identifies the difference between design-as-intended and design-as-implemented as potentially presenting a challenge to the DBR process:

A fundamental challenge in developing a design science in education is that the enacted design is often quite different from what the designers intended ... where the goals and principles underlying the design are undermined by the way it was enacted. (p. 17)

In this study, the enactment of the design process increased the understanding of the process and theory in practice. For example, in the design of the semi-structured interview as a data collection method, the understanding of LPP-in-practice became clearer, because it was applied to determine what the TTM vocation was, how it was structured and how instruction in that case was undertaken. Similarly, the TPACK framework allowed us to identify technology-as-needed for the vocation from technology-for-potential pedagogical approaches in TTM instruction.

DBR was purposefully about discovery, hence a difference between design and implementation was of interest. From a pragmatist perspective, the world of the design is in a process of becoming one, in which significant emergent objects are those that need special attention (Rohde et al., 2007). However, early enactment of the DBR and the discovered hDAS needed to be careful and systematic as the design adapted to the educational design situation.
Collins (2004) explains that differences of design-as-intended and design-as-implemented occur because, during implementation, design decisions are required that go beyond the original design:

*Any implementation of a design requires many decisions that go beyond the design itself. This occurs because no design can specify all the details, and because the actions of participants in the implementation require constant decisions about how to proceed at every level. Designs in education can be more or less specific, but can never be completely specified. Evaluation of designs can only be made in terms of particular implementations ... In evaluating any design it is important to keep in mind the limit of the evaluation.* (p. 18)

In this study, the swim notation provided an overview of the way the hDAS was enacted, focused the analysis on the effect of participants in the context of theory-inculcated design, and provided the same context for theory-inculcated development processes. Collins’ (2004) concern that participants have an effect that steers the design in a different direction can be alleviated by thinking of participants as taking occasional, natural dips in the hDAS. The nature of the process to design and develop the MUVE is of interest as it provided data, from which to reflect on theory and the design tools.

Comparison of methodologies

At this point, it is worth discussing where hDAS sits in the context of research into ISD used for the design of MUVE-like instructional environments. Soto (2013), identify three categories of ISD models in the design of MUVEs for instruction. The first category (and most prevalent) ISD approach uses ADDIE (Allen, 2006); the second category applies Agile in an ISD process and the third category explicitly selects educational theory to use in the design process.

This section compares each category of ISD with hDAS.

Category 1 instructional designs and hDAS
Wang and Hsu (2009) present an example of an ISD that uses the ADDIE model for the design of MUVE-like instructional environments. Typically, there are five advantages of using the MUVE (Wang & Hsu, 2009): an “enriched learning experience” (p.76); “strengthening a sense of social presence” (p. 77) and “multi-level interaction” (p. 77) of students with content, and relationships of students with instructors and amongst students; “promoting constructivism” (p. 78) and “enriched multi-media resources” (p. 78). Wang and Hsu then describe ADDIE as it was applied in the design. Analysis was undertaken to determine the requirements for the learning context. In this case, the instructor conducted an online survey to determine students’ backgrounds and motivations. Design was the major task; the instructor created a list of tasks and made them into instructions for the students. Development was undertaken by the instructor, who worked on the navigation in the VW, took images for the webpage and made sure the objects of interest were in the VW. During implementation of the intervention, student instruction was assisted through a learning management system on a webpage outside the MUVE. Wang and Hsu (2009) report that the students were enthusiastic about the intervention. Evaluation was facilitated by inviting a faculty member to observe the MUVE. Wang and Hsu concluded,

In this case, ADDIE constituted a systematic method that helped the instructor design learning tasks that would take place in an SL virtual environment and that would ensure SL’s function as a tool assisting teaching and learning. (p. 81).

The use of ADDIE described by Wang and Hsu (2009) differed from hDAS in several ways: (1) it did not undertake any investigation into educational theory; (2) ADDIE did not inform the design process; (3) it was an ad-hoc, checklist approach to designing and developing an instructional situation; (4) it did not inculcate theory into ADDIE; (5) although ADDIE expressed behavioural learning theory, opportunities for constructivist learning were not pursued and (6) did not inculcate constructivist-guided activities during the instructional design.

This comparison shows that the hDAS discovered in this thesis focuses on research into
how to design MUVEs for VET whereas using ADDIE as a checklist for instructional design of the MUVEs would not.

Category 2 instructional designs and hDAS

In the second category of ISD, the application of Agile in an instructional design process is presented in two studies. Dass and Cid (2018) describe the application of Agile in the design of a medical simulation, and Cooney and Little (2015) describe how Agile was used to overcome issues with ADDIE in a large project. Both papers compare ADDIE with Agile in the context of implementing instructional design. Cooney and Little’s (2015) study is representative of the application of Agile in instructional design. They describe using Agile principles in the context of an ISD project that was not making good progress, seemed to be understaffed and,

using industry standard development metrics provided by the Association for Talent Development (formerly ASTD) (2009), the authors estimated traditional instructional design would require approximately 60 hours of development time for each hour of training, or approximately 4800 hours to complete the two-week course. (p. 2)

They implemented a KanBan-style Agile process (Raju & Krishnegowda, 2013) that avoided issues with the first generation ADDIE, in which they had difficulty with the formal turnover of work from one step to the next in the sequence, and the Agile process removed the complex communication that would arise in later iterative versions of ADDIE. Moving to Agile as a process for ISD, the project was delivered by the small team. They note that Agile has been used in various forms for ISD and conclude that, “What is missing from all of these is an emphasis on the Agile values and principles fundamental to Agile ISD’s success, and a meaningful commitment to incorporating scrum methods” (p. 11).

Comparing the Agile-based ISD process as applied by Cooney and Little (2015) with the hDAS reveals several differences. Cooney and Little describe the use of the Agile principles to ensure they kept on track during the ISD process, while in hDAS, the Agile principles become a foundation for directing the Agile software development method in
DISCUSSION AND RECOMMENDATIONS

the process. The hDAS does not explicitly use Agile to manipulate design; it is the process through which design is enabled, and hence, hDAS is guided by the Agile principles. Poppendieck and Poppendieck (2003) discuss the application of Agile in educational situations and explain how the terminology from Agile software development would need to be adjusted to apply similar concepts in the educational situation. The Agile-based ISD process, as applied by Cooney and Little (2015), does not consider educational theory and is not informed by research that tailors an Agile software development method to suit the changing situation as the educational design is better understood. These features are the hallmark of the hDAS methodology.

Category 3 instructional designs and hDAS

The final category discussed are ISD models that explicitly select educational theory to use in the ISD process. Davies, et al. (2018) present an ISD model to address the gap between the development of simulation systems and the applied use of educational theory. They apply a five-stage educational framework called the ADELIS model to ensure that both learning and assessment are valid in the simulation intervention. The focus is on developing an authentic learning activity. According to Davies, et al., the framework provides opportunities for measuring the intervention, the learning and behaviours in the immediate situational context, and the impact of the exercise from the view of educators and participants. Design using the ADELIS framework starts with the selection of a part of a course or curriculum that is suited to simulation and considers the simulation across course units and interconnections between simulations, such as, establishing appropriate knowledge sets using Cynefin domains as a theory of knowledge. The first process is followed by a constructive alignment process where the intervention through the simulation design is aligned to develop Learning Outcomes (LO) using an educational taxonomical vocabulary, based on the Los assessment is derived based on appropriate theories that suit the learning process from that simulation. The third step develops content based on the Los using educational theory that underpins and addresses Los and assessment criteria, and the required psychological and technical quality (fidelity) that encourages participant buy in is determined. In the fourth step aims methods of associated research, with validated and reliable evaluation tools are determined by the designer. In the fifth step a protocol is established for the simulation developer that identifies and
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assures educational fidelity and authenticity in the simulation.

The ADELIS Model is a framework, from which to induce a process for the design of simulations for interventions, that are going to be developed by a developer who is a third party to the design process. Educational research is part of the framework, but there is a sense that the research is not intrinsic to the overall process. hDAS is a research methodology by design, hence enacting the hDAS methodology intrinsically becomes design based research. hDAS prescribes a Swim technique for analysis that generates semi-summative evaluations of the process, while at the same time reporting of the effect of theory in the context of the enacted hDAS process, that includes design development and running of interventions in with the MUVE is live educational contexts. ADELIS presents a framework that does not include refinement of its use in practice in the direct manner that is intrinsic to hDAS. hDAS goes beyond ADELIS in the aspect of development of the MUVE, by inducing and tailoring an Agile software development method that suits the design of the MUVE based intervention through practice and as the needs of the intervention are discovered.

hDAS provides a solution that is supported by Cockburn (1999) “one method per project” assertion and proposal for real-time adjustments to the methodology. Cockburn (1999) presents a rationale for real-time adjustment of a software development methodology.

“Once we understand that every project deserves its own methodology, then it becomes clear that whatever we suggest to start with is the optimal methodology for some other project” (web page, in section Real-Time Adjustments to the Methodology)

This research avoids the trap, in which although the software development process is Agile, the methodology was tailored to fit an early understanding of the requisite design, however as the focus of the design is refined and better understood the original methodology no longer suits the project. The hDAS process resolves this trap by hybridising with DBR to maintain the fitness for educational purposes over time.
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hDAS works with vocational practitioners early (in phase one) and throughout the DBR methodology, the enacted process not only followed an education design research tenet described by McKenney and van den Akker (2005) to guide and structure their study “Design and development activities related to an innovation must be conducted in collaboration with and not for those involved”, p 47. That need for collaboration with vocational practitioners throughout the process, given that they are the education equivalent to “Business people” for whom software is produced, meets the ‘Manifesto for Agile Software Development’ principle (Beck et al., 2001 b) “Business people and developers must work together daily throughout the project”, p 2. Since both disciplines are attempting to design appropriate and suited artefacts it is likely similar design rules or “proto-theoretic guides” would be identified by both disciplines. This similarity between DBR tenets and Agile software development principles suggested the opportunity for hybridisation of Agile software development process with DBR.

This multidisciplinary study went beyond the synergy that comes applying an approach from the educational field into another discipline. At one meta-logical level the DBR focuses on the development of a MUVE and its application in a classroom based intervention. At this level the artefacts that are the topics of DBR are the MUVEs and interventions, for example how theory was inculcated into the MUVE during the design and development of the MUVE, and the way theory guides analysis of recordings of the design and development and during interventions run in classrooms. At a higher meta-logical level the discovered hDAS is a topical artefact of the DBR. The software engineering became a hybrid with educational design research and this is only possible to observe because of the detailed analysis of the process, as depicted in summary in the Swim diagrams and subsequent reflection on Swims presented in Chapter 4 and Chapter 5.

Through the description of the design and development of hDAS, a system for producing a MUVE in vocational training has been described in detail for the first time. Although for example, Dede (2017) identified the use of constructivist theories by his research team, there was no research into ways in which those theories were deployed within that research by the software engineers. Similarly, socially responsive design identified as a theory used for the Quest Atlantis project (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005), but they did not go into details of their software engineering processes. The
software engineering details were also missing from Jossberger, Brand-Gruwel, van de Wiel, and Boshuizen (2015; 2018) who described teachers’ perceptions and students’ perspectives in teaching and learning of workplace simulations in vocational education.

Also, some studies have identified theories that inform their software design, without describing the software development process. For example, Molka-Danielsen, Prasolova-Førland, Fominykh, and Lamb (2017) developed a specialized VR simulation for training communications in management during a crisis situation in which “learning modules were design based on socio-cultural theories of learning, in particular, an active learning system based on Activity Theory” (Molka-Danielsen et al 2017, p 4).

Esteve-Mon, Cela-Ranilla, and Gisbert-Cervera (2016) undertake a DBR process that has the same phases as McKenney and Reeves (2013) in the design and development of Eteach3D a 3D virtual environment for evaluating digital competence of pre-service teachers, that reproduces the physical classroom environment in a 3D VW. Although they describe iterative prototypes and formative evaluation of the Eteach3D system, Esteve-Mon, Cela-Ranilla, and Gisbert-Cervera (2016) do not describe a software engineering process, nor do they include an educational theoretic underpinning in their design process.

DBR software engineering does not make use of nested scientific processes to produce theory. Requirements of a DBR methodology process, described by Easterday, et al (2014) and listed in Chapter 3: “design[s] a product while using other methodologies as nested processes” (p. 222), and “make use of nested scientific processes to produce theory” (p. 222) were directly integrated rather than strictly “nested”. Being “nested”, implies separation of the DBR process, where it acts as a shell in which other methodologies and scientific processes are practiced. In this study the process integrated a tailored Agile software design methodology in a hybrid with DBR. Unlike research that is based on a hypothesis that is tested with an experiment, in this design research (Reeves, 2000), (see Figure 3.1 for detail), the production of artefacts such as MUVE that are implemented in an educational context become the test for the theory informed design. The DBR treated theoretic frames as pervasive and inherent in the DBR process, it focused on the
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participants in the DBR process as sources of observations from which to reflect on the application of the educational frames within the learning contexts as well as in the development of the MUVEs. Thus there is no need for additional tests to validate this hybrid DBR Agile theory informed design process.

It is relevant to discuss the theories that were used to seed the DBR. As introduced in the methodology chapter software engineering was impacted by DBR so that theory seeding guided the solicitation of requirements. LPP and TPACK to guided solicitation of requirements of both of the MUVEs. The success of such theory seeding is innovative. Although TPACK is often used in teacher education (Blackwell, Lauricella & Wartella, 2017; Bueno-Alastuey & Esteban, 2016; Chang, Jang & Chen; 2015; Patahuddin, Lowrie, & Dalgarno, 2016; Phillips, 2017; Reyes, Reading, Doyle, & Gregory, 2017; Szeto, & Cheng, 2017), it is rare to see TPACK being used as a framework in the design of learning systems. Basset and Silva (2012) presented the design of a student learning centre website using TPACK as a framework, demonstrating that TPACK can be used as a theoretic frame for the design of educational resources. No literature was found that described the use of TPACK as a framework in the design of interventions using MUVEs nor has it been used in the design and development of the MUVE. Similarly, LPP does not appear to have been previously used as a theoretic frame that guides the design and development of a MUVE.

When integrated into the gathering of the requirements of the MUVE based interventions, TPACK directed the educator towards consideration of technological concerns in pedagogy and in the content knowledge. Pedagogical content knowledge (PCK) (Shulman, 1986), is presented as the basis of the derivation of TPACK (Misra & Koehler, 2006). However, in the formulation of TPACK (Mishra & Khoeler, 2006), pedagogical content knowledge is subsumed by adding technological concerns. PCK identifies the need to consider that there may be a suitable pedagogy for a given content knowledge space. Whereas, looking at the Venn diagram representation of TPACK (Mishra & Khoeler, 2006) see Figure 2.3, it moves the focus of concerns to include: suitable technology for a pedagogical approach, and suitable technology for content knowledge spaces, and the need to determine a suitable combination of technological pedagogical content knowledge,
leaving pedagogical content knowledge as one of many, where all other concerns are influenced by a technological focus. The TPACK focus on technological concerns is relevant in the design of MUVEs for vocational situations because the effect of technology cannot be avoided, in the technological nature of the MUVE and in the definition of vocational education – that is practice centred; in which practice of techniques of and in the technological context of a vocation are central.

The following discusses the selection and effect of LPP and TPACK from their inculcation into the hDAS method as the hDAS was enacted and derived during the two cases, TTM and Ship’s bridge communication. In the present study, the selection of one theory LPP and one theoretic framework TPACK were considered to be sufficient. These theoretical perspectives were seen as orthogonal, i.e. they did not appear to confound guidance in design and development. They did not confound each other because TPACK (Mishra & Koehler, 2006) identifies concerns for consideration during instructional design with technology, based on the pedagogical content knowledge theory of Shulman (1986), i.e. a frame for teaching and learning. Whereas LPP is a theory of authentic situated learning that is concerned with the vocation’s and the individual’s participation in their progress within the vocation. Hence applying LPP provides details for pedagogical, and content knowledge, as well as technological concerns from arising in the vocation. It was discovered that the design of MUVEs in this study was guided by this complementary effect of both LPP and TPACK.

In both cases LPP for authentic situated learning is a fit with the vocation, as follows. In both TTM and Maritime studies, practitioners considered training at the place of work or being as close as possible to the place of work desirable. Both vocations provide ‘tokens of office’ that signal legitimately for the trainee and the vocation indicates a journey from the legitimate periphery of the discipline to becoming participant in the discipline– that is a community of practice as in the apprentice cases described in Lave and Wenger (1991).

In the TTM case the program manager produced the most information about TTM practices in response to LPP prompts during interviews. The sense was that TPACK
helped more than LPP in the design of the MUVE. LPP was effective in focusing the interview on the TTM practices. The best outcome in the TTM case appears to have been from TPACK that opened up the semi-structured interview producing valuable information about how the MUVE should be designed for the intervention. In the TTM case the valuable contribution from the TPACK to the design process may have been because the tutor was designing a MUVE based intervention in the context of her course. In that situation TPACK informed the process of design as it is should.

In the Ship’s bridge case, the data collection method was redesigned to identify influences in the intervention that would come for the context of the course within the broader community of practice and the running of the intervention in the institution. The effect was to spend a little more time on LPP influenced concerns during the interviews. In the Ship’s bridge case TPACK had the same effect on the design of the MUVE as it had had in the TTM case; it informed the process as it should.

In the Ship’s bridge case there was a stronger sense of a community of practice from the mariners as a vocation. For comparison, in the TTM case, TTM was treated as necessary but not central to the discipline in both Engineering and Surveying. Whereas, in the Ship’s bridge case, bridge communication was treated as an integral part of a trainee’s vocation. Ships bridge communication training is required for officers on the bridge. Completing that training allows trainees to move more strongly into their community of practice.

During Phase Two in the Ship’s bridge case, interventions were run by a Master of the vessel, who induced appropriate behaviour for a Ship’s bridge in the classroom. It was discovered that Master mariner tutors can moderate the effect of technology in the classroom because they are used to training with simulations, and because of the inculturation of the trainees into the vocation. The LPP was found to be represented in the mariner case. Although TPACK was to be used in subsequent analysis of the recording of interventions in Phase Two, it was discovered that failure of technology only occasionally interfered in the run of an intervention.
In the second case the enacting of hDAS Phase Two led to an impression that LPP was more effective in this case, because the Masters were in their environment as mariners during the implemented interventions. Whereas, Analysis of the first case could give the potentially misleading impression that TPACK was in some way stronger in the TTM case. However, that was not supported from analysis in the second case, TPACK was found to be equally useful in Phase One in the Ship’s bridge case as it was in Phase One in the TTM case. Similarly, the observation that the effect of LPP in the first case was less significant could be because Phase Two was not enacted in the TTM case. However, that was not supported by analysis, LPP was effective during Phase One of both cases, by providing a context and focus in the design of fit for purpose MUVEs suited to an intervention as identified by vocational practitioners. Hence, both LPP as a theory and TPACK as a theoretically founded frame for considering technology in the design of instruction, are found to have been effective in these cases.

This on-going study adds to the body of knowledge through practical design and development of MUVEs for vocational education and training by studying the pragmatic design and development of interventions using MUVEs in two vocational contexts. This research confirms, for these two authentic situated contexts, LPP and TPACK as theoretic frames that progress design and development of interventions using MUVEs – when inculcated into the hDAS methodology the theories help us understand how MUVEs can be designed for vocational education and training. Using the DBR Agile software design methodology correlates hDAS processes, when both are integrated, as they are in the discovered hDAS process. The research pro-actively and explicitly induced analysis with reflection on educational theoretic frames in this study LPP and TPACK as they are applied in practice, to the design of interventions using a MUVE in live courses. This provides an on-going process for further research into the design and development process in authentic situated contexts.

6.4 Future Research

In this section future research is presented to provide a context in the on-going development of hDAS. This section presents future research on the present MUVEs at
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TI2. This section discusses how hDAS deployed at different institutes can provide research from different contexts. It explores research outcomes over several iterations of hDAS. Proposed research on multi-disciplinary aspects of hDAS methodology, through research into Information Systems practice and Agile methods in Software Engineering is discussed. Potential research that deploys hDAS methodology with different educational theory is discussed.

Research through further development of both MUVEs at TI2, will refine and mature the current research and its outcomes. In the TTM vocational context, hDAS Phase One can be repeated starting with the present TTM MUVE, to observe effects when new practitioners are introduced, and to refine the MUVE to suit interventions as required by those vocational practitioners. Phase Two for the TTM context, can be enacted at TI2 to develop and refine understanding of the effects of LPP and TPACK in hDAS in that context. In the maritime vocational context, running further interventions in an extension of Phase Two, with further formative evaluation followed by development Sprints for further development of the MUVE from those interventions would provide an opportunity to gather more data while the MUVE-based intervention is used in more training sessions with different cohorts of trainees.

Research using hDAS at different institutes provides further opportunities to refine and mature the hDAS methodology in VET contexts. Research using hDAS in other types of training organisations, such as military provides opportunities to observe hDAS with LPP and TPACK in situations that are different from the technical institutes that have been the location of the present study. The speed and quality of the research through enacting hDAS methodology in a context that has better resources can increase the opportunity to iterate hDAS methodology over several cycles. That can provide the opportunity to reflect on theory as it effects several hDAS iterations and potentially observe emerging practices that are derived from further reflection on design rationale.

Reflection on the on-going DBR can focus on IS design theory research to develop an understanding of how design methods of Information Systems design, software
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engineering and educational design based research are informed by multidisciplinary research as practice theory research (Rohde, et al., 2017). For example, the research presented by Dittrich (2016) considers methods in practice compared with theoretical methods, to develop concepts of method as practice patterns from an understanding of “software development as social and epistemic practices”, p. 220. Her interest in gains from emergent design practices – rationales, that diverge from practices recommended by theory can be tested in longer term hDAS methodology enacted over several cycles.

Similarly, future research of multidisciplinary perspectives of the on-going hDAS methodology as it is enacted, can develop an understanding of the rationalities of different discipline practices in their effect on the processes. Focusing on the Agile methodology, the proposal by Wufka and Ralph (2015) describe Agility in Agile methods through a process theory of change, “Process theories, … attempt to explain and describe how entities change over time”, p 60, can be used to consider the Agility of the methodology in this study. Hence, for example, in a pragmatic manner, processes derived from participant Swims can be investigated to observe change in the artefacts – entities over time, towards an understanding of the Agility of hDAS.

Other theories can be tested in further iterations that enact the DBR Agile methodology. For example, Molka-Danielsen, et al (2017), study the design of learning modules for training emergency management professional in VR. They developed a repertoire of response patterns based on a cognitive task analysis of the emergency situation, with the oversight of naturalistic decision making theory frame recognition primed decision (RPD). That repertoire of response patterns then guided instructional design of the VR environment to support it. If deploying the hDAS methodology leads to the RPD model inculcated as a theoretic frame, then inquiry would be led by cognitive task analysis to produce a repertoire of patterns suited to the on-going TTM and Ship’s bridge communication vocational situations. Hence RPD would be tested and give rise to a variant of the hDAS method.

As hDAS is on-going, future cycles can lead to research into suitable interventions with
MUVEs that are implemented with different technology, and potentially in situations other than a classroom, convenient to the learner. In the following section mitigations of limitations of the research as the study proceeds presented, for the on-going research.

6.5 Limitations

This section identifies limitations of the research as the study proceeds. As the research proceeds it will need to continue to mitigate these limitations, for conscientious and systematic research outcomes. The section considers how to mitigate for the participant researcher who has number of roles, describes how the relationship between the researcher and participant colleagues was mitigated in this study and it describes how financial limitations had an effect on the study. Although hDas was implemented by a one person development team, how hDAS works for larger team is discussed. Finally the section discusses the limit from developing MUVEs through an hDAS methodology on a different platform.

A major limitation is the number of roles taken by the participant researcher, that included designer, developer and technician. For example, as the MUVE developer who produced the coding it is possible that some of the processes remain undocumented within a Sprint. This was guarded against by consistent use of the tools used to support the Agile process, as described above. In another example of how multiple roles were managed, taking the technician and researcher roles during classroom based interventions could have a negative effect on the quality of the recording of participants. This was guarded against by structuring the times at which researcher and technician roles took place during the intervention. Further, this was guarded against by recording with more than one system, to provide potential triangulation through analysis of both recording systems and to provide backup if a system failed. During the second Ship’s bridge classroom intervention, screen recording of participants’ avatars failed. This potential loss of data was reduced by a separate audio recording of participants in the classroom. The alternative audio recording was digitally manipulated to provide a record of sound at the same level of volume no matter where the sound came from in the classroom, so that even if audio from one part of the room had less volume in the raw recording the volume of the recording of that area was the same as the volume throughout the room when the record was transcribed and
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analysed.

As a colleague of the professional experts and teachers in the same institution it is possible that the specification of the requirements were biased through their familiarity with the researcher – the colleague could have identified requirements that were influenced by the researcher. This was guarded against by the researcher not being close to the participant colleagues, and by strict adherence to the designed data collection methods, recording and systematic interviewing. Further the potential bias was guarded against by triangulation of the record of the same interview conducted with colleagues at different times.

The research was limited by the resourcing of the tertiary college in each case. Should the hDAS methodology be adopted into a better resourced context such as that of the armed forces, then more progress would have been made in both the development of the interventions and their corresponding MUVEs. The quality of the 3D environments and their support services would also be improved and potentially participants would have had a more consistent experience.

In this study, hDAS methodology was enacted and implemented by a one person development team. A one person team does not have the benefit of other developers’ experience and insight that comes from working in a team of developers. This limitation was mitigated by the developer by discussing the development process with software development colleagues, and by searching for example solutions to similar problems reported in online forums, e.g. the scripting forum Stackoverflow ("Newest ‘linden-scripting-language’ Questions", 2019). A benefit from working in a team is division of labour. When enacting hDAS in a team, new roles can be introduced to take advantage of the teams capacity in development, and research. For example: Scrum roles could be introduced in a tailoring of the Agile method with a Scrum Master (Sutherland & Schwaber, 2017). An hDAS methodology with a team of developers would require normal software source code revision and version control, for example at prevalently used source code revision version control system at present is GitHUB ("Build software better, together,” 2019). Enacting hDAS methodology would mitigate issues that arise in a larger
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tram by tailoring a suited Agile method for the team.

This study developed and implemented MUVEs using one platform, that is OpenSimulator (2014). Developing and implementing MUVEs in other platforms gains advantages and is constrained according to the facilities and characteristics of the platform. For example, if the MUVE development platform produced displays and audio input and output on mobile devices then the MUVEs would be available in mobile contexts. The hDAS methodological process would remain the same. If the hDAS method used a cross-platform 3D game engine development system, for example Unity3D (Unity3D company, 2019) the development can take advantage of the facility to create a MUVE that can be used on many systems, such as mobile, web and personal computing workstations. However, since Unity3D (Unity3D company, 2019) does not provide multi-user and avatar based interaction with audio by default, then the Product backlog (Sutherland & Schwaber, 2017) of the tailored method would reflect the need to develop those necessary facilities.

Overall potential limitations were managed by recording and undertaking systematic interviews, triangulation and by making contingency plans.

6.6 Concluding Remarks

This on-going DBR research study has discovered a novel DBR Agile methodology by enacting a DBR methodology in a pragmatic way through taking interpretive turns during each phase. The continuing processes of enacting the hDAS methodology has produced some observations of the effect of LPP and TPACK as theoretic perspectives that answer the question “How can MUVEs be designed for vocational education and training?”.

Branching out into design and development of MUVEs for vocational education and training using other theories and technologies will provide further opportunities for research in information systems design, software engineering and educational design based research.

The MUVEs illustrated in this thesis have clear purposes identified in detail through the
methodology, which is one key to improving the design and application of simulations in education. Authentic learning with situated immersive role play continues to offer exciting possibilities for education and strategically important industries working in high risk contexts. Although virtual worlds including MUVEs are challenging to implement in education and training at present, the literature indicates that this is likely to become more widespread in future with improvements to educational contexts in colleges and student access using their own devices.
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Appendix A1 Platforms for MUVEs – open sandboxes

The MUVE environments considered in this project were third generation VWs presented through 3D graphical environments. Examples include: ActiveWorlds (Activeworlds Inc., 2009); Second Life® (Linden Lab, 2009); Blue Mars (Avatar Reality Inc, 2010); Twinity (Metaversum, 2009); Project Wonderland (Sun Microsystems Laboratories, 2009) and OpenSimulator (2014). These open sandbox game-like environments can be installed as software on sets of desktop PCs and in classroom laboratories. They do not require highly specialized, technically engineered environments, which can be very expensive to set up. Hence, they meet the requirements of a MUVE that can be implemented for interventions in vocational training at a New Zealand polytechnic.

OpenSimulator (2014) was selected to be used in the study. As identified by Ritke-Jones (2010) OpenSimulator (2014) had advantages: it can be deployed on to an intranet within a polytechnic through the installation of a single desktop VW viewer application onto classroom PCs with a VW server on the same intranet, it is mainly open source – the whole of the VW simulation software is available, however the voice communication interface uses proprietary third party software, which is generously provided by free license up on application by Vivox (2019), the scripting system and workings of the VW environment are based on Second Life, which was being used in many educational research

Other technologies that were considered are Web3D, and display technologies, VR headsets and 3D glasses. Augmented Reality(Billinghurst, Clark, & Lee, 2015)was not considered in this study. Web3D has the inherent advantage that the MUVE could be delivered through a web browser and therefore it would be available anywhere a suitable web browser application could be used. The following section describes this technology in more detail, giving a context for the decision not to use Web3D. Web3D is a technology in which MUVEs can be implemented. Web3D has its origin in Virtual Reality Modelling
Language (VRML) which is a mark-up language for expressing 3D objects, interactions and animations. The first VRML symposium was held in 1995 (Nadeau & Moreland, 1995). The VRML Symposium was then held annually from 1997 to 2000. In 2001 the VRML Symposium included Web3D in its title and included the subtitle “International conference on 3D Web technology”. The symposium then continued as the International Conference on 3D Web Technology. The 14th International Conference on 3D Web Technology was held in Darmstadt, Germany in 2009 (Fellner et al., 2009). Over the 14 years of the VRML symposium two publications that describe education using Web3D technology have appeared in the conference proceedings.

Brutzman (2002) describes using Web3D technology for teaching 3D graphics concepts in a class held in 1999. His class created a 3D virtual kelp forest simulation for a museum. He concludes that VRML is very useful when teaching 3D graphics and that the students had a motivating experience, when they showed the public through their virtual kelp forest. Fellner & Hopp (1999) claim that “distributed work is becoming a major issue for a large part of the work force and distributed collaborative research has almost become the norm”. They describe “tele-teaching” and “tele-learning” as important applications for remote data access. However, they suggest that at that time “tele-education” had not discovered distributed 3D virtual environments. They believed

that the demand for interactive exploration of distributed 3D databases over the internet and for collaboration within virtual 3D environments will soon become one of the driving forces of future development.

Their paper, is mainly concerned with the technical constraints in the implementation of their system.

Chittaro & Ranon (2007) introduce the educational use of virtual reality based on Web3D technologies. They describe the range of applications that Web3D technologies can be applied to, from medical training applications to collaborative learning environments. They confirm the assertion that virtual environments can “provide a wide range of experiences, some of which are impossible to try in the real world because of distance, cost, danger or impracticability”. They claim that while there has been growth in
“educational virtual environments” (EVEs) in vocational (their medical example) and informal contexts, the use of EVEs in “formal contexts has seen slower growth”., p They discuss five issues that may have caused slower growth in formal contexts: (1) funding for which they claim Web3D would be more cost effective (2) The second issue they identify is a lack of studies with validated results and a lack of long-term studies that confirm positive effects experienced in short term usage of the EVE. (3) They confirm the need to consider the attitude of the teacher towards the adoption of the EVE into their classroom environment. They confirm need for proper designs of EVEs. (4) Finally, they identify a need for proper integration of the EVE into curricula. While Web3D technology may provide a foundation for a MUVE, and they can be used to implement EVEs, Web3D is not the focus of this study. The issues raised by Chittaro & Ranon (2007) provide additional motivations for undertaking the current study because EVEs are used in educational contexts in a manner that would be similar to the educational contexts in which MUVEs could be used.

VR headsets, such as the currently popular Oculus Rift (Oculus, 2019) and the HTC Vive (Vive, 2019) and mobile telephone based 3D displays such as the Google Cardboard (Google, 2018) based headsets were considered, because they provide a sense of immersion in the MUVE, that potentially could increase the sense presence in the MUVE. However, getting a class set of these headsets is expensive, and adds complexity when running interventions in classrooms.

VR using 3D glasses, was also considered, the arguments against using them in this study are similar to those presented for VR headsets, the technology requires extra equipment in classroom laboratories, also with normal classroom computer display screens, this technology requires either anaglyphic rendering of the 3D VW or equipment that interleaves different views for glasses that rapidly switch the display from one eye to another to achieve a stereo display. A possible advantage of VR using 3D glasses is that the classroom can be seen when looking away from the screen. Using VR through 3D headset or 3D glass technology is left for future research.
## Appendix A2 Agile Methods

### Table A2. Descriptions of mainstream Agile Methods identified by Campanelli and Parreiras (2015).

<table>
<thead>
<tr>
<th>Identified Agile Method</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Extreme Programming (XP)</td>
<td>Citing Beck (2000) and Campanelli and Parreiras (2015), XP focuses on cost savings, unit tests before and during code activities, frequent full system integration, pair programming, simple design and frequent releases of working software (p. 86). Reflecting five years of XP practice, the XP methodology is revised in Beck and Andres (2004). They assert that focus of XP is programmer practice that is guided by XP values, principles and practice, as a sustainable lifestyle in the context of the individual programmer within a software development team. According to Beck and Andres (2004), XP values are communication, simplicity, feedback, courage and respect. Beck and Andres (2004, Chapter 20 Applying XP) view XP as political in nature, for example they suggest that undercurrent organisational values may make XP ineffective.</td>
</tr>
<tr>
<td>Scrum</td>
<td>As defined by Sutherland and Schwaber (2017) Scrum is “A framework within which people can address complex adaptive problems, while productively and creatively delivering products of the highest possible value” (p. 31). Eloranta, Koskimies, and Mikkonen (2016) describe the method of the Scrum framework, see Figure 3.3 in Chapter 3.</td>
</tr>
<tr>
<td>Kanban</td>
<td>As described by Raju and Krishnegowda (2013), Kanban “is a method for making incremental and evolutionary improvements in the software development process. Kanban method limits the number of features/functions locked in work in progress (WIP) and creates a pull system only when the current prioritized feature/function is developed. This helps to balance the overall development activities by elimination the clog in the development cycle” (p. 44). Kanban only works on one task at a time, like Lean software development on which is based is driven by customer demand.</td>
</tr>
</tbody>
</table>
| Feature-Driven Development (FDD) | Attributed to Jeff de Luca and Peter Coad, FDD is undertaken in phases or processes, that involve OO modelling design and development, with whole team planning and reviews, these are: Develop an overall Model, Build a features list, Plan by feature, then for each feature, Design by feature, Build by feature. According to Highsmith (2002 a) “FDD asserts that:  

- A system for building systems is necessary in order to scale to larger projects  
- A simple, well-defined process works best  
- Process steps should be logical and their worth immediately obvious to each team member  
- "Process pride" can keep the real work from happening  
- Good processes move to the background so team members can focus on results  

- Short, iterative, feature-driven life cycles are best”, (p. 151). |
| Dynamic Systems Development Method (DSDM) | According to Highsmith (2002 a) regarding the “… DSDM development process. Each of the major phases: Functional Model iteration, Design and Build iteration, and Implementation—are themselves iterative processes. DSDM’s use of three interacting iterative models and time-boxes (for both iterations and releases) can be confusing initially, but once the definitions are sorted out, they can be used to construct very flexible project plans.” (p. 140). Highsmith (2002 a) writes that DSDM, “clearly evokes the ideas of an exploratory development approach.” (p.139). |
| Adaptive Software Development (ASD), | As described by Highsmith (2002 a) “…The practices of ASD are driven by a belief in continuous adaptation—a different philosophy and a different life cycle—geared to accepting continuous change as the norm. In ASD, the static plan-design-build life cycle is replaced by a dynamic Speculate-Collaborate-Learn life cycle … It is a life cycle dedicated to continuous learning and oriented to change, reevaluation, peering into an uncertain future, and intense collaboration among developers, management, and customers.” (p. 173). He describes the conceptual components of the ASD Speculate-Collaborate-Learn life cycle. According Highsmith (2002 a) “An ASD life cycle has six basic characteristics” (p. 175), it is “Mission focused” (p. 175), “Feature based” (p. 175), Iterative” (p. 175), “Time-boxed” (p. 175), “Risk driven” p. 175 and “Change tolerant” (p. 175). |
| Crystal | Cockburn (1999) describes Crystal as a family of methodologies designed to fit projects. It has a strong focus is on human communication and practices and understanding roles within a project. |
| Rational Unified Process (RUP) | According to the Rational software development company (1998) “The Rational Unified Process proposes an iterative approach, which means that you test throughout the project. This allows you to find defects as early as possible, which radically reduces the cost of fixing the defect. Tests are carried out along three quality dimensions reliability, functionality, application performance and system performance. For each of these quality dimensions, the process describes how you go through the test lifecycle of planning, design,” (p. 12). |
Appendix A3 Ethical consent forms and letters

Consent Forms and Letters – samples

Telephone: +64 4 9202690
Email: Todd.Cochane@weltec.ac.nz
29 March 2019

Project Title: How can Multi-User Virtual Environments be used effectively in vocational contexts? Case study findings for communities of practice from design-based research.

I agree to the proposed study to be undertaken by Todd Cochrane and I understand that:

• The participation of my institution is voluntary and that I may withdraw this consent at any time.
• Any information or opinions provided will be kept confidential to the researcher and that any published or reported results will not identify my institution.
• All data from this research will be securely stored in password protected facilities and/or locked storage at the University of Canterbury for five years following the study after which it will be destroyed.
• The findings from this research may be used to prepare articles for publication in national and/or international journals and for presentations at conferences.
• I may receive either a copy of the full report or a summary of the findings of this study and have provided my email details below for this purpose.

By signing below, I agree to my institution’s participation in this research project.

Name: 
Institution: Wellington Institute of Technology
Date: 
Signature:
Email address:

☐ I would prefer a copy of the full report / a summary of the findings.

Please return this completed consent form in the envelope provided.

If you have any questions about this research, please do not hesitate to contact me. Details are at the top of this letter. The contact for the complaints procedure is in the footer.

Thank you for your contribution to this study.
Dr Linda Sissons,
CEO,
Wellington Institute of Technology.

Dear Dr Sissons,

I am writing to you to seek your permission to undertake research with WelTec staff and students on the role and effectiveness of Multi-User Virtual Environments (MUVEs) in vocational education. This research project is being undertaken towards my PhD studies under the supervision of Canterbury University College of Education staff, Professor Niki Davis and Dr. Donna Morrow.

The project methodology has been reviewed by the University of Canterbury Educational Research Human Ethics Committee and has been approved as being sound.

As I am a lecturer at WelTec I am seeking your permission to use a WelTec course within the Diploma in Civil Engineering to use for my research. The project, if approved, will investigate the use of MUVE in assisting the teaching and student learning experience of Temporary Traffic Management. I do not teach on this course so will not be directly involved in any way that could compromise the learning process.

The research project will be conducted over a two year period and will invite two tutors to be involved in designing and developing teaching and assessment materials and delivery methodologies using MUVE. I will facilitate this process providing development expertise, mentoring and feedback using weekly meeting with these staff members. The course will be delivered in trimester two and then the staff members will be interviewed to obtain feedback on their experiences. Feedback from staff and students will be used to make changes to the MUVE materials and delivery and the course will be delivered in the following year to another cohort of students. Staff delivering the course and students participating in this study will be once again invited to participate in evaluation of its effectiveness.

I have included a copy of the proposed research so that you can read in detail how the research is to be undertaken.

The results of this study will be made available to WelTec who may make use of it to enhance it teaching and learning. They may also be submitted for publication to national and/or international journals or presented at educational conferences. You may at any time ask for additional information or results from the study.

If the participation of your staff meets your approval, please fill in the attached consent form.

If you have any questions about this project you can talk to me, Todd Cochrane (04 9202690 or tco35@student.canterbury.ac.nz) or Niki Davis (033458246 or niki.davis@canterbury.ac.nz). If you have any complaints you may also contact the Chair of the Educational Research Human Ethics Committee; see contact below.

Thank you for taking the time to consider this request. I look forward to your response.

Yours sincerely

Todd Cochrane
Research title: How can Multi-User Virtual Environments be used effectively in vocational contexts?

To: Tutor Participant

Date: 29 March 2019

Dear Participant Tutor,

My name is Todd Cochrane and I am a Ph.D. student at the College of Education at the University of Canterbury under the supervision of Professor Niki Davis and Dr. Donna Morrow. My field of interest is education through Multi-User Virtual Environments (MUVEs) and my research concerns the effective use of MUVEs in teaching and learning for vocational contexts. In this study, I aim to explore how to use a MUVE to provide Temporary Traffic Management (TTM) learning and teaching.

If you decide to take part in this research, over a two year period, you will participate in two iterations of the following design-based research process. You are invited to participate in the design and development of the MUVE, in the delivery of teaching using the MUVE and in further interviews on the efficacy of the MUVE. The design and development of the MUVE based intervention will take place in the four months prior to running a course that uses the intervention. During that time you can expect to have at least a weekly design and development meeting with me. When teaching using the MUVE you will have the opportunity to provide feedback and have it adjusted to suit their teaching. After teaching using the MUVE has finished the you will be involved in a semi structured interview lasting thirty minutes to an hour that aims to gather the your experiences using the MUVE.

In this study your students will use the MUVE as part of their normal course of studies. They will use a MUVE on a computer as they would with any other software used for teaching and learning in their courses. At the end of the course they will be invited to fill in a questionnaire about their experiences while using the MUVE. After the course they will be invited to participate in a semi structured interview lasting thirty minutes to an hour that aims to gather more details of their experiences using the MUVE.

I have included a copy of the proposed research so that you can read in detail how the research is to be undertaken.

This study may be submitted for publication to national and/or international journals or presented at educational conferences. You may at any time ask for additional information or results from the study.

You are free to withdraw from the process at any of its stages and/or not answer part of the questions involved in the process. The research data will be anonymous. Your name and your institution's name and any other information that could identify you and your institution will be replaced with an alias. The data will be held securely and kept for a minimum period of 5 years following completion of the project before being destroyed. If you are willing to participate, please fill in the attached consent form.

This project has been reviewed and approved by the University of Canterbury Educational Research Human Ethics Committee.

If you have any questions about this project you can talk to Todd Cochrane (04 9202690 or tco35@student.canterbury.ac.nz) or Niki Davis (033458246 or niki.davis@canterbury.ac.nz ). If you have any complaints you may also contact the Chair of the Educational Research Human Ethics Committee; see contact below.

Thank you for your consideration.

1. This project has received ethical approval from the University of Canterbury Educational Research Human Ethics Committee

2. Complaints may be addressed to:
   The Chair, Educational Research Human Ethics Committee
   University of Canterbury, Private Bag 4800, CHRISTCHURCH
   Email: human-ethics@canterbury.ac.nz

   University of Canterbury Private Bag 4800, Christchurch 8140, New Zealand. www.canterbury.ac.nz
Project Title: How can Multi-User Virtual Environments be used effectively in vocational contexts?
Case study findings for communities of practice from design-based research.

Declaration of Consent to Participate

I have read and understood the information provided about this research project.
I understand that my participation is voluntary and that I may withdraw this consent at any time.
I understand that any information or opinions provided will be kept confidential to the researcher and that any published or reported results will not identify me or my institution.
I understand that all data from this research will be securely stored in password protected facilities and/or locked storage at the University of Canterbury for five years following the study after which it will be destroyed.
I understand that the findings from this research may be used to prepare articles for publication in national and/or international journals and for presentation at conferences.
I understand that I may receive either a copy of the full report or a summary of the findings of this study and have provided my email details below for this purpose.

By signing below, I agree to participate in this research project.

Name:
Institution: Wellington Institute of Technology
Date:
Signature:

Email address: I would prefer a copy of the full report / a summary of the findings:

Please return this completed consent form in the envelope provided as soon as possible.
If you have any questions about this research, please do not hesitate to contact me. Details are at the top of this letter. The contact for the complaints procedure is in the footer.

Thank you for your contribution to this study.

1. This project has received ethical approval from the University of Canterbury Educational Research Human Ethics Committee

2. Complaints may be addressed to:
The Chair,
Educational Research Human Ethics Committee
University of Canterbury, Private Bag 4800, CHRISTCHURCH
Email: human-ethics@canterbury.ac.nz

University of Canterbury Private Bag 4800, Christchurch 8140, New Zealand. www.canterbury.ac.nz
Research title: How can Multi-User Virtual Environments be used effectively in vocational contexts?

To: Participant Student

Date: 13th October 2010

Dear Participant,

My name is Todd Cochrane and I am a Ph.D. student at the College of Education in the University of Canterbury under the supervision of Professor Niki Davis. My field of interest is education through Multi-User Virtual Environments (MUVEs) and my research concerns the effective use of MUVEs in teaching and learning for vocational contexts. In this study, I aim to understand how use a MUVE to provide Temporary Traffic Management (TTM) learning and teaching.

During your normal Temporary Traffic Management studies you have the opportunity to use a MUVE designed to help you learn and practice TTM.

If you decide to take part in this research. At the end of your TTM studies you will be invited to fill in a questionnaire that will be used gather your experiences while using the MUVE. After your course you will be invited to participate in a semi structured interview lasting thirty minutes to an hour that aims to gather more details of your experiences using the MUVE.

This study may be submitted for publication to national and/or international journals or presented at educational conferences. You may at any time ask for additional information or results from the study.

You are free to withdraw from the process at any of its stages and/or not answer part of the question involved in the process. The research data will be anonymous. Your name and any other information that could identify you will be replaced with an alias. The data will be held securely and kept for a minimum period of 5 years following completion of the project before being destroyed. If you are willing to participate, please fill in the attached consent form.

This project has been reviewed and approved by the University of Canterbury’s College of Education Ethics Committee.

If you have any questions about this project you can talk to Todd Cochrane (04 9202690 or tco35@student.canterbury.ac.nz) or Niki Davis (033458246 or niki.davis@canterbury.ac.nz). If you have any complaints you may also contact the Chair of the college of Education Educational Research Human Ethics Committee; see contact below.

Thank you for your consideration.
Appendix A4 UML Sequence diagrams have Swim Lanes.

As shown in Figure A4.1, in the UML sequence diagram, objects are presented in vertical swim lanes that are labelled with the name of the object, each object is given a vertical line that represents time over potentially many instantiations, lives, of an object during a sequence. The lives of interacting objects are depicted in a UML Sequence Diagram as a series of track like rectangles connected by vertical lines, arranged into vertical swim lanes.


The activation of an object - making it “live” - is depicted by a vertical rectangular track that usually follows a pattern: the instantiation of the object - that allocates computer memory for the object instance, followed by a set of interactions with the live object and ends with the disposal of the object from computer memory when it is no longer active. Horizontal directed arrows between objects depict the interactions that are calls of methods of the object at the arrow head end of the arrow by the object at the start of the arrow. Dashed horizontal directed arrows between arrows indicate a response from an object at that point in the sequence, that response may not be immediate. A sequence of calls to related objects’ methods is indicated by the sequence of the arrows as they occur vertically. In the Swim notation, swims and their respective durations, are depicted as rectangular strips arranged in a sequence, in which swims by different participants, artefact
APPENDICES

development or service implementation swims, are arranged into their own parallel swim lanes.
### Appendix A4 Agile Buddy Record Summary

*Table A4. ABRS  A summary of the record of the Agile process from "Agile Buddy".*

<table>
<thead>
<tr>
<th>Id</th>
<th>Title</th>
<th>Description</th>
<th>Status</th>
<th>Created By</th>
<th>Date Created</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Temp traffic management diagram viewer</td>
<td>Learners have a way to select and view all Temp Traffic Management diagrams in the local roads supplement.</td>
<td>In Progress</td>
<td>Todd Cochrane</td>
<td>2012-02-14 15:10:28 +1300</td>
<td>user story</td>
</tr>
</tbody>
</table>
| T2  | OpenSim Developer Tool Chain with back up and version control - AUTOMATIC CHECK IN | An OpenSim developer can start a local version of the OpenSim build in an automatically started viewer. When the developer logs out of the viewer a sequence of scripts provide version check in and automatic update of the changes to a development server.  
1. The OAR is exported from the local run of OpenSim  
2. The OAR is uploaded to a region in the development version of OpenSim  
3. The OAR is checked into a source control management system (GitHub)                                                                                                                                                                                                                                                                               | Open           | Todd Cochrane       | 2012-02-15 11:15:19 +1300 | user story        |
| T1-1| Local Roads Supplement - convert and upload into OpenSim             | The contents of the Local Roads supplement in pdf format are to be converted to png then uploaded to OpenSim - the Wellington region. These are to be put into a HUD viewer that can be used by the Engineering Student Avatars.                                                                                                                                                                                                                                                        | Complete       | Todd Cochrane       | 2012-02-16 09:19:50 +1300 | task              |
| T1-AT1| The viewer allows navigation and viewing of the LRS in a HUD on an Engineering Avatar |                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Not Accepted   |                    | 2012-02-16 09:23:57 +1300 | acceptance test  |
| T1-AT2| The Viewer displays 3D versions of the TMDs from the Local Roads Supplement |                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Not Accepted   |                    | 2012-02-16 09:24:46 +1300 | acceptance test  |
| T1-3| Design the TTM reader                                                | Develop a series of storyboards for the reader. What is the best approach to this?                                                                                                                                                                                                                                                                                                                                                                                   | Open           | Todd Cochrane       | 2012-03-14 11:10:17 +1300 | task              |
| T3  | Autonomous car streams for roads                                    | A stream of cars appear and drive along the TTM sim roads.                                                                                                                                                                                                                                                                                                                                                                                                     | In Progress    | Todd Cochrane       | 2012-03-16 14:56:38 +1300 | user story        |
| T3-1| Develop a Simulated self driving car "engine"                       | The self driving car engine is attached or linked to any existing car, it will then drive around any of the simulations roads until it reaches a dead end.  
It may have to make random decisions about intersections, turning.  
It avoids all objects on the road, heading right for objects on the left, heading left for objects on the right. Stops if one (or more objects combined) represent a forward obstacle.                                                                                                                                                                           | Open           | Todd Cochrane       | 2012-03-16 15:02:21 +1300 | task              |
| T3-2| Check out sensor technology to decide how to sense objects on roads  |                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Complete       | Todd Cochrane       | 2012-03-16 15:05:26 +1300 | task              |
| T3-3| Find out how to estimate the speed of vehicles in Second Life        |                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Complete       | Todd Cochrane       | 2012-03-16 15:07:42 +1300 | task              |
| T3-4| Develop a car source                                                | The car source contains a car, which is rezed at a point in front of it. Contents can be one or more cars. The source selects cars to rez in sequence                                                                                                                                                                                                                                                         | Complete       | Todd Cochrane       | 2012-03-19 09:59:30 +1300 | task              |
| T3-5| Develop a car sink                                                  | The car sink takes cars with a range a removes them from the sim. This can be undertaken by issue a remove command to a self driving car.                                                                                                                                                                                                                                                                                                                   | Complete       | Todd Cochrane       | 2012-03-19 10:01:13 +1300 | task              |
| T1-4| Build Street Layouts for TMDs                                      | A small town needs to be built to provide 3D versions of the LRS Traffic Management Diagrams (TMDs) the following are a minimum                                                                                                                                                                                                                                                                                                                     | Open           | Todd Cochrane       | 2012-03-19 14:02:10 +1300 | task              |
TMD30, TMD31, TMD 34, TMD 98, TMD 99, and TMD 100

Record data
Any time there is a data session a task is added and notes are made.

In Progress
Todd Cochrane
2012-03-20 08:39:03 +1300
user story

T4-1 Introduce students to the TTM project
An introductory session for students who are participating in the project.
Complete
Todd Cochrane
2012-03-20 08:41:23 +1300
task

T4-2 Debrief the student Introduction with Leigh
Discuss with Leigh the introduction.
Complete
Todd Cochrane
2012-03-20 08:51:55 +1300
task

T4-AT1 TTM project - lesson planning meeting
Determine lesson planning for TTM course.
Not Accepted
2012-03-20 08:53:50 +1300
acceptance test

T4-5 T4-6 2012 04 20 Brief meeting with Bob McGrath
Met with Bob in the Engineering coffee room.
Bob wants to provide TTM instruction to his students despite it not being formally part of the prescription - he believes he has a responsibility to ensure that his students have instruction on safety and TTM prior to "going out and working for FULTON HOGAN", "I dont want students to leave and work for these companies on roads without having any road safety instruction.
Bob wants to introduce TTM concepts then to give students an opportunity to use the TTM environment - in a 3 hour session - or 2 2hr sessions.
We discussed running a usability test followed by students filling out usability centred questionnaires, the same students will then be invited to participate in face to face interview to gain further information regarding their perspective as learners and potential instructors.
Complete
Todd Cochrane
2012-04-20 12:38:57 +1200
task

T4-7 Write and submit ethics application for WelTec - include example questionnaires and interviews
Weltec Ethics committee permission is still to be written and submitted
Open
Todd Cochrane
2012-04-20 12:46:51 +1200
task

T4-8 Build a sign selector and viewer
Open
Todd Cochrane
2012-05-07 16:08:19 +1200
task

T5 Script update system for objects in a region
Create a system that allows for the update of scripts in specified objects. Providing one to many distribution of the update.
Open
Todd Cochrane
2012-05-08 14:15:40 +1200
user story

T5-1 Create id transmitter plus script acceptor
each object that can have scripts updated needs to contain a starter script ( boot strap? ) that creates a "load script pin", and send the object ID to a script distributor.
Open
Todd Cochrane
2012-05-08 14:22:53 +1200
task

T5-AT1 Transmits the object ID on a distribution channel "-853211"
Accepted
2012-05-08 14:24:15 +1200
acceptance test

T5-AT2 Sets up a LoadScript Pin number 853211 on the object.
Accepted
2012-05-08 14:24:58 +1200
acceptance test

T5-AT3 Accepts a script
Accepted
2012-05-08 14:25:27 +1200
acceptance test

T5-AT4 The distribution system has to work when it is REZED- test by rezing the distribution object.
Accepted
2012-05-09 09:32:29 +1200
acceptance test
Appendix A4. 3DVW server setup.

Setting up and providing access to the 3D VW server; about the Internet Protocol ports

In the enactment of Phase one, the main support service deployed is a 3D VW server, in which the MUVE is implemented, see Virtual World Server in Figure A4.4. OpenSimulator (OpenSimulator, 2014) is the 3D VW platform that was selected over others. Advantageous characteristics of OpenSimulator include: established 3D viewer technology, for example Phoenix Firestorm (The Phoenix Firestorm Project Inc., 2018), built-in VW building and scripting systems, potential spatial audio chat. The Phoenix Firestorm 3D Viewer was selected because it includes a pre-processor extension to the scripting system that facilitates modular coding.

As depicted in Figure A4.2 below, the systems that support the OpenSimulator are: an SQL database service, and a publicly accessible serving computer system on which to implement the 3D VW server. It is useful to provide a domain name for that publically accessible computer system, because a text name is usually easier to remember than an Internet Protocol (IP) number, and because often the use of IP numbers for services accessed from institution networks is prevented as part of a security policy. As depicted in Figure A4.2 the OpenSimulator server and an SQL database server are implemented on cloud service. The VW server and the SQL database server do not need to be on the same computing system nor do they need to be provisioned by the same cloud computing service. In this case both are implemented on the same cloud computing system, on a single virtualised computer.
The OpenSimulator server requires a number of IP ports to be accessible from the network that contains the computer that runs the 3D Viewer, through to the network and computing system that runs the 3D VW server. These communicating networks are depicted in Figure 4.14 as “Institute’s network”, and the “Cloud service/s” the VW Server is implemented on. As depicted in Figure 4.14, to allow multi-user access to the OpenSimulator VW server, four kinds of IP ports are made available in the two networks.

An IP port that allows communication between the OpenSimulator VW server and the SQL database server. This port is not required to be available for service requests from the institute’s network. Configuration of this port in the computing system is undertaken as part of the installation of the SQL database server, which is usually providing a database service for a number of applications on that system as well as for the OpenSimulator 3D VW service. Access to that port is usually through a local loop that does not require it to be accessed from outside of the computing system, hence this port is not depicted in Figure A4.2.

An IP port used by a “log in” service that provides “log in” for each avatar. This service identifies a user of the 3D VW with a given avatar. That in turn lets the user to act through the avatar in the 3D VW. When logged in an avatar is present in a particular region. As shown in Figure A4.2, this IP port needs to be available in both of the networks.
A different IP port is used for each “Region” that is served by the 3D VW, see Figure A4.2. A “region” is a unit of simulation that is managed by a running OpenSimulator server. Each “Region” usually represents a metaphorical island with in which avatars can interact in a direct way with other avatars who are present. For example, you can see other avatars and their movement when they are close enough to be seen, only when they are on the same, bound by a square of simulated land (that may be visible or not above an ocean) an “island”. Movement between “islands” is restricted to special mechanism that removes the avatar from the current “region” and puts it in to another. This mechanism is metaphorically “teleporting” the avatar between islands. As the need for larger areas arose, larger simulation areas, were provided by the OpenSimulator development community. One example is the concept of a “Mega-Region” that is a tessellation of smaller regions, that allow avatars to move between regions that are part of the “Mega-Region” without having to “teleport”, and provides for seeing and hearing avatars between them. Hence, in that case the “Region” includes a number of smaller simulation regions. All of the IP port numbers allocated to regions must be made available for communication with the OpenSimulator 3D VW server in both networks.

Finally, IP ports for communication with a voice service are required to be available on both networks, see Figure 4.2. Voice communication is provided by a third party who generously offered to allow OpenSimulator based voice sessions to make use of their service. That organisation provides proprietary voice communication libraries, encapsulated in a linkable form as a Dynamic-Link Library(DLL) (Microsoft, 2018), to the developers of the 3D VW viewers. OpenSimulator tells the voice service the spatial location of the avatar that is using the voice service, and receives an indication that talking is happening. The voice service uses the spatial location of the avatar, in the 3D VW viewer, to spatially locate sound for an avatar who is listening to the voice communication, through stereo or spatially enabled audio systems to the user. The voice service provides the streaming of audio, usually from a microphone, from the computer that runs the talking user/avatar’s 3D Viewer, to the location of the avatar in the 3D VW, giving the impressing that sound is coming from the talking avatar. All 3D Viewers logged in the that region who are “close enough to hear” are transmitted that location, the voice software in the 3D
Viewer then locates the voice sound relative to the location of the listener.

Anecdotally, through private communications with Information Technology service groups at two New Zealand polytechnics, and with academic staff members from a number of other New Zealand polytechnics, IT service groups carefully maintain as few systems offering IP based services as they can, to reduce the risk of implementing a system that is vulnerable to network exploitation, and that could lead to putting the whole service at risk. IT service groups manage internal communication as well as communication from outside of the institute’s network. To achieve this, communication through IP ports is restricted both in requests for services internally and request for services from outside the network. Hence, when a computer system that requires IP port based communication to services is requested, there is a reluctance to provide that facility until the risk from the service is well understood. The consequence is that it can take time for these services to be made available from within the institute’s network. In the case of the institute that hosted the development of the TTM 3D MUVE, provision of the 3D VW that included access though all of the IP ports required to run the server, took many years.
Appendix A4 I1A Interview One

<table>
<thead>
<tr>
<th>Time</th>
<th>Person A</th>
<th>Person B</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00:04</td>
<td>So, um hello there how are you… nice to you meet you again, um, after our various discussions today…</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:00:16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:00:17</td>
<td>… um the, the idea behind this meeting is to um, talk about what the educational um, aspects might be for Temporary Traffic Management from your point of view and I have divided into six or so sections, and, which I hope will cover things but this is just a guide …</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:00:41</td>
<td>Okay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:00:42</td>
<td>… and as we go through, if you think of anything, and um, we will just explore that, those ideas …</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:00:48</td>
<td>Right yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:01:01</td>
<td>Okay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:01:01</td>
<td>So its ah, so the fist section is what do Engineers or people need to know about TTM and, um, then the knowledge space that makes up TTM and the technology …</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:01:19</td>
<td>Okay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:01:19</td>
<td>… that you might need to do Temporary Traffic Management, um, and if there are any existing resources, if there, that are used in teaching TTM or learning about TTM …</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:01:31</td>
<td>Okay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:01:32</td>
<td>… Um, what approaches are taken when you run a course, is there a particular way you do it or any ideas that you have about it …</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:01:38</td>
<td>Okay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:01:39</td>
<td>… um, ah, the equipment and resources that make it easier to, that you might use existing, or ah, to teach, ah um ah, TTM and things that maybe in the environment that might make it easier or harder, um, and what the teaching approach that you use within [???] might need, um, is there anything ah, about TTM that actually makes you teach in a particular way, or you have to learn in a particular way, um, and then ah, given that you have a way of ah, to teach TTM are there any ‘gotchas’ when you go about doing it, am, so in terms of the resources and the knowledge space and the, and the discipline and things like that, okay so, um, the first sort of area that I would like to ask you about it, um, what do our Engineers and Surveyors, and anyone else who is in this discipline need to know um, when they are teaching, ah sorry, when they are learning about TTN …</td>
<td></td>
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</tr>
<tr>
<td>0:02:47</td>
<td>Okay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:02:47</td>
<td>… um</td>
<td></td>
<td></td>
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<tr>
<td>0:02:49</td>
<td>Well really it’s um, we just give them the basic sort of overview of TTM because once they are out working for a firm if they are involved in this area they will do their Level 1 or, or further qualification anyway so they will be required to go on a course paid for by their firm and um, then that will um, they will get their qualification through one of the industry providers of that training, um so we don’t attempt to give them that sort of qualification here, really we are just introducing them, ah, to the subject and making sure that they know it is required and, and [for?] particular sorts of work and how they can keep themselves safe if they’re working on the roads etc</td>
<td></td>
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<tr>
<td>0:03:32</td>
<td>So um I, I have just forgot that I um, should have asked first to, to describe Temporary Traffic Management and, and what it is aswell</td>
<td></td>
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<tr>
<td>0:03:42</td>
<td>Okay, so the, ah, Temporary Traffic Management is just for obviously if you are working on the road it’s just temporary because the job, the job may go on for several years but, but it is temporary because it is not a permanent fixed, ah, solution to your traffic control, so your signage is all temporary and um, the management of your traffic is just supposed to go on for a finite period of time, um, but obviously you have got to provide all of your correct cone tapers, signs etc. to keep the motorists save, and also to keep the workers on the site safe, so that is pretty much what it comes down to</td>
<td></td>
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<tr>
<td>0:04:21</td>
<td>So it is about keeping people safe …</td>
<td></td>
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</tr>
<tr>
<td>0:04:23</td>
<td>It is</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0:04:23</td>
<td>… and putting cones, cones up [???] …</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDICES

Person A  | Yeah that, yeah there’s sort of heaps, there is quite a lot involed in it obviously and this book I have got here just covers the local roads …
0:04:26  
Person B  | Right this is the, ah
0:04:34  
Person A  | … the Temporary Traffic Management for Local Roads and it is a supplement to um …
0:04:35  
Person B  | [???]
0:04:38  
Person A  | … it’s not Transit anymore it’s NZTA ah Code of Practice
0:04:39  
Person A  | So the New Zealand Transport …
0:04:42  
Person B  | Agency
0:04:44  
Person A  | … Agency, and Code of Practice in Temporary Traffic…
0:04:44  
Person B  | For Temporary Traffic Management
0:04:47  
Person A  | … but what do you call that “COPTTM” or something it is
0:04:48  
Person B  | “COPTTM”, I think there is, we have [????]
0:04:51  
Person A  | Alright, okay
0:04:53  
Person A  | So what’s a, what’s a static worksite is that area …
0:04:56  
Person B  | Oh, as you are going to be staying there for a considerable period of time, it’s like, you are not moving, an example of a moving one is like you will see on the motorways for the mowers, and if they will have the attenuators etc. following along the road …
0:05:24  
Person A  | Oh right, yes …
0:05:37  
Person A  | … while the mowers, mowing on the side …
0:05:38  
Person A  | … ah I see, yeah
0:05:39  
Person B  | … that’s a, um moving situation, so static you might be doing a survey at maybe at an intersection and so you have got to be out, ah, in the, either in the traffic lane or hopefully just on the side of the road, or you know
0:05:40  
Person A  | Do the surveyors need to know
0:05:53  
Person B  | Surveyors need to know, how protect themselves and what they should be doing, they should have a generic traffic plan, generally, that’s um, local authorities may have already approved, and they should stick to that to make sure they can …
0:05:56  
Person A  | And there’s a, a way to um, it’s, so they need to know how to create these traffic plans
0:06:08  
Person B  | Ah, yes and we, we try to give them some exaples and there are examples provided in the, in this little book, um, that I talked about before, and, ah, generally they just need to know how it’s set out, but usually it has to be someone a bit more senior than what they will be when they first start, that signs off on those sort of plans
0:06:13  
Person A  | So there is a sort of, um ah, the, the senior um, ah person has some sort of qualification …
0:06:33  
Person B  | Oh within the traffic, you might have a Traffic Control 1 which is the initial level and then you also have a person on each site that is incharge of that site and that’s the, [???] I’ve forgotten it, CMF person …
0:06:39  
Person A  | Right yip
0:06:54  
Person B  | … and they will be incharge of that site
0:06:54  
Person A  | As, as the, Yeah
0:06:58  
Person B  | And, but they may be running more than one site during the day, so they will just go around making sure that everyone is doing what they are suppose to be doing, but, um, as a general rule you need to have your, um, TC1 qualification to work on the roads
0:06:58  
Person A  | Right so, um, ah the person …
0:07:12  
Person B  | [???] state highways
0:07:15  
Person B  | … that sets up [or a?] Surveyor needs to have ah, TC1
<table>
<thead>
<tr>
<th>Time</th>
<th>Person</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:07:19</td>
<td>Person B</td>
<td>Who or, yeah the TC1</td>
</tr>
<tr>
<td>0:07:21</td>
<td>Person A</td>
<td>TC1 yeah</td>
</tr>
<tr>
<td>0:07:21</td>
<td>Person B</td>
<td>Yeah [??] what it [??] in my car</td>
</tr>
<tr>
<td>0:07:23</td>
<td>Person A</td>
<td>So, oh okay yeah</td>
</tr>
<tr>
<td>0:07:24</td>
<td>Person B</td>
<td>[??] but I think that is what it is still call yes, um, and if you go on the website for NZTA they have got the link to I think it is [Training aspirations is?] the provider at the moment …</td>
</tr>
<tr>
<td>0:07:34</td>
<td>Person A</td>
<td>Oh right</td>
</tr>
<tr>
<td>0:07:34</td>
<td>Person B</td>
<td>… for the training for this</td>
</tr>
<tr>
<td>0:07:36</td>
<td>Person A</td>
<td>So in, in, would the, so the Engineers and all of your Surveyors at any rate they need to have enough knowledge to be able to go, to know that they have to get one of these …</td>
</tr>
<tr>
<td>0:07:46</td>
<td>Person B</td>
<td>Oh that’s right…</td>
</tr>
<tr>
<td>0:07:47</td>
<td>Person A</td>
<td>TC1’s</td>
</tr>
<tr>
<td>0:07:47</td>
<td>Person B</td>
<td>… it is more making them aware of, of the fact that they do need a, um Traffic Management Plan if they are working on the roads …</td>
</tr>
<tr>
<td>0:07:53</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>0:07:53</td>
<td>Person B</td>
<td>… um, especially like, generally if you are doing some work as a sub-consultant, ah, your consultant in charge will ask to see your health and safety plan anyway, to, they will make sure that you know what you are doing and they will require you to actually put in one of these plans or they may do it for you</td>
</tr>
<tr>
<td>0:07:13</td>
<td>Person A</td>
<td>And, and, this, temporary traffic management is that part of a more general discipline of some sort or is it, or [does it seem to?] teir in lots of different disciplines, or I am not sure …</td>
</tr>
<tr>
<td>0:08:23</td>
<td>Person B</td>
<td>Oh you do, well engineering obviously…</td>
</tr>
<tr>
<td>0:08:25</td>
<td>Person A</td>
<td>Yip</td>
</tr>
<tr>
<td>0:08:25</td>
<td>Person B</td>
<td>…. [than?] surveying</td>
</tr>
<tr>
<td>0:08:26</td>
<td>Person A</td>
<td>Yip</td>
</tr>
<tr>
<td>0:08:26</td>
<td>Person B</td>
<td>Um, but yes anything you do, ah like sports events, um, like cycle races, you know all that sort of thing running races whatever …</td>
</tr>
<tr>
<td>0:08:35</td>
<td>Person A</td>
<td>Well you forget about those don’t you</td>
</tr>
<tr>
<td>0:08:35</td>
<td>Person B</td>
<td>… um, yeah all of these people that are going to be on the roads they will, they will have to have that, ah ralleys and, all the rest of it, anything that requires you to, um, be either slowing traffic down …</td>
</tr>
<tr>
<td>0:08:46</td>
<td>Person A</td>
<td>So these guys …</td>
</tr>
<tr>
<td>0:08:46</td>
<td>Person B</td>
<td>… or shifting it off it’s line or whatever</td>
</tr>
<tr>
<td>0:08:48</td>
<td>Person A</td>
<td>We need to know how to deal with the static, um[???]</td>
</tr>
<tr>
<td>0:08:53</td>
<td>Person B</td>
<td>Oh well you would tend to concentrate on the static just because that, because it is taught in Surveying [???] you are doing a fairly static um, sort of work with your surveying, um, they, we do also have surveys where you have to travel along the road, and they do become sort of movable, but what usually happens is you then employ a major firm like Maverick or Fulton Hogan and they will set out maybe two kilometers of road for you so you are actually, you are still really in a static situation you are just moving from one end of it to the other</td>
</tr>
<tr>
<td>0:09:24</td>
<td>Person A</td>
<td>So, given you have got this sort of um, understanding of static, is there technology that you need to, as part of the static [thing is there?] a particular technology that you need to use in a static um, situation</td>
</tr>
<tr>
<td>0:09:37</td>
<td>Person B</td>
<td>Oh, there’s just particular requirements, you are still using all of the same things, well your not using equipment like attenuators you know …</td>
</tr>
<tr>
<td>0:09:44</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>0:09:45</td>
<td>Person B</td>
<td>… the big trucks and things, ah but you still have to have the same sort of signage and cones and all the rest of it …</td>
</tr>
<tr>
<td>0:09:50</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>0:09:50</td>
<td>Person B</td>
<td>… but it’s not, yeah, I don’t know if I would call it technology but it’s yeah</td>
</tr>
<tr>
<td>0:09:53</td>
<td>Person A</td>
<td>Equipment</td>
</tr>
<tr>
<td>0:09:54</td>
<td>Person B</td>
<td>Yeah, equipment yeah</td>
</tr>
<tr>
<td>Time</td>
<td>Person</td>
<td>Text</td>
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<td>-------</td>
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<td>----------------------------------------------------------------------</td>
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<tr>
<td>0:09:55</td>
<td>Person A</td>
<td>[???] equipment that makes up TTM …</td>
</tr>
<tr>
<td>0:09:58</td>
<td>Person B</td>
<td>Yeah, that’s right</td>
</tr>
<tr>
<td>0:10:00</td>
<td>Person A</td>
<td>… um, ah, so, I think you have mentioned this, ah, um, COPTTM is one of the resources available to help when they are talking about, when people talk about TTM, are there any other, um resources around ah …</td>
</tr>
<tr>
<td>0:10:16</td>
<td>Person B</td>
<td>Well yeah …</td>
</tr>
<tr>
<td>0:10:16</td>
<td>Person A</td>
<td>… apart from the National, this is the National one or</td>
</tr>
<tr>
<td>0:10:17</td>
<td>Person B</td>
<td>… this is one, this is the sort of local roads one …</td>
</tr>
<tr>
<td>0:10:19</td>
<td>Person B</td>
<td>Oh that’s a local one</td>
</tr>
<tr>
<td>0:10:20</td>
<td>Person A</td>
<td>… yeah so in this one they have got um, lots of different examples …</td>
</tr>
<tr>
<td>0:10:24</td>
<td>Person B</td>
<td>yeah</td>
</tr>
<tr>
<td>0:10:24</td>
<td>Person A</td>
<td>… and set ups sort of things they can look at um, but this is also available in PDF so it’s coloured and all the rest of it so …</td>
</tr>
<tr>
<td>0:10:30</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>0:10:31</td>
<td>Person B</td>
<td>… you know I can use sheets out of that for, for teaching purposes, um, the actual manual on the NZTA website is very large …</td>
</tr>
<tr>
<td>0:10:41</td>
<td>Person A</td>
<td>Oh right</td>
</tr>
<tr>
<td>0:10:42</td>
<td>Person B</td>
<td>Yeah, so this is why I tend, because prefer to be, portable</td>
</tr>
<tr>
<td>0:10:45</td>
<td>Person A</td>
<td>Okay</td>
</tr>
<tr>
<td>0:10:45</td>
<td>Person B</td>
<td>I stick to this, but it is available as PDF’s and things so I can put pages of that on …</td>
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<tr>
<td>0:10:50</td>
<td>Person A</td>
<td>So this can come …</td>
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<tr>
<td>0:10:51</td>
<td>Person B</td>
<td>… on the, on the smart wall</td>
</tr>
<tr>
<td>0:10:52</td>
<td>Person A</td>
<td>… come off, you can pop this off the website and</td>
</tr>
<tr>
<td>0:10:55</td>
<td>Person B</td>
<td>Yeah, yeah so, so I tend this is mine so that I can do some planning out of here for when I want to …</td>
</tr>
<tr>
<td>0:10:59</td>
<td>Person B</td>
<td>Oh you have a</td>
</tr>
<tr>
<td>0:11:00</td>
<td>Person B</td>
<td>… [???] on, but um I, when I come to get the pictures off I usually get them off there</td>
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<tr>
<td>0:11:05</td>
<td>Person A</td>
<td>Because they are better quality …</td>
</tr>
<tr>
<td>0:11:07</td>
<td>Person B</td>
<td>Better quality and I can put them directly obviously …</td>
</tr>
<tr>
<td>0:11:09</td>
<td>Person A</td>
<td>… right, I see yeah</td>
</tr>
<tr>
<td>0:11:09</td>
<td>Person B</td>
<td>… on the smart wall etc. and I can always ah, give them as handouts and, so I have got some hand outs that are blank, just situations they might face, um, at the worksite …</td>
</tr>
<tr>
<td>0:11:20</td>
<td>Person A</td>
<td>Yeah</td>
</tr>
<tr>
<td>0:11:21</td>
<td>Person B</td>
<td>… and then they will tell me where all the signs have to go etc</td>
</tr>
<tr>
<td>0:11:23</td>
<td>Person A</td>
<td>So that sort of leads to the, um, it would be nice to have an understanding of how you would run um, a course or a class if …</td>
</tr>
<tr>
<td>0:11:35</td>
<td>Person B</td>
<td>Okay yeah …</td>
</tr>
<tr>
<td>0:11:35</td>
<td>Person A</td>
<td>… what sort of what approach do you take</td>
</tr>
<tr>
<td>0:11:35</td>
<td>Person B</td>
<td>… um, yeah generally it’s covered just in the one, ah, session, although sessions can be anywhere from lika 2-4 hours …</td>
</tr>
<tr>
<td>0:11:43</td>
<td>Person A</td>
<td>Right yip, yeah</td>
</tr>
<tr>
<td>0:11:43</td>
<td>Person B</td>
<td>… so, it depends how much you want to concentrate on it really,um, but, yeah generally I just introduce the whole concept of traffic management and [???] as part of the health and safety component …</td>
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<tr>
<td>0:11:45</td>
<td>Person A</td>
<td>So you put it within health and safety …</td>
</tr>
<tr>
<td>Time</td>
<td>Person</td>
<td>Speech</td>
</tr>
<tr>
<td>-------</td>
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</tr>
<tr>
<td>0:11:46</td>
<td>Person B</td>
<td>... and, that’s where it comes in generally [at least?] some of it, and, um, then within that we will start, we will just talk generally about the different situations, um, and we will discuss other things like the mowers and all the rest of it and things that um aren’t, [???] area, and then I will focus it down onto the static areas and then provide them with some example and then give them a, a scenario of their own and they will tend to work on that in groups and</td>
</tr>
<tr>
<td>0:12:26</td>
<td>Person A</td>
<td>So in, you mentioned earlier is, on an intersection there’s a scenario …</td>
</tr>
<tr>
<td>0:12:31</td>
<td>Person B</td>
<td>Yeah, that’s right [???] they have got to be aware that they have got to have signage on, so for an intersection they have got to have signage on all, for all of those roads, or two obviously if it’s going straight through, um, and, yeah, so there, [within the?] massive amount of things they will have to carry around with them so sometimes it’s um, employing someone else to do it for you, um because the …</td>
</tr>
<tr>
<td>0:12:54</td>
<td>Person A</td>
<td>… just to do, set it up into …</td>
</tr>
<tr>
<td>0:12:55</td>
<td>Person A</td>
<td>… yeah you need to hold [???] carry your survey equipment [your hat] you would need a trailer on the back to be able to put all the traffic management gear on, there is such a lot of it these days, um, although I shouldn’t really say this but a lot firms sometimes might try to skimp a little bit on ….</td>
</tr>
<tr>
<td>0:13:11</td>
<td>Person A</td>
<td>Oh really …</td>
</tr>
<tr>
<td>0:13:11</td>
<td>Person B</td>
<td>… on how much [???] …</td>
</tr>
<tr>
<td>0:13:12</td>
<td>Person A</td>
<td>Oh okay</td>
</tr>
<tr>
<td>0:13:13</td>
<td>Person B</td>
<td>… [???] it’s just because it ah it’s possible to carry all this with you …</td>
</tr>
<tr>
<td>0:13:17</td>
<td>Person A</td>
<td>Yes</td>
</tr>
<tr>
<td>0:13:17</td>
<td>Person B</td>
<td>… and ah, so yeah we try and encourage them that, this isn’t the correct attitude and their whole thing is designed to keep them and the public safe so …</td>
</tr>
<tr>
<td>0:13:27</td>
<td>Person A</td>
<td>So …</td>
</tr>
<tr>
<td>0:13:27</td>
<td>Person B</td>
<td>… play by the rules</td>
</tr>
<tr>
<td>0:13:28</td>
<td>Person A</td>
<td>… that sort of, yeah, that, so what part of your um, the teaching you are doing is about recognising the state of the, ah, the attitude of the, um …</td>
</tr>
<tr>
<td>0:13:40</td>
<td>Person B</td>
<td>Oh yeah well they can come across, or what we might consider ‘cowboys’ in any sort of area but yeah, so that if they strike this, the idea is they should be considered for their own safety first obviously and I have sort of stressed they shouldn’t go into situations that they don’t think are safe and that’s up to them, you know they have got the [???]or whomever, but ah, yeah just to make them aware that there are rules and this is what is suppose to happen and there really isn’t any excuse for it not happening so</td>
</tr>
<tr>
<td>0:14:12</td>
<td>Person A</td>
<td>So that’s ah, an important part of the</td>
</tr>
<tr>
<td>0:14:15</td>
<td>Person B</td>
<td>Well it is something I do, …</td>
</tr>
<tr>
<td>0:14:16</td>
<td>Person A</td>
<td>[releases?] or [???]</td>
</tr>
<tr>
<td>0:14:17</td>
<td>Person B</td>
<td>… it is something I do stress just because I think when they are young and they are just starting …</td>
</tr>
<tr>
<td>0:14:20</td>
<td>Person A</td>
<td>Yeah</td>
</tr>
<tr>
<td>0:14:21</td>
<td>Person B</td>
<td>… they can be forced into situations …</td>
</tr>
<tr>
<td>0:14:22</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>0:14:23</td>
<td>Person B</td>
<td>… that perhaps aren’t the safest for them</td>
</tr>
<tr>
<td>0:14:27</td>
<td>Person A</td>
<td>So I sort of get the feeling that they come into the classroom, and then they are given pictures of [risk?]</td>
</tr>
<tr>
<td>0:14:34</td>
<td>Person B</td>
<td>Yeah, well yeah but, a brief lecture that will cover the basics of it, and yeah they will be given ….</td>
</tr>
<tr>
<td>0:14:41</td>
<td>Person A</td>
<td>Yip</td>
</tr>
<tr>
<td>0:14:42</td>
<td>Person B</td>
<td>… a hand out to go with that, to go what’s [wrong?] do it on the board ah, but then yeah they will be asked to, um, get into groups and, they will consider these scenarios, one or more scenarios as a group, and, um, then come up with their solutions, some [of them?] I get to present they’ll come up …</td>
</tr>
<tr>
<td>0:15:01</td>
<td>Person A</td>
<td>So when they, when they are building their solutions what do they do</td>
</tr>
<tr>
<td>0:15:04</td>
<td>Person B</td>
<td>Really they are drawing themselves …</td>
</tr>
<tr>
<td>0:15:06</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>Time</td>
<td>Speaker</td>
<td>Transcript</td>
</tr>
<tr>
<td>-------</td>
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<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>0:15:06</td>
<td>Person B</td>
<td>… so maybe they should know how to draw, but really they are just adding things to the diagram so they are adding cones etc, I thought if I had lots of time of making little, like, my own little mini signs and cones and all that sort of thing …</td>
</tr>
<tr>
<td>0:15:20</td>
<td>Person A</td>
<td>Oh yes</td>
</tr>
<tr>
<td>0:15:20</td>
<td>Person B</td>
<td>… but of course that’s something we never really get time for, so, yeah that is why this is, um looking forwarding to seeing your ideas on this as something they can actually do themselves would be excellent</td>
</tr>
<tr>
<td>0:15:34</td>
<td>Person A</td>
<td>Well that, that would, that would come out in our next ah, phase we talk about …</td>
</tr>
<tr>
<td>0:15:38</td>
<td>Person B</td>
<td>Yeah</td>
</tr>
<tr>
<td>0:15:38</td>
<td>Person A</td>
<td>… what [are the?] good things to do but, that is, so what are the ways to, um, the way it is being taught, the way we teach this, um, you were sort of hinting that it would be nice to have …</td>
</tr>
<tr>
<td>0:15:53</td>
<td>Person B</td>
<td>Some resources</td>
</tr>
<tr>
<td>0:15:54</td>
<td>Person A</td>
<td>… some resources for it as well brilliant</td>
</tr>
<tr>
<td>0:15:57</td>
<td>Person B</td>
<td>Yeah anything to make it a bit more real for them</td>
</tr>
<tr>
<td>0:16:01</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>0:16:01</td>
<td>Person B</td>
<td>I mean you can show the pictures of different scenarios as well that you come across in real life …</td>
</tr>
<tr>
<td>0:16:07</td>
<td>Person A</td>
<td>Yeah</td>
</tr>
<tr>
<td>0:16:07</td>
<td>Person B</td>
<td>… like just, you know sometimes I will stop as I come across roadworks and take the odd picture …</td>
</tr>
<tr>
<td>0:16:11</td>
<td>Person A</td>
<td>… a photo oh right yes …</td>
</tr>
<tr>
<td>0:16:13</td>
<td>Person B</td>
<td>… yeah</td>
</tr>
<tr>
<td>0:16:13</td>
<td>Person A</td>
<td>So you have actually developed this little, you have got a [respository?] of them or something</td>
</tr>
<tr>
<td>0:16:17</td>
<td>Person B</td>
<td>Well I have got a few photos yes, sometimes I can’t lay my hands on them too quickly but …</td>
</tr>
<tr>
<td>0:16:21</td>
<td>Person A</td>
<td>Yeah</td>
</tr>
<tr>
<td>0:16:22</td>
<td>Person B</td>
<td>… I know I have them, so yeah you sometimes you can’t really tell well that’s not right you know, so I sort of pull over but sometimes you are half way down, in the middle of the traffic …</td>
</tr>
<tr>
<td>0:16:32</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>0:16:32</td>
<td>Person B</td>
<td>… and you realise that would be a good photo opportunity, but yeah there are some I might get at the moment because there doing some on ah, Featherston Drive, in Upper Hutt …</td>
</tr>
<tr>
<td>0:16:41</td>
<td>Person A</td>
<td>And you have noticed some ah good examples</td>
</tr>
<tr>
<td>0:16:44</td>
<td>Person B</td>
<td>Just the odd thing that is a little bit stranger or that, when it’s not complete clear to people what they should be doing …</td>
</tr>
<tr>
<td>0:16:49</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>0:16:50</td>
<td>Person B</td>
<td>… and that’s of course the potential for accidents, but what they have done there is they have slowed people to 30 …</td>
</tr>
<tr>
<td>0:16:56</td>
<td>Person A</td>
<td>And you mean by people you mean the people driving cars</td>
</tr>
<tr>
<td>0:16:57</td>
<td>Person B</td>
<td>… ah the, normal drivers [???]</td>
</tr>
<tr>
<td>0:17:00</td>
<td>Person A</td>
<td>Right, yeah</td>
</tr>
<tr>
<td>0:17:01</td>
<td>Person B</td>
<td>… and, of course that’s, when you have the general public not knowing exactly what they should be doing that’s when it poses a risk also to the, to the workers because they can sort of react unexpectedly, and then, go straight off into the worksite or whatever, so, yeah, it’s sometimes unexpected things like there will be something drop in the road or something like that, so</td>
</tr>
<tr>
<td>0:17:23</td>
<td>Person A</td>
<td>So, by having these photos of the, of the situations as part of the resources that will, um, make it easier for the teaching or enable …</td>
</tr>
<tr>
<td>0:17:33</td>
<td>Person B</td>
<td>Yeah it just makes it [???] a bit more realistic for them, they can see you know it’s just not pure [reading] of something and they actually [happens?]</td>
</tr>
<tr>
<td>0:17:43</td>
<td>Person A</td>
<td>And do you present that as part, as part of this lesson that you do um, before they do their [planes?] or something like that …</td>
</tr>
<tr>
<td>0:17:50</td>
<td>Person B</td>
<td>Yeah sometimes just to illustrate either, either good practice, so the, the worksite it set up really nicely, um, or perhaps something that, they can see should, well hopefully which they can see should be done better, or, or you just ask them to look at and say [now where would you?] go if you were driving your car, or, whatever</td>
</tr>
</tbody>
</table>
Um, when you are teaching about TTM, is there anything the will, we have got kind of close to answering these questions anyway because we, I know if there is anything about Temporary Traffic Management itself that, um, determines the way you, am approach it, it might be, ah so what I am saying is something about TTM that would um, lend your ah, approach the instruction in a particular way

So you are trying to give …

… [???] information

… magazine flyers or something of an example

Yeah that, well you mainly just, yeah just keeping it to those practical situations like the intersection say survey of an intersection or perhaps um, ah, different manholes, you know when you pop the lids of manholes and take inverts and things, saying what sort of protection you would need if they were in, in the traffic lane, so just things they are likely to encounter as young Engineers or Surveyors when they, when they first go out [so?] it’s quite a normal activity …

… so, um, I don’t sort of really go, a lot of time we as Surveyors large ah, graphic surveys of, of State Highways when they are trying to either put in parking lanes or correct the sapes etc. um, I don’t tend to concentrate on those because there, on that scale you have a firm come in to do all the traffic management for you and that …

… but yeah, it is not really up to you at all, it’s, they do their own traffic plan etc. ah, so more, probably just keep more to the, the local roads and smaller sort of work

So, you have talked about this, dipping …

…. and what else they are, what else are they taking in that you …

…. oh that, um, that sometimes um, you would have to, if you are redesigning sort of stormwater networks …

…. ah, you need to get like the flood levels of the manholes but then you also need to get the invert level which is the …. invert you mean like a lot of invert …

…. in the pot, in the actual pipe inside the manhole …

… you have to take the lids off …

… and then somebody has to get in the manhole …

… and so the last thing you want to see when you pop your head back out is, is a truck heading straight for you …

…. in movies of course, yeah no they, just ways of things to protect like those sort of things you will have your work vehicle actually parked, in the traffic …

Oh well you, you see it in movies of course, yeah no they, just ways of things to protect like those sort of things you will have your work vehicle actually parked, in the traffic …
So, given that you have got this way that you are teaching, um, are there any ah, um, things that or "gotchas" in the teaching that …

Well probably there is, probably just, hard to explain to them ah, what the site looks like, why you have the cone tapers and, the idea they think they are quite big gaps between the cones and that but really probably if I could get some more, if they could get more of an idea of what it is like when they are actually traveling up the road towards those things that they can see it is actually suppose to look like a continuous line of cones …

… but that sort of thing is a bit hard, I suppose I could play a movie or something like that …

… a clip, um, it’s just giving them the appreciation of that’s why you have the significant spacings, that they match with the speed …

… and just things like that, somethimes it’s, a sense you have to show them something like that rather than trying to explain it

So having a movie as a resource would hep

… [getting] sorts of things …

… so it is, if ….  

… are there any, or any sort of um, before you go to the class is there a whole lot, ah is there anything that …

Oh well before, well obviously I have got to copy all of the material ….  

Yip

… I am going to give them that’s pretty much what, and just make sure that I have got my smartbord presentations sort of all sorted out

Right

um, and having a quick read over myself just to refresh my memory that um, what I am doing, um, obviously you have got to get on the website to make sure there hasn’t been any sort of major changes in the meantime since you taught it the last time, um, yeah and probably, yeah just, probably I should put all of my photos in, I should have the same in just one folder, all for that lecture perhaps …

… so that then it would be a bit more efficient that what I have got at the moment whereas all of my photos are in one place and I, of course the notes are in another

Right

Oh I see yeah

so I am not overly organised, and ah, getting there you know the longer I am here

Um and, if you were, if you, if, I know you are mainly focused on surveying, but if you were going to be, if, do you have any thoughts about if you were teaching a civil engineer or anything it would be any …

Um, There are

… major changes that you would end up doing and

Well generally you have, I mean the surveying course is part of the civil engineering anyway so the only other place it is probably taught is in, maybe traffic and highways and um that sort of area, which is, actually Bob’s subject, so um, it would be more his area there, um, but, definitely, I think all of their civil engineering subjects um, somewhere within the sillibus there should be this, this sort of coverage because they will be working in these situations where they are required to know about it, um, it just happens that they have put it in the surveying …

Right

… sillibus so far
<table>
<thead>
<tr>
<th>Time</th>
<th>Person B</th>
<th>Person A</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:24:36</td>
<td>And, um, you mentioned that you are, you are involved with providing basic instructions to people who then go on to um, take an exam or something and you show them that ticket that you have</td>
<td>And, um, you mentioned that you are, you are involved with providing basic instructions to people who then go on to um, take an exam or something and you show them that ticket that you have</td>
</tr>
<tr>
<td>0:24:49</td>
<td>Generally I think it’s a one day course for the um, basic one that’s the traffic basics and that’s you go along and attend this …</td>
<td>Generally I think it’s a one day course for the um, basic one that’s the traffic basics and that’s you go along and attend this …</td>
</tr>
<tr>
<td>0:24:58</td>
<td>But what does it warrant is it …</td>
<td>But what does it warrant is it …</td>
</tr>
<tr>
<td>0:24:59</td>
<td>… oh, I think it is called a warrant really …</td>
<td>… oh, I think it is called a warrant really …</td>
</tr>
<tr>
<td>0:25:02</td>
<td>Right yeah</td>
<td>Right yeah</td>
</tr>
<tr>
<td>0:25:03</td>
<td>… yeah it’s just, I am not sure myself I have seen it referred to a couple of different things but I think it is labelled as TC1 or something like that, and then they expect you to get a certain number of those right and at the end of the day, um, they sort of make sure, they table up all of the results of all of these quizzes and you will either get your ah, card [???] or you don’t really, so</td>
<td>… yeah it’s just, I am not sure myself I have seen it referred to a couple of different things but I think it is labelled as TC1 or something like that, and then they expect you to get a certain number of those right and at the end of the day, um, they sort of make sure, they table up all of the results of all of these quizzes and you will either get your ah, card [???] or you don’t really, so</td>
</tr>
<tr>
<td>0:25:37</td>
<td>So as these guys process with their surveying are they expected to improve their …</td>
<td>So as these guys process with their surveying are they expected to improve their …</td>
</tr>
<tr>
<td>0:25:44</td>
<td>… um</td>
<td>… um</td>
</tr>
<tr>
<td>0:25:45</td>
<td>… their skills in this area …</td>
<td>… their skills in this area …</td>
</tr>
<tr>
<td>0:25:46</td>
<td>… not, what …</td>
<td>… not, what …</td>
</tr>
<tr>
<td>0:25:47</td>
<td>… as surveyors</td>
<td>… as surveyors</td>
</tr>
<tr>
<td>0:25:47</td>
<td>… to know that sometimes they may want to do the STMS qualification which is the one where you can be site supervisor …</td>
<td>… to know that sometimes they may want to do the STMS qualification which is the one where you can be site supervisor …</td>
</tr>
<tr>
<td>0:25:56</td>
<td>I see yeah</td>
<td>I see yeah</td>
</tr>
<tr>
<td>0:25:57</td>
<td>… but the um, surveyors will tend to, if they get on much bigger jobs as I say they tend to employ another firm …</td>
<td>… but the um, surveyors will tend to, if they get on much bigger jobs as I say they tend to employ another firm …</td>
</tr>
<tr>
<td>0:26:04</td>
<td>[???] employ another firm</td>
<td>[???] employ another firm</td>
</tr>
<tr>
<td>0:26:06</td>
<td>… but the engineers within local authorities they generally need to do that qualification, ah the TC1, the STMS and then they go on there is a further one for being able to audit …</td>
<td>… but the engineers within local authorities they generally need to do that qualification, ah the TC1, the STMS and then they go on there is a further one for being able to audit …</td>
</tr>
<tr>
<td>0:26:19</td>
<td>Oh right</td>
<td>Oh right</td>
</tr>
<tr>
<td>0:26:19</td>
<td>… [???] site</td>
<td>… [???] site</td>
</tr>
<tr>
<td>0:26:20</td>
<td>So you mentioned people are driving around, is that, would that be an auditor</td>
<td>So you mentioned people are driving around, is that, would that be an auditor</td>
</tr>
<tr>
<td>0:26:34</td>
<td>Yeah, well that, they will go around and they will audit sites, so if you are doing a job in the Wellington City area, someone employed by Wellington City will be auditing your, um set-up of your worksite, um, yeah so that’s a further, so people in that situation they will be required that extra qualification being able to audit other peoples</td>
<td>Yeah, well that, they will go around and they will audit sites, so if you are doing a job in the Wellington City area, someone employed by Wellington City will be auditing your, um set-up of your worksite, um, yeah so that’s a further, so people in that situation they will be required that extra qualification being able to audit other peoples</td>
</tr>
<tr>
<td>0:26:43</td>
<td>And we, [???] in our, in this area not actually doing any of that kind of training for …</td>
<td>And we, [???] in our, in this area not actually doing any of that kind of training for …</td>
</tr>
<tr>
<td>0:26:51</td>
<td>We don’t, we don’t do anything other than this basic introduction ….</td>
<td>We don’t, we don’t do anything other than this basic introduction ….</td>
</tr>
<tr>
<td>0:26:53</td>
<td>Right</td>
<td>Right</td>
</tr>
<tr>
<td>0:26:54</td>
<td>… um, to traffic management, Temporary Traffic Management</td>
<td>… um, to traffic management, Temporary Traffic Management</td>
</tr>
<tr>
<td>0:26:58</td>
<td>Um, I think we have actually covered everything in my list of questions, um, so basically it is about what Surveyors and Engineers need to know which you covered thoroughly in your description I think um, and then about the ah equipment and related to the knowledge, [essentially] cones and things …</td>
<td>Um, I think we have actually covered everything in my list of questions, um, so basically it is about what Surveyors and Engineers need to know which you covered thoroughly in your description I think um, and then about the ah equipment and related to the knowledge, [essentially] cones and things …</td>
</tr>
<tr>
<td>0:27:22</td>
<td>Oh yeah</td>
<td>Oh yeah</td>
</tr>
<tr>
<td>0:27:22</td>
<td>… and signs</td>
<td>… and signs</td>
</tr>
<tr>
<td>0:27:24</td>
<td>All the specifics for all of those of course and the little pictures in here of all of the different signs etc.</td>
<td>All the specifics for all of those of course and the little pictures in here of all of the different signs etc.</td>
</tr>
<tr>
<td>0:27:29</td>
<td>And there is an existing resource in the, COPTTM ah, TTM</td>
<td>And there is an existing resource in the, COPTTM ah, TTM</td>
</tr>
<tr>
<td>0:27:35</td>
<td>Yeah the NZTA site all of the Temporary Traffic Management signs and, requirements for the [size of the?] cones and all the rest of it, and um, there’s examples in here or Temporary Traffic Management plans and</td>
<td>Yeah the NZTA site all of the Temporary Traffic Management signs and, requirements for the [size of the?] cones and all the rest of it, and um, there’s examples in here or Temporary Traffic Management plans and</td>
</tr>
<tr>
<td>0:27:51</td>
<td>So these, this …</td>
<td>So these, this …</td>
</tr>
<tr>
<td>0:27:52</td>
<td>… [???]</td>
<td>… [???]</td>
</tr>
</tbody>
</table>
This is a plan here

Right

Yip and [???] here …

… there is a grid of some sort isn’t it

down a little bit, yes, but it’s just, um it gives you your site layout distances so, in case you have
forgotten over on this side, and then you state how here how you are complying with it, um …

Oh right

… and it can be approved etc.

I sort of imagined there would be a picture of this as well

Oh usually attached to it, yes you will have your plans etc.

Oh I see yeah

… generally this, a lot of these plans you can use these um, as your generic plan…

Right

… so you can say I’m doing this situation here

Yeah

… and I think we may find, there may be a little, site set up 34 and you may find that that will have
[??!] 34 in here and um, so you don’t have to provide, as long as you have that situation you don’t
have to provide …;

So you have actually, the students would have access to this as part of their …. 

I, I…

… [case?]

… because I have only got the one copy of this I do let, put the PDF up on the [???] or the J drive …

Right

… that we will be using

Yeah, yeah

Or, if we have any of those set up for this there would I suppose

Yeah

But I tend to prefer to use the [???] …

Right

… and um, so the PDF would, pretty much this book is on there so they can have a look at all of
these different scenarios …

Right

… and generally I might give them a quiz to take away at night, saying okay well this is a situation
come back to me with a plan

So you mentioned to, 2-4 hours as well

Yeah, we tend, so the quicker you have to cover other health and safety issues, we might have a
whole four hour session on the health and safety side of things but, um, the traffic management
would only be part of that

Right

But usually it would be at least 2 hours, just because it has got

And in that, situation you give them the take home quiz that they might bring back the next day
<table>
<thead>
<tr>
<th>Time</th>
<th>Person A</th>
<th>Person B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:29:48</td>
<td>Yeah, so they might, it might not be a formal assessment, this is just [????] so I can double check that they have understood.</td>
<td></td>
</tr>
<tr>
<td>0:29:55</td>
<td>Do they have um, any assessments, how do, how do you assess them.</td>
<td></td>
</tr>
<tr>
<td>0:29:58</td>
<td>This is [????] quite close to the end of the semester.</td>
<td></td>
</tr>
<tr>
<td>0:30:01</td>
<td>Right.</td>
<td></td>
</tr>
<tr>
<td>0:30:01</td>
<td>And so they tend to reassess for examination.</td>
<td></td>
</tr>
<tr>
<td>0:30:03</td>
<td>Oh I see, right, so this sort of becomes part of an exam question.</td>
<td></td>
</tr>
<tr>
<td>0:30:07</td>
<td>Yeah, [????] there is a health and safety component in the exam.</td>
<td></td>
</tr>
<tr>
<td>0:30:09</td>
<td>Right.</td>
<td></td>
</tr>
<tr>
<td>0:30:10</td>
<td>Yeah, and so as well like set out the cones etc they are required to know the basics which are at the front here, you know like descriptions of what is advanced warning etc. so all the things at the front here and the glossary and everything [????] site traffic management supervisor.</td>
<td></td>
</tr>
<tr>
<td>0:30:29</td>
<td>ST is it.</td>
<td></td>
</tr>
<tr>
<td>0:30:30</td>
<td>STMS.</td>
<td></td>
</tr>
<tr>
<td>0:30:31</td>
<td>MS.</td>
<td></td>
</tr>
<tr>
<td>0:30:32</td>
<td>Yeah, but um yeah, just, pretty much the first few pages of this, is traffic operation so they need to understand traffic, how to direct traffic and worksite protection and all of these different firms and what the rules.</td>
<td></td>
</tr>
<tr>
<td>0:30:47</td>
<td>And ah, as well, have you had any feedback from them about these classes, I guess you have your normal …</td>
<td></td>
</tr>
<tr>
<td>0:30:55</td>
<td>Um, not.</td>
<td></td>
</tr>
<tr>
<td>0:30:55</td>
<td>… about how they feel about them and the [????] evaluation of it.</td>
<td></td>
</tr>
<tr>
<td>0:30:57</td>
<td>Yeah, not too much, I mean the, usually the evaluations have been done by the time we get to this …</td>
<td></td>
</tr>
<tr>
<td>0:31:02</td>
<td>Oh I see.</td>
<td></td>
</tr>
<tr>
<td>0:31:03</td>
<td>… they are done um a few weeks before the end of the semester.</td>
<td></td>
</tr>
<tr>
<td>0:31:06</td>
<td>Oh right, it sounds like an interesting strategy I might try that one.</td>
<td></td>
</tr>
<tr>
<td>0:31:09</td>
<td>So I think, well most of ours are done fairly, we have one early one two or three weeks ….</td>
<td></td>
</tr>
<tr>
<td>0:31:14</td>
<td>Yeah.</td>
<td></td>
</tr>
<tr>
<td>0:31:14</td>
<td>… I think we are all the same aren’t we …</td>
<td></td>
</tr>
<tr>
<td>0:31:15</td>
<td>Oh we, were slightly different.</td>
<td></td>
</tr>
<tr>
<td>0:31:17</td>
<td>Oh okay.</td>
<td></td>
</tr>
<tr>
<td>0:31:18</td>
<td>But um it is usually halfway into [??].</td>
<td></td>
</tr>
<tr>
<td>0:31:22</td>
<td>We have, we have a quite early one that’s just ….</td>
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<tr>
<td>0:31:23</td>
<td>Right.</td>
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<tr>
<td>0:31:24</td>
<td>… you know what’s going well …</td>
<td></td>
</tr>
<tr>
<td>0:31:25</td>
<td>Yeah.</td>
<td></td>
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<tr>
<td>0:31:25</td>
<td>… what’s helping you what’s not helping you…</td>
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<tr>
<td>0:31:27</td>
<td>Yeah, that’s.</td>
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<tr>
<td>0:31:27</td>
<td>Etc.</td>
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<tr>
<td>0:31:27</td>
<td>That’s ….</td>
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<tr>
<td>0:31:28</td>
<td>Yeah.</td>
<td></td>
</tr>
<tr>
<td>0:31:28</td>
<td>That’s one.</td>
<td></td>
</tr>
<tr>
<td>Person A</td>
<td>Person A</td>
<td>Person B</td>
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<tr>
<td>0:31:29</td>
<td>Yeah the, well close to the beginning, and then, towards the end but not right at the end because otherwise no one has got time to collate them all</td>
<td></td>
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<tr>
<td>0:31:36</td>
<td>Oh I see</td>
<td></td>
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<tr>
<td>0:31:38</td>
<td>We have, although I don’t think it’s, it’s not like an exit interview or anything, I think it’s a few weeks before end of term</td>
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<tr>
<td>0:31:44</td>
<td>Right</td>
<td></td>
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<tr>
<td>0:31:45</td>
<td>But I would have to check</td>
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</table>
## Table A4 I2A  Interview two – first interview with PC

<table>
<thead>
<tr>
<th>Time</th>
<th>Person A</th>
<th>Person B</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00:00</td>
<td>The purpose of our meeting is to get information about Temporary Traffic Management as it is taught and where it lives the disciplines that we, or you, teach and generally to get a good scope of teaching, the issues, the technology that might affect that, the teaching and the learning perhaps and also the, um overal knowledge that might be required when dealing with it</td>
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<tr>
<td>0:00:55</td>
<td>Sure</td>
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<tr>
<td>0:00:55</td>
<td>So I have organised this into a series of sections one is sort of a general question about Temporary Traffic Management and where it lives, the next area is about, um, when, where, what is needed for Temporary Traffic Management and then when run your course, what approaches you would take or can taken and then the equipment and resources that are needed to do that, then the, what, is there something specific that Temporary Traffic Management that causes you to teach in a particular way, that would be an area to think about and given that you have got a way when you are teaching, are there any (???) that you have got to work out or things you have got to prepare for. So those are the sort of five or six areas that I would like to discuss today…</td>
<td></td>
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<tr>
<td>0:01:56</td>
<td>Yip</td>
<td></td>
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<tr>
<td>0:01:56</td>
<td>… and if we come up with any other thoughts along the way we can hopefully just expand out of those, so my sort of first, ah, It is kind of like an interview but it is also any thoughts you have we can explore them…</td>
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<tr>
<td>0:02:11</td>
<td>Sure</td>
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<tr>
<td>0:02:11</td>
<td>… so when, in Temporary Traffic Management what do Engineers and Surveyors need to know?</td>
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<tr>
<td>0:02:23</td>
<td>They need to be[????] first with the Code of Practice for Temporary Traffic Management to a degree that would allow them capability to design, organise and test a Temporary Traffic Management site, under varying conditions and by conditions I mean the appropriate level of Traffic Management for the particular and [registrated?] traffic for that road that they are working on. They need to be able to test the system that they have designed for compliance before they order the Traffic Management System [to the degree as mentioned] here they have to order their own [????] worksite for compliance so it tells a thought that [precise] knowledge of the signage, the procedures, the cone [tapers?], the speed limits the [limitation?] signs and any other Traffic Management devices that they use</td>
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<tr>
<td>0:03:42</td>
<td>So there is quite a range of existing knowledge on, in that National Temporary Traffic Management document</td>
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<tr>
<td>0:03:52</td>
<td>Yeah…um</td>
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<tr>
<td>0:03:52</td>
<td>… but there are skills beyond that [????]</td>
<td></td>
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<tr>
<td>0:03:57</td>
<td>Um yeah, the Code of Practice simply lays out the way in which the Traffic Management Systems must be used and then ther is a level about that which is checking and compliance for the precision of what [????] used or implemented</td>
<td></td>
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<tr>
<td>0:04:20</td>
<td>I just notice that I didn’t ask you about what Temporary Traffic Management actually is in general, if you could, sorry about that I would have thought it was…</td>
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<tr>
<td>0:04:25</td>
<td>Okay</td>
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<tr>
<td>0:04:26</td>
<td>… [????]</td>
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<tr>
<td>Time</td>
<td>Speaker</td>
<td>Text</td>
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<td>0:04:30</td>
<td>Person B</td>
<td>Temporary Traffic Management has a fairly explicit definition that is laid down in the Code of Practice which is most often referred to as [???] Code of Practice of Temporary Traffic Management, um, which I might add is, actually under the [???] at this point in time is under the</td>
<td></td>
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<tr>
<td>0:04:50</td>
<td>Person A</td>
<td>...well that is right... remember you mentioned you mentioned that they are in the process of rebuilding it</td>
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<td>0:04:52</td>
<td>Person B</td>
<td>… but to go back to the original [???], temporary Traffic Management is the process whereby the public safety and workplace safety is ensured for, um, people who are transiting an area of road of which work stops and which requires some kind of health and safety regionally to ensure that safety [???] plans, it is a protective mechanism, um...</td>
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<td>0:05:34</td>
<td>Person A</td>
<td>[???] extends down to somebody for example knowing the [???] of the road</td>
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<td>0:05:40</td>
<td>Person B</td>
<td>Any, any activity that takes place other than being a road user that involves an external agency maintaining the facility, sorry hedge line, um, anything that involves dig outs, um lane marking road sweeping, overhead work and cables even down to management of events, for example such as cycle lanes.</td>
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<tr>
<td>0:06:15</td>
<td>Person A</td>
<td>Yes, cycle races</td>
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<tr>
<td>0:06:15</td>
<td>Person B</td>
<td>… or any, anything that impacts on the use of the road by the public, um the motoring public by another party will require Traffic Management</td>
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<tr>
<td>0:06:30</td>
<td>Person A</td>
<td>Does Temporary Traffic Management come, it seems like it comes across a lot of activities and a number of disciplines…</td>
<td></td>
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<tr>
<td>0:06:43</td>
<td>Person B</td>
<td>Yip</td>
<td></td>
</tr>
<tr>
<td>0:06:43</td>
<td>Person A</td>
<td>… that Engineers and Surveyors need to know about.</td>
<td></td>
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<tr>
<td>0:06:44</td>
<td>Person B</td>
<td>Yip…</td>
<td></td>
</tr>
<tr>
<td>0:06:45</td>
<td>Person A</td>
<td>… anyone that is involved with the road</td>
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<tr>
<td>0:06:46</td>
<td>Person B</td>
<td>… Engineers, Surveyors, Event Organisers, ah, the utility companies, that have services located in or near a road, or over a road, um, it doesn’t extend to the use of [???] for road transport [???], so that is covered by a separate practices but, if they were required to remove or replace services during the, the operation, say overhead lines, then that would require Temporary Traffic Management</td>
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<td>0:07:30</td>
<td>Person A</td>
<td>LPP is there a progression within Temporary Traffic Management from? I notice you mentioned the number of cars, the volume of traffic</td>
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<tr>
<td>0:07:46</td>
<td>Person B</td>
<td>Yeah</td>
<td></td>
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<tr>
<td>0:07:46</td>
<td>Person A</td>
<td>… the use of this, are different licences or…</td>
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<tr>
<td>0:07:47</td>
<td>Person B</td>
<td>Ah yes…</td>
<td></td>
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<tr>
<td>0:07:48</td>
<td>Person A</td>
<td>… or…</td>
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<tr>
<td>0:07:48</td>
<td>Person B</td>
<td>LPP, T … the system of highways is organised into a hierarchy of essentially at the bottom end moving from low volume roads though to extremely high volume loads that the, the traffic volume is determined by [NZTA], we don’t have a general daily traffic who didn’t know any traffic, and the number of lanes as well, um, and the, the licencing of the Traffic Controllers and what is known as SMTS or Site Traffic Management Supervisors um is hierarchical so you start at level one controller then essentially can work at that, on that level of road and then moved right up the hierarchy to specialised or better qualified Traffic Managers who are able to install Traffic Management</td>
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<tr>
<td>0:07:48</td>
<td>Person A</td>
<td>Reviewed the system of highways is organised into a hierarchy of essentially at the bottom end moving from low volume roads though to extremely high volume loads … the, the traffic volume is determined by something called the [calculated daily volume of traffic] … and the number of lanes as well, um, and the, the licencing of the Traffic Controllers and what is known as SMTS or Site Traffic Management Supervisors um is hierarchical so you start at level one controller then essentially</td>
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<tr>
<td>Time</td>
<td>Person A</td>
<td>Person B</td>
<td>Notes</td>
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<tr>
<td>0:09:00</td>
<td>LPP, Pathways towards, CK, P, PCK</td>
<td>So those levels that that, is there a, is it on ‘ on the job training’ that gets them to the level …</td>
<td>can work at that, on that level of road and then moved right up the hierarchy to specialised or better qualified Traffic Managers who are able to install Traffic Management</td>
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<tr>
<td>0:09:04</td>
<td>Ah</td>
<td></td>
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<tr>
<td>0:09:09</td>
<td>… or how does that work?</td>
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<td>0:09:09</td>
<td>Person B</td>
<td>No there is a formal training process, there are a number of training providers that are from private companies through PTEs such as New Zealand Institute Highway Technology and ah, some in house training schemes by companies like Fulton Hogan, however there is a requirement of the Polytechnic or University to, I suspect, at least be University level [???] across a number of courses, construction management, construction practices, ah, I guess to a lesser extent contract administration through to Traffic Management and design, say an inner city worksite or multi-story building ah, and roadside maintenance, traffic engineering and traffic and highway engineering which, um, which all have components of the Heavy Traffic Management System taught, although we, we don’t issue a Temporary Traffic Management qualification per say because we are not qualified or licence to do that</td>
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<td>0:10:26</td>
<td>Person A</td>
<td>So where would, ah, here prepare people in a way that they could be aware of the requirements, [???] licence</td>
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<tr>
<td>0:10:36</td>
<td>Person B</td>
<td>Yeah …</td>
<td></td>
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<tr>
<td>0:10:37</td>
<td>… or</td>
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<td>0:10:38</td>
<td>Person A</td>
<td>… once they have left our courses they should be able to walk straight in to the NZTA and test. They are taught to, a standard that would allow them to do that,</td>
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<td>0:10:51</td>
<td>Person A</td>
<td>TK, TCK</td>
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<tr>
<td>0:10:51</td>
<td>TK, TCK</td>
<td>That sounds useful isn’t it. Um, now with the, when you think about Temporary Traffic Management, um, you mentioned a whole lot of equipment earlier, for example cones and things like that and there is obviously this document, um, the national document, that describes the categories of information that need to be covered and there is also obviously equipment to run as well</td>
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<td>0:11:27</td>
<td>Person B</td>
<td>Yeah….yeah, there is a standard, um a standardised list of approved equipment, um that can range from the simple devices as a cone and to different sizes of cones relating to different, essentially different site distances for notice on operating the roads at different speeds, um, right through to the other end of the spectrum where they are using attenuator trucks to provide advance warning for a merging traffic management situation where the job place is moving such as for example[??], yeah so there is a hierarchy, there is a range of levels of complexity of machinery that is required or devices that are required as you go through the different …</td>
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<td>0:12:28</td>
<td>Person A</td>
<td>… these are required by the companies who are doing the job and they ....</td>
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<td>0:12:32</td>
<td>Person B</td>
<td>Yeah …. It is very expensive the investment in equipment is very very large indeed, you know a generator truck would probably cost you two or three hundred thousand dollars, or a cone can cost you as little as $20.00, um, and then there is of course there is the personnel who, who are an additional cost, but ah yeah there is a definitely a vast range of equipment we can’t afford to buy</td>
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<td>0:13:00</td>
<td>Person A</td>
<td>TPK</td>
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<tr>
<td>0:13:00</td>
<td>TPK</td>
<td>And, and, are, are there any, I mean, you mentioned there the national standards document that you have referred to and that is an existing resource. Are there any other resources that, um, in your …</td>
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<tr>
<td>0:13:13</td>
<td>Person B</td>
<td>Virtually …</td>
<td></td>
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</tbody>
</table>

213
0:13:14 Person A | Virtually none
0:13:15 Person B | … virtually none
0:13:17 Person A | … I noticed that you have presented, a CD which, I think your student created that one
0:13:23 Person B | Yeah, that um, that was part of a, part of a project that students were required to do, ah, that particular student was extremely knowledgeable and he works in traffic management and is an auditor, so and he works for a consultant in Dannevirke, and he produced this CD which was [??]
0:13:48 Person A | What would be an example of a resource that you can use to help with your teaching, is there…
0:13:55 Person B | Yeah
0:13:56 Person A | … is there any other resources or virtually nothing?
0:13:57 Person B | Virtually none, no, and I think that is where the usefulness of your proposed project might, um, might lay.
0:14:08 Person A | Within the current ah, teaching environment, is there anything that might make it a bit more difficult to, in terms of the…
0:14:16 Person B | Yeah
0:14:16 Person A | … resources, in terms of the technology?
0:14:18 Person B | The difficulty is that we can’t really take student, you know live students out on a live road and do real things with them, ah, obviously for safety reasons we would have to put up temporary traffic management ourselves, in order to be able to take a class onto the road, and ah, have some disruption to the public, ah, they don’t tend to appreciate that very much, and it is not a particularly easily controlled situation because students can [??] fairly [??] things at times and you cannot forsake the whole notion of having a standardised methodised practice is to avoid errors and ah, which is on a learning situation…
0:15:12 Person A | There’s is a kind of safety around it
0:15:14 Person B | … there is a real, a strong concern safety both for the students and for the public when you take them onto the road. It is not a situation that you can, can manage adequately as, as something…
0:15:30 Person A | [??]
0:15:30 Person B | … struggling to be a teach if there is [??] 30-35 students running around…
0:15:37 Person A | … and I imagine there is a sort of knock on effect that once you, if you are on the road in a learning situation you are not really quite aware of everything that is going on …
0:15:47 Person B | Ah …
0:15:49 Person A | … between the actual …
0:15:50 Person B | … yeah …
0:15:51 Person A | … process of …
0:15:52 Person B | … yeah it is [??] problem and a multifactorial problem, that is complicated by any students who perhaps don’t follow instructions particularly well so they tend to believe perhaps that if they have the right answer and being in a live situation is not the time to find out that it is wrong, so …
0:16:15 Person A | Yeah
0:16:16 Person B | … so when you do run a course..
0:16:21 Person A | … I am sort of aware of time and that I am taking up
0:16:24 Person B | … yeah no that is cool …
<table>
<thead>
<tr>
<th>Time</th>
<th>Person A</th>
<th>Person B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:16:25</td>
<td>Okay, um, what approaches are taken when you [???]</td>
<td>It is a very much a paper based exercise, um, as much as we try to, um, get as much of the fundamental idea of Temporary Traffic Management across um, and, and I think this is true for all trainers … That they take this classroom approach, now you can get out the plastic placemat with the little road made you sort of [???] toy cars and the toy cones and you can teach them using a model, the physical model, um, some students react quite well to that, some don’t which you know, with various learning styles that present them their own difficulties or advantages and, ah, otherwise it tends to be really rather old school teaching, like here is the book, this is what the standard test you must do, you must learn that and you must be able to apply that in real life so it is not an ideal way of learning, um, I have tried [??], sort of 2D models…</td>
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<td>0:17:51</td>
<td>So with the Temporary Traffic Management when you are in the classroom, is there a particular [order?] or level that you follow or a pattern that you might follow, or</td>
<td>Ah, yeah we typically start with the level 1, ah the low volume roads and ah simple dig out scenarios or simple scenarios that [???] find what might happen on the road that need temporary traffic management, and ah, having taught the fundamentals of how to lay out the site and [???] perhaps model that or role play it, [???] the lack of actual real recourses there are thing like you know signs and such that becomes very much [???] a lot of reality to…</td>
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<td>0:18:45</td>
<td>Is there a way that you assess the assessment process for this is there a…</td>
<td>Yeah, it is assessed in a couple of ways, normally I would get them to create a couple of traffic management plans, um, using scenarios that I have provided and, um, you know just simply assess them in their design Temporary Traffic Management System, and ah, if a student got something wrong then we need to go back and revisit the reasons why they got it wrong, and then ah, try and sort of teach, teach them the correct method. It is pretty black and white in the sense that at a low volume if lower volume roads, this, the layouts, the [???] it is actually pretty simple, ah, as you increase the degree of complexity they get to control them quite quickly, and so the complex situations, they are not always that well thought out, and a good example of that is when a student has an absolutely brilliant perfect Temporary Traffic Management system prepared for [an approach?] from one direction but they have actually forgotten that traffic comes the other way as well, ah, or where lane change on multi lane roads where they have to actually remove barriers and get vehicles to transit [??] direction</td>
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<td>0:21:14</td>
<td>So when, did they, you present in a sort of on the board…</td>
<td>It is a very unique situation, where, where a student can be shown a glaringly poor example of Temporary Traffic Management, ah, therefore they are learning what is good and in some ways that is quite a good thing and if, um, it is also sometimes, not, not bad for them to actually see the other side of the coin, what can go wrong if you do get it wrong, and the reasons why it has gone wrong. Not all</td>
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<td>Time</td>
<td>Person</td>
<td>Utterance</td>
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<td>0:22:01</td>
<td>Person A</td>
<td>“I would imagine would be quite a lot more complex…”</td>
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<td>0:22:07</td>
<td>Person B</td>
<td>“… yeah, although the [...] does actually lay out a lot of good complex situations, however the graphics that they use are 2D on paper they don’t necessarily demonstrate a real situation particularly well, and it is [...] complex situations [...] so…”</td>
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<tr>
<td>0:22:31</td>
<td>Person A</td>
<td>“So the other thing that you mentioned is that they might get simulation with the models as one of the….”</td>
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<tr>
<td>0:22:38</td>
<td>Person B</td>
<td>“…yeah…”</td>
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<tr>
<td>0:22:39</td>
<td>Person A</td>
<td>“…techniques you use from time to time in your classroom?”</td>
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<td>0:22:40</td>
<td>Person B</td>
<td>“… yeah I have tried using the ah…”</td>
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<tr>
<td>0:22:42</td>
<td>Person A</td>
<td>“You don’t find that to be a particularly, that doesn’t, does that, are there, is there is something about the simulation with regard to, their learning, you mentioned it earlier that there might be some kind of…”</td>
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<td>0:22:58</td>
<td>Person B</td>
<td>“Yeah… I think you will find that sometimes [...] adult students or at least particularly with adults, tend to find it a little weird to play with toy cars on a plastic, ah plastic mat, and ah, and so they tend not to take the model very seriously and it doesn’t work or transmit the idea of the enormity of the, of a poorly managed worksite, you, it is okay to [...] model cars sort of crushing and ah…”</td>
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<tr>
<td>0:23:40</td>
<td>Person A</td>
<td>“It doesn’t show the consequence…”</td>
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<tr>
<td>0:23:42</td>
<td>Person B</td>
<td>“[...] it doesn’t actually convey the true um [...] the problem is they get it wrong”</td>
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<tr>
<td>0:23:49</td>
<td>Person A</td>
<td>“So in general the approach that you are using, essentially requires a classroom…”</td>
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<td>0:23:54</td>
<td>Person B</td>
<td>“Yeah”</td>
</tr>
<tr>
<td>0:23:55</td>
<td>Person A</td>
<td>“… and maybe a smart board and video [...]”</td>
</tr>
<tr>
<td>0:23:58</td>
<td>Person B</td>
<td>“Yes very much, very much the standard quality for teaching unfortunately”</td>
</tr>
<tr>
<td>0:24:03</td>
<td>Person A</td>
<td>“Um, is there anything about teach TTM, about TTM, that we, although we might have touched on this already I am just trying to re-enforce that, um, determines how you approach it, I suppose it is the hierarchy isn’t”</td>
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<tr>
<td>0:24:19</td>
<td>Person B</td>
<td>“Yeah the hierarchy, it is a massive document, there is a huge amount of material in there, um, and I think the students become a little overwhelmed with, with um, the […] to be honest. They look at this thing and say well do we really need to know all of this, and if they are going to manage a worksite then, yes they do, ah, at some level, ah, at the very least they must be able to assess a Temporary Management Plan or Traffic Management Plan that has been submitted to them via a subcontractor who is a specialised Traffic Management Operator, um, and they have to be able to say well yes [...] to live with that system, but they also bare the consequence of something going wrong, so”</td>
</tr>
<tr>
<td>0:25:18</td>
<td>Person A</td>
<td>“So there is a, with, with the document basically presents itself as a weighty document.”</td>
</tr>
<tr>
<td>0:25:27</td>
<td>Person B</td>
<td>“…oh [...]”</td>
</tr>
<tr>
<td>0:25:28</td>
<td>Person A</td>
<td>“… I guess by the same token it is complete and thorough so that…”</td>
</tr>
<tr>
<td>0:25:35</td>
<td>Person B</td>
<td>“It is and I guess that arises out of the, the sort of feeling that NZTA for a fear of litigation under the Health and Safety [...] and the ACC and various other Acts I guess that should NZTA’s Engineer’s approve something or their Agent approves something and there is a consequent, consequently there is an injury or subsequently I should say there is an injury then where does the liability rest and, and that becomes a problem so they are being very complete and thorough in their production of this [...] however it is so weighty that most local bodies for example have developed a much smaller document that”</td>
</tr>
</tbody>
</table>
covers the usual range of traffic management compliance in that area and even some contractor companies have done the same thing, they are trying to reduce this weightiness to a manageable size.

0:26:43
Person A
So, [???] teaching you to alleviate this [???]

0:26:29
Person B
[???] don’t have time to [???] no, we don’t it is as simple as that so, ah, [???] teacher to that which can be achieved within the time available

0:26:59
Person A
Are there any [???] in terms of, just in, we may have touched this as well, in terms of teaching in the knowledge space, the teaching of it and the resources all coming together, if you go into a classroom, what do you have to be aware of, um...

0:27:21
Person B
Um, yeah well that is a huge questions, ah, anything really, the limitation of the equipment that we have got, the limitation of the students to observe so much information in such a short space of time, ah, given that most students, I guess that [???] students anyway are strong visual learners, to be sat in a room and told to read something and hear this lecture and apply that in somewhat, um, doesn’t really, the education doesn’t cut the mustard, I think it is much better because it is [???] out on its site is quite the kinesic activity, um, you know [???] simulation there is not a, a, um, in a safe situation then, yeah that would be great, I mean they learn from that and they learn very quickly, um, ideally I would have [???]...

0:28:35
Person A
[???]

0:28:35
Person B
… [???] driving over the current roads, laid out and the field marking line, or whatever they use and ah, to actually be able to drive through simulations on, and see what the effect was, how do they not, [???] that, ah, everybody reacts differently to those situations and it is rather an interesting observation that, a great deal of temporary traffic management presents so much information to the driver that they become, or can become confused and I, I think that is essentially what is happening in the classroom, the students that they, they can become easily confused by the [???] information that they have to [???]

0:29:28
Person A
So, in your practice is there a, how do you approach that, if they can [???]

0:29:37
Person B
Yeah, much depends on the group, but yes delivering very much smaller, smaller pieces of information separated by gaps that they are required to go and fill in for themselves and then come back and [???] to the class or to present an assignment or [???], to be honest with you I haven’t actually found the perfect strategy for teaching this year…

0:30:06
Person A
…right…

0:30:08
Person B
… it is not something that lends itself to simple approach, you know there is no such thing as an average learner really, but yeah [???]

0:30:22
Person A
Before you go to class is there anything that you need to be aware of [???] going to, or starting to teach a group of students before they start…

0:30:35
Person B
You really get to know how much they know for a start, [???] pre-assessment of their exposure to Temporal Traffic Management, and I guess that most [???] licenced drivers, most drivers would have had some personal experience of traffic management and they may have formulated a view that is, um, either very productive or perhaps counter productive, it is usually through teaching that you [???] you have been held up getting to a rugby game or some form of event by Temporary Traffic Management will be predisposed to thinking that it is, you know, just an inconvenience….

0:31:22
Person A
Right

0:31:23
Person B
… rather than a safety mechanism, ah, whereas someone who has experienced an accident and had the [security?] and protection Temporary Traffic Management provides at the accident site might think well hey this is very good [???], ah and there could be a whole spectrum of predisposition to accept [???] system
<table>
<thead>
<tr>
<th>Time</th>
<th>Person</th>
<th>Text</th>
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<tbody>
<tr>
<td>0:31:56</td>
<td>Person B</td>
<td>Yeah, yeah</td>
</tr>
<tr>
<td>0:31:59</td>
<td>Person A</td>
<td>… [???] there be, um, other concerns as they move up or is it…</td>
</tr>
<tr>
<td>0:32:04</td>
<td>Person B</td>
<td>Um, I guess one of the things that most students are aware of because they have had, either been working or exposed to a work environment in some way, ah, they are often very mindful of the costs associated with traffic management, it is a very very expensive business and since, [???] became mandatory and [???], the traffic management industry if you like has grown very quickly and has become in some cases a much greater cost than actually carrying out the work on the road, so you may have a traffic site where there is $20,000 worth of traffic management and the pothole getting repaired may be two or three hundred dollars…</td>
</tr>
<tr>
<td>0:32:57</td>
<td>Person A</td>
<td>Oh gosh</td>
</tr>
<tr>
<td>0:32:58</td>
<td>Person B</td>
<td>… so students are well aware of that and mindful of it and because of their attitude towards monetary things they tend to say well what a waste of money…</td>
</tr>
<tr>
<td>0:33:13</td>
<td>Person A</td>
<td>The temporary traffic</td>
</tr>
<tr>
<td>0:33:14</td>
<td>Person B</td>
<td>… yeah so they have this</td>
</tr>
<tr>
<td>0:33:17</td>
<td>Person A</td>
<td>So you prepare you prepare yourself for that, or aware of that [???]?</td>
</tr>
<tr>
<td>0:33:22</td>
<td>Person B</td>
<td>Yeah, I think, um, with any education there is some degree of attitude on [???], for me the students, how to treat it is, I guess [function?] by how well you manage your classroom</td>
</tr>
<tr>
<td>0:33:39</td>
<td>Person A</td>
<td>Ah, and in terms of ah, just, [???] back before you go to class is there an apprehension with regard to, that is a leading question isn’t, what I mean is, is there anything else that you need to be careful about, or anything that you definitely need to know before you walk into that classroom…</td>
</tr>
<tr>
<td>0:33:56</td>
<td>Person B</td>
<td>Oh yeah, you have to, I mean I have to know Temporary Traffic Management…</td>
</tr>
<tr>
<td>0:34:01</td>
<td>Person A</td>
<td>Right</td>
</tr>
<tr>
<td>0:34:02</td>
<td>Person B</td>
<td>… Code of practice, pretty much upside down and back to front, you know as an Educator you have got to be mindful of the fact that you are putting yourself out there as an expert and if you get it wrong the consequence of that is pretty major, you know you could be [???] an entire class of students potentially, [???] totally the wrong idea about a particular aspect of [???], you know they go out and practice that…</td>
</tr>
<tr>
<td>0:34:33</td>
<td>Person B</td>
<td>The consequence of that is one they fail their first audit and failing audits accrues negative brownie points if you like, [???], ah and so many points you are out, you know because, ah, it is as simple as that, and [???] may have a consequence for their employer and it can have, at worst, very severe safety implications for the [???] public or the [???], so you have got to be mindful that you get things right, there is no, 100% is only just good enough [???] quite important</td>
</tr>
<tr>
<td>0:35:19</td>
<td>Person A</td>
<td>Of course</td>
</tr>
<tr>
<td>0:35:23</td>
<td>Person B</td>
<td>Being well prepared with [personal] documents [???]…</td>
</tr>
<tr>
<td>0:35:23</td>
<td>Person A</td>
<td>Yeah</td>
</tr>
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</table>
| 0:35:29 | Person B | I think the greatest apprehension is that there is a lack of resources that we have available and ah, to teachers, um, and is essentially something that can be self-taught to a large extent, um, provided the assistance of [???] support, I mean, in that I guess that is the case for anything, there is, at the lower end of it, the learning heirarchy if you like,
<table>
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<tr>
<th>Time</th>
<th>Person A</th>
<th>Time</th>
<th>Person B</th>
</tr>
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<tbody>
<tr>
<td>0:36:46</td>
<td>Yeah</td>
<td>0:36:47</td>
<td>… or not necessarily how well they do but how to do [???] design [???] that would be ideal</td>
</tr>
<tr>
<td>0:36:56</td>
<td>So eventually your resources and that [???]</td>
<td>0:37:00</td>
<td>Yeah well there aren’t any…</td>
</tr>
<tr>
<td>0:37:00</td>
<td>Person A [???]</td>
<td>0:37:01</td>
<td>Person B … there [may be papers] in Temporary Traffic Management [???]</td>
</tr>
<tr>
<td>0:37:08</td>
<td>Person A So things like, [???] sort of your little simulations and things and stuff that the…</td>
<td>0:37:14</td>
<td>Person B Yeah… we don’t even have those [???] so ah yeah, It would be useful to have some sort of equipment in a model scale that is available, I sort of made myself [???]</td>
</tr>
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<td>0:37:43</td>
<td>Person A Is there anything else in terms of your general thoughts about teaching [???] that might …</td>
<td>0:37:54</td>
<td>Person B Well I think it is not just teaching a course as a [???] about traffic management principals in the sence that they may be required to control cars in the carpark even, or to, or to get people like Event Managers on a [???] they need to know what Temporary Traffic Management may be to be able, at least to be able to assess that so they could, they are aware of the requirement to hire an expert or produce a plan, and to go through the process of</td>
</tr>
<tr>
<td>0:38:39</td>
<td>Person A In your experience is there other, do you have any sort of, ah, information about how other people, for example the [???] area, might [???] recreation area might, ah…</td>
<td>0:38:58</td>
<td>Person B [???]</td>
</tr>
<tr>
<td>0:39:00</td>
<td>Person B … well basically the same way, do it out of your book and then do it off paper based models and I don’t think it necessarily works very well, there is a lot of theory about sufficient practice and I think [???] to get to [???] is to actually get the student to practice what they have learn in a more [???] takes the message on really, and that the more able they become to really, to properly practice in real life, you know I think a [???] would be the ability of [???] like a nurse who, to be able to grab a manequin and and practice CPR there is no, learning that CPR from a book [are you going to actually] be able to simulate that use of practice, um, and you know, you don’t go get, go and practice on real people until [???], you are going to need what you learnt to survive on, ah, and I guess that same problem presents with this particualr subject that you can’t take them on the road, it is difficult to arrange a scenario [???]</td>
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<tr>
<td>0:40:37</td>
<td>Person A Look I really appreciate what you did today and I think we have gathered a lot useful information and I, my task now is to go through and convert that into a, some recorded notes, which I can [???] and pass back you…</td>
<td>0:41:00</td>
<td>Person B Yeah absolutely</td>
</tr>
<tr>
<td>0:41:03</td>
<td>Person A …so I really appreciate what you did today and thank you for your time, and energy and, ah, from here I will make appointments with regards to the development of the system</td>
<td>0:41:19</td>
<td>Person B Yeah</td>
</tr>
<tr>
<td>0:41:20</td>
<td>Person A So at this point really we are looking at the, the way we learn and teach in an education [???]</td>
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<td>Time</td>
<td>Person</td>
<td>Transcript</td>
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<td>0:41:30</td>
<td>Person B</td>
<td>Yeah, [???] one of the thing that the whole notion of it is [???] virtual reality model if you like is, is that, it would be a immensily useful tool for, a huge range of education institute and ah, and people, and I think, I think I have said this before, [???] one of those things that could be incorporated with driver testing or driver education, um, and that is a, I don’t mean in terms of sitting in a, sitting a person in a driving simulator, but I guess that [???] logical end point we could probably do that</td>
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<td>0:42:19</td>
<td>Person A</td>
<td>So I, today at any rate I really appreciate, this is, this is expanded quite a lot of knowledge about how the education of this works an the various dimension of that, so, and ah, thank you for your time</td>
<td></td>
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<tr>
<td>0:42:36</td>
<td>Person B</td>
<td>[???] on the record, one of the things that, you know, when we talk about driver experience, the, the first time the driver experiences confusion at a, at an unusual situation is not the time that they actually want to have, you know, some kind of bad reactions to that confusion, they really need to be aware of, that possibly an extension of the project, looking at driver behaviour could be something further down the track</td>
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<td>0:43:16</td>
<td>Person A</td>
<td>Yeah, I imagine there…</td>
<td></td>
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<tr>
<td>0:43:17</td>
<td>Person B</td>
<td>… [???]</td>
<td></td>
</tr>
<tr>
<td>0:43:19</td>
<td>Person A</td>
<td>…. Slighty different…</td>
<td></td>
</tr>
<tr>
<td>0:43:22</td>
<td>Person B</td>
<td>Yeah, oh yeah [???] possibly a further researchable [???] later on</td>
<td></td>
</tr>
<tr>
<td>0:43:32</td>
<td>Person A</td>
<td>Again, I really appreciate this….</td>
<td></td>
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Appendix A5.1 Wheel interaction and implementation

*Turning the Wheel without using the built in object Drag facility*

Interaction style for turning the wheel was changed from clicking on the left or right of the wheel handle to turn the wheel, to drag right and drag left” to turn the wheel clockwise and anticlockwise respectively.

The viewer provides drag and lift of virtual world objects, set with a physical property, through an avatar in the virtual environment, as a person would lift and drag objects in the real world. Hence it should be possible to implement a wheel object that can be turned by dragging the wheel with simulated physical characteristics, by building the equivalent to a physical steering mechanism in the virtual environment.

However, in this simulation system, *physical* objects repel each other when close to each other in the simulated world, about the equivalent to 10cm to 20cm apart in the *real world*. That means a Wheel would need to be constructed with bearings that are about that far apart. Physical objects that are linked retain repulsive force against each other. When an object is unlinked either by script or by an editor(builder), that force is applied between the objects causing them to spring apart, often at high velocity. When *physical* objects are linked to non-physical objects they propagate the repelling force across to other attached objects. The consequence is that the now linked objects start to rotate or move, which destroys the layout of objects in the environment.

According to the Open Simulator Community (2014) the number of objects that can be linked is limited to 255 in the Virtual World Viewer code base, furthermore, according to Linden Research Inc. (2016) for their server after version 1.26, the limit is 256 linked objects, with an upper limit of 32 linked objects for physical objects. Hence, to simulate large vessels in detail, as in this case, the vessel is made up of sections that are not linked. Since sections of the simulated vessel are not linked, the vessel must be made up of objects that are not “physical”, because if they were they would repel each other and sections would not appear to be connected.
The approach taken was to implement a system that turn the Wheel using drag interaction without using the “physical drag” feature. In-world touch event handling identifies the start of a “touch” (equivalent to a mouse down), an on-going touch (if the mouse is still down and moving) and an “end” of touch when the mouse is released.

A script implementing the handling of these events was attached to the root prim of the Wheel. An attempt made at rotating the wheel using the touch based drag, a drag over part of the wheel causing rotation of the Wheel depending on the direction and duration of the drag. However, as the Wheel rotates in response to rotate command, touch events continue to be generated, generating a set of touch events in the opposite direction, that when processed, cause the Wheel to turn in the opposite direction. When the drag goes beyond the wheel, touch events are no longer generated, making the coding of the drag handling more complex.

Hence an invisible gesture capturing cuboid object (an invisible box) has been placed over the Wheel, drags are captured when a person attempts a drag on the Wheel. The drag is actually acting on the gesture capturing cuboid. Turn information from the gesture is transmitted to the Wheel using a simulation Talk channel. The Talk channels are a programmatic messaging system built into the simulation system that allows communication between objects and Avatars in the simulation. A specific channel has been set up for communication of touch data from the gesture capture. Touch information is transmitted to the Wheel. Since rotation takes more simulated time (0.2s) in the simulator than generating touch events (0.022s - one simulator frame) (Linden Research, Inc, 2012), the Wheel script takes a sample of the touch events transmitted only asking the Wheel to rotate after a certain number of samples. If too few samples are taken the Wheel turn is too large, if too many samples are taken Wheel rotation is called too often generating many built in rotation delays, resulting in a slow response. Hence, the sample rate was adjusted to reach a balance between too much turn and too slow response.
Appendix A6.1 Script re-use between MUVEs

An example of an LSL script called Give Folder is presented in Table A6.1. As depicted in Figure A6.1 and Figure A6.2 it provides similar functionality in the TTM MUVE and the ship’s bridge MUVE.

Table A6.1 The LSL script Give Folder is used in the TTM and Ship’s Bridge MUVEs

```
// Give Folder
list inventory = [];
default {
  state_entry() {
    integer i;
    for ( i = 0; i < llGetInventoryNumber(INVENTORY_ALL); i++) {
      string item = llGetInventoryName(INVENTORY_ALL, i);
      if (llGetInventoryPermMask(item, MASK_OWNER) & PERM_COPY) {
        inventory += [item];
      }
    }
    integer index = llListFindList(inventory, [llGetScriptName()]);
    inventory = llDeleteSubList(inventory, index, index);
  }
  touch_start(integer total_number) {
    llGiveInventoryList(llDetectedKey(0), llGetObjectName(), inventory);
  }
}
```

When the script is running it gives the contents of an object in the simulation to the avatar that touches the object. The script Give Folder is used in both MUVEs to provide avatar uniforms and shapes.

Figure A6.1 The Give Folder script in the TTM MUVE gives a uniform.

Figure A6.1 depicts the script being used in the TTM MUVE, where it is placed into a blue box. When the script is running an avatar that ‘touches’ that box is given an student engineer avatar shape and uniform.
Figure A6.2 The Give Folder script in the Ship’s Bridge MUVE gives a uniform.

Figure A6.2 depicts the same script placed in a storage cabinet of the simulated ship in the Ship’s Bridge MUVE. It provides avatars that touch the cabinet a uniform to use while training on the simulated bridge.