
*Towards a Generalised
Pedagogical Framework for
Creating Mixed-Mode Role-Play in
a 3D Virtual Environment*



Enas A Jambi

School of Computer Science and Electronic Engineering University of
Essex

A thesis submitted for the degree of

Doctor of Philosophy

10 January 2020

Abstract

Role-play has proved itself to be an effective teaching method, and role-play within a virtual environment has been found to be more especially so. Thus, there have been many studies concerned with role-play and computer simulation used together; however, up to this point, limitations may still be found with respect to the work which has been done in this area. Some of the major outstanding problems associated with creating virtual environments for learning are: finding the simplest way to model and represent abstract concepts as 3D objects; and implementing the students' interactions - with each other, with their instructor, and with the represented objects. Also, many projects have focused on only one pedagogical topic.

My vision is to introduce a generalized method that facilitates the construction of learning scenarios and renders them as message-passing role-play activities. Then, these activities could be deployed in a virtual environment (VE) in order to help students to become more immersed in the learning process. Each such activity is to be constructed by humanizing a 'non-human' object, whereby the students embody and imitate an (often abstract) object which is part of a technological system and which occurs in a virtual world. This can lead to many benefits, such as being able to better support the students' ability to imagine and visualize such objects, making them more engaged with their learning, enhancing their conceptual understanding, strengthening their reasoning when solving problems related to the topic area, and reinvigorating their interest in learning.

This research presents an evaluation of an approach for the creation of a role-play simulation in a role-play supporting virtual environment, which harnesses the advantages of 3D virtual environments in an effective way - in order to benefit the students' learning in terms of improving their understanding of abstract concepts. Moreover, this approach is generalized and thus extends the previous studies by offering a system that can be applied to a wide range of topics - that involve message-passing role-play scenarios. The approach is presented within a conceptual pedagogical framework that is supported by an analysis of the findings and results from experiments that were conducted in order to validate the framework from both the learning and technical perspectives.

To my parents ..

To my little angels .. Eyad & Mohammed ..

Acknowledgments

First, my most heartfelt thanks go to the most merciful Allah for all the blessings that he has granted to me from the moment of my birth to this point in my life.

It is difficult to express in words the gratitude and the thankfulness I feel towards my parents Abdulaziz and Nailah for their endless love and support. They have always encouraged me and my siblings in our pursuit of knowledge and continuing efforts to educate ourselves in order that we can deal with the contingencies of life. My sincere thanks and gratitude also go to my brothers, Thamir and Abudllah, and sisters, Fatima and Ghidaa, for always being there for me. My special thanks go to my big brother, Thamir, who has acted as a second father to me and always goes the extra mile in supporting me.

In usual situations, the parents are the ones who stand behind their children until they reach their goals; in my situation, however, my children, Eyad and Mohammed, are the ones who gave me the strength and motivation to reach the end point of the PhD journey. Although we were separated physically in recent years for unavoidable reasons, they nevertheless always knew how to lift my spirits so that I kept going.

I would also like to express my grateful appreciation to my supervisor, Dr Michael Gardner, for his generous guidance, advice, help, and the encouragement, patience, enthusiasm and immense knowledge with which he supported me in this research. Likewise, my thankfulness goes to Prof. Victor Callaghan for his invaluable advice and thought-provoking feedback at various different stages of the work. Not to be forgotten, my appreciation as well to all my colleagues and friends at the Immersive Education Lab group.

I would like to thank the University of Jeddah for giving me the opportunity to complete my PhD in the U.K.—without their financial support, this journey would not have been accomplished. I am also thankful to the College of Computer Sciences and Engineering – Girls’ campus (CCSEG), of the University of Jeddah, for permitting me to conduct my experiment at their campus. Special thanks go to my colleagues and my students for helping me in this. And my deepest gratitude is owed to my colleague and friend Ghadeer Al-Mehmadi without whose help I could not have finished the experiments.

Finally, thanks to all my extended family and friends in Saudi Arabia. My endless gratitude to my friend and sister Samah Flemban. And my thanks also to all my friends in the U.K.; they were my family here while I was living alone.

Table of Contents

| | |
|---|------------|
| Abstract | i |
| Acknowledgments | iii |
| Table of Contents | iv |
| List of Tables | ix |
| 1 Introduction | 1 |
| 1.1 Motivation | 3 |
| 1.2 The Big Vision..... | 5 |
| 1.3 Hypotheses..... | 7 |
| 1.4 Contributions..... | 9 |
| 1.5 List of publications | 10 |
| 1.6 Thesis Outline..... | 10 |
| 2 Literature Review | 12 |
| 2.1 Role-Play in Science Education..... | 13 |
| 2.1.1 CRC Card Method..... | 14 |
| 2.2 Learning Theories & Learning Design | 17 |
| 2.3 Role-Play in the 3D Virtual Environment..... | 24 |
| 2.4 The Data Driven Approach | 29 |
| 2.5 Teaching Computer Networks..... | 30 |
| 2.6 Summary..... | 32 |
| 3 Research Framework | 34 |
| 3.1 The Conceptual Framework | 35 |
| 3.1.1 Data Layer..... | 37 |
| 3.1.2 Task Design Layer..... | 43 |
| 3.1.3 Objects Layer..... | 43 |
| 3.1.4 Simulation Layer | 45 |
| 3.2 Mixed-Mode Role-Play System Architecture..... | 46 |
| 3.2.1 Instructor GUI..... | 47 |
| 3.2.2 RPVE Generator..... | 48 |
| 3.2.3 Simulator | 49 |
| 3.2.4 Student GUI..... | 50 |
| 3.3 Summary..... | 50 |

| | |
|--|------------|
| 4 Experimental Framework | 52 |
| 4.1 The MMRP System Model | 53 |
| 4.1.1 Student GUI Implementation | 55 |
| 4.1.2 RPVE Generator Implementation | 56 |
| 4.1.3 Simulator Implementation | 56 |
| 4.2 Hypotheses Validation | 60 |
| 4.3 Network Learning Stage..... | 61 |
| 4.3.1 The Conventional Learning Phase | 64 |
| 4.3.2 The MMRP Stage..... | 65 |
| 4.4 FSM Stage: Change the database to deal with a new subject | 74 |
| 4.4.1 MMRP Implementation of FSMs | 74 |
| 4.5 Summary..... | 77 |
| 5 The Learning Focused Pilot Experiment: Method and Results | 79 |
| 5.1 Method | 81 |
| 5.1.1 Location and Participants | 81 |
| 5.1.2 The Pilot study overall Procedure..... | 83 |
| 5.1.3 The learning stage of the experiment..... | 85 |
| 5.1.4 The Pre-questionnaire | 88 |
| 5.1.5 The Network Knowledge Test..... | 89 |
| 5.1.6 The Post-Questionnaire..... | 90 |
| 5.1.7 The Observation | 93 |
| 5.1.8 Reliability of instruments..... | 93 |
| 5.1.9 Data analysis..... | 95 |
| 5.2 Results..... | 96 |
| 5.2.1 Learning effectiveness | 96 |
| 5.2.2 Learning gain | 98 |
| 5.2.3 User Engagement and User Acceptance | 101 |
| 5.2.4 Correlation results concerning the relationships between UE, UA and network learning and knowledge | 106 |
| 5.3 Lessons from the pilot experiment..... | 108 |
| 5.4 Chapter Conclusion | 111 |
| 5.5 Summary..... | 112 |
| 6 The Technically Focused Experiments: Analysis and Result | 114 |
| 6.1 The Evaluation | 115 |
| 6.2 Data Collection..... | 116 |
| 6.3 Discussion, Finding and Results: | 119 |
| 7 Conclusions and Future Directions..... | 121 |
| 7.1 Summary of Achievements | 122 |
| 7.2 Revisiting the Contributions | 124 |
| 7.3 Future work..... | 129 |

| | |
|---|------------|
| Appendix | 132 |
| Research instruments..... | 132 |
| <i>A. 1 Consent Form.....</i> | <i>132</i> |
| <i>A. 2 Background Report</i> | <i>135</i> |
| <i>A. 3 Wireshark Original Lab Manual.....</i> | <i>136</i> |
| <i>A. 4 Wireshark Modified Lab Manual</i> | <i>147</i> |
| <i>A. 5 Post-test.....</i> | <i>156</i> |
| <i>A. 6 CG Engagement Survey.....</i> | <i>157</i> |
| <i>A. 7 MMRP Engagement Survey</i> | <i>158</i> |
| <i>A. 8 SPSS output.....</i> | <i>159</i> |
| References | 161 |

List of Figures

| | |
|---|----|
| Figure 2-1: A Class-Responsibility-Collaborator (CRC) index card. Reprinted from “A laboratory for teaching object oriented thinking” by Beck, K. and W. Cunningham. in ACM Sigplan Notices. 1989. ACM. | 15 |
| Figure 2-2: The revised CRC card. Reprinted from “CRC cards for product modelling” Hvam, L., J. Riis, and B.L. Hansen, Computers in Industry, 2003. 50 (1): p. 57-70 | 16 |
| Figure 2-3: Learning Cycle. Reprinted from “Learning technology and usability: a framework for understanding courseware” by Mayes, J.T. and C.J. Fowler, Interacting with Computers, 1999. 11 (5): p. 485-497 | 19 |
| Figure 2-4: A model for learning science through drama. Reprinted from “Drama and learning science: an empty space?” by Braund, M., British Educational Research Journal, 2015. 41 (1): p. 102-121..... | 20 |
| Figure 2-5: Virtuality Continuum. Reprinted from “A taxonomy of mixed reality visual displays “ by Milgram, P. and F. Kishino, IEICE TRANSACTIONS on Information and Systems, 1994. 77 (12): p. 1321-1329..... | 21 |
| Figure 2-6: Dalgarno and Lee model of learning affordances in 3-D VLEs. Reprinted from “What are the learning affordances of 3-D virtual environments?” by Dalgarno, B. and M.J. Lee, British Journal of Educational Technology, 2010. 41 (1): p. 10-32..... | 22 |
| Figure 3-1: The Conceptual Framework of the Mixed-Mode Role-Play (MMRP) | 37 |
| Figure 3-2: The Data-Driven Process | 38 |
| Figure 3-3: A Class-Responsibility-Collaborator (CRC) index card..... | 39 |
| Figure 3-4: MMRP CRC card structure | 41 |
| Figure 3-5: ER Model..... | 42 |
| Figure 3-6: Rendering the objects into the RPVE..... | 44 |
| Figure 3-7: Process of interaction between the objects | 45 |
| Figure 3-8: The MMRP’s System Architecture | 46 |
| Figure 3-9: The Instructor GUI subsystem | 47 |
| Figure 3-10: RPVE Generator subsystem | 48 |
| Figure 3-11: Simulator subsystem..... | 49 |
| Figure 3-12: Student’s GUI subsystem | 50 |
| Figure 4-1: The changes in the MMRP login screen..... | 55 |
| Figure 4-2: Student screen | 56 |
| Figure 4-3: Using USBWebserver to create the RPVE | 57 |
| Figure 4-4: Application Layer CRC Card..... | 58 |
| Figure 4-5:The Internet TCP/IP Layers. Reprinted from Kurose, J.F. and K.W. Ross, Computer networking: a top-down approach. Vol. 5. 2010: Addison-Wesley Reading..... | 62 |
| Figure 4-6: The lab software | 62 |
| Figure 4-7: Wireshark interface | 65 |
| Figure 4-8: The overall environment view. The humanized object is the Transport layer represented by an avatar. The other automated objects (Application, Link, Network, and physical layers) are represented by capsules. Each layer is surrounded by its protocols represented by cubes. | 66 |
| Figure 4-9: The object’s view where the Application role is in action and it is automated and controlled by the system. | 67 |
| Figure 4-10: The user’s view where the Transport Layer is the humanized object (i.e. the student’s role is to imitate the Transport layer)..... | 67 |
| Figure 4-11: The Humanized-object’s life cycle | 68 |

| | |
|--|-----|
| Figure 4-12: UoL | 69 |
| Figure 4-13: An example of the update info. | 70 |
| Figure 4-14: The three runs for the HG participant | 71 |
| Figure 4-15: The three runs for the SG participant | 72 |
| Figure 4-16: The three runs for the MG participant | 73 |
| Figure 4-17: The FSM RPVE. | 75 |
| Figure 4-18: An example of an FSM CRC card | 76 |
| Figure 4-19: S1 is the 'Humanized' object played by the student..... | 77 |
| Figure 4-20: An automated object | 77 |
| Figure 5-1: CCSEG | 81 |
| Figure 5-2: UJ Lab | 83 |
| Figure 5-3: Screen as seen by CG participant..... | 86 |
| Figure 5-4: Overall attitude scores of the two groups | 102 |
| Figure 5-5: A screenshot of an MMRP participant's screen..... | 105 |
| Figure 6-1: The overall view of the FSM RPVE | 115 |

List of Tables

| | |
|---|-----|
| Table 4-1: Scenario Table | 59 |
| Table 4-2: Main Object Table | 60 |
| Table 4-3: Subpart Table | 60 |
| Table 5-1: The self-report questionnaire completed prior to the experiment | 89 |
| Table 5-2: The Post-test | 90 |
| Table 5-3: User Acceptance items..... | 91 |
| Table 5-4: The Engagement Subscales | 92 |
| Table 5-5: FA items..... | 92 |
| Table 5-6: PA items | 92 |
| Table 5-7: AE items..... | 93 |
| Table 5-8: SA items..... | 93 |
| Table 5-9: Reliability of the attitude scales | 95 |
| Table 5-10: Descriptive statistics for the four groups on post-test network knowledge | 96 |
| Table 5-11: Descriptive statistics for the two groups in terms of post-test network knowledge | 97 |
| Table 5-12: Descriptive statistics for network knowledge, rescaled to percentage | 99 |
| Table 5-13: Descriptive statistics for the attitude scales | 102 |
| Table 5-14: Inferential statistics for the attitude scales | 103 |
| Table 5-15: Correlations between attitudes and post intervention network knowledge | 107 |
| Table 6-1: FSM table | 115 |

Chapter 1

1 Introduction

“To accomplish great things we must first dream, then visualize, then plan... believe... act!”

- Alfred A. Montapert

When I was teaching “Introduction to Networks” to undergraduate students, I perceived that one of the main challenges the students faced when taking this course was the difficulty in visualising and imagining how a network operates. To overcome this, teachers will often use videos and simulators that convey the idea of how the operating system divides the information into small chunks, encapsulates it inside headers and tails for each layer, labels each with a destination host address, and then sends them through the network.

But, in general, educators and teachers face significant challenges when introducing and explaining abstract concepts to their students. Students find it demanding to visualise abstract objects, and this makes it hard for them to understand such concepts. There are a number of different teaching strategies and methods that can be used in this regard, and familiarity with these is what initiated the primary investigations for this study.

As the actor in the learning process the student’s needs should be considered paramount. As Zembylas [1] emphasizes, this means taking care of the student’s emotions and motivations as

well as their cognition; all of these things are significant in science education. He pointed out the importance of linking cognitive activities and the emotions in science learning. Concentrating only on student cognition will reduce the student's appreciation of the elegance of science and its attachment to real life. Giving attention to emotional responses and cognition equally, builds the student's self-esteem and enables them to accept and comprehend the ambiguity of some science facts. Moreover, Zembylas indicated that socio-constructivism enhances the link between cognition and the emotions.

In light of this, Computer Based Simulation (CBS) is introduced as a computer based interactive environment that gives students the opportunity to explore a complex system and focus on their conceptual understanding of it[2]. CBS is expected to enrich the student's emotional responses and build their confidence in relation to their work, leading to the promotion of conceptual reasoning and thoughtful understanding[3]. CBS relates to a constructivism and scientific discovery learning system [4], which supports the Learning-by-doing theory. Learning-By-Doing covers simple approaches and steps for building educational simulations and instructional games for education that enhance the engagement of the student, giving them a sense of control over their experiments, and can provide the student with immediate feedback [5].

When analysing the literature, specifically that which regards learning support methods that use interaction, it emerges that several studies have pointed out the advantages of using role-play in education [6-12]. Role-play, which is a form of drama, is one of the techniques used to convey ideas and help the student overcome the difficulty of imagining how to relate learned concepts to the real world [9]. The participants interact according to their roles in a structured sequence in order to solve a task collaboratively. This can help the students to explore the subject from several points of view. It is also a form of simulation that enables the students to become more immersed in the subject and thus more motivated to learn [4]. Role-play is a participatory method that has

been used to teach subjects in the area of Computer Science. For example, McGuffee [13] used it when teaching Reliable Data protocols.

Role-play also supports collaboration, which is another key activity that can enhance students' cognitive understanding and critical thinking. This is due to its ability to expose students' different backgrounds and ways of thinking and understanding to each other [14]. Nowadays, regarding the impact of new technologies, the orientation in education is towards collaborative and shared space learning [15]. Collaborative learning can save time and reduce the amount of resources required in an educational process. Sooksomchitra [16] showed how utilizing computer-supported collaborative learning (CSCL) provides a sharing environment that very effectively supports the students in embracing life-long learning. 3D Virtual Environments are useful platforms that have the effect of engaging students in immersive learning environments [17]. A shared environment such as this can expand knowledge amongst student peers and have a greater impact on the quality of their education.

Aiming to enhance students' learning by utilising the previously presented methods, this thesis proposes a pedagogical conceptual framework that generates a role-play task whereby a student can embody and imitate a real, existing, system object's behaviour in a role-play activity deployed in a 3D virtual environment. The research aims to investigate an approach to producing such a framework and model as a template to be repurposed and reused for any topic that entails message-passing role-play scenarios. A prototype will be implemented in order to validate this framework. In addition, the learning benefits of this approach will be fully investigated in a number of empirical experiments.

1.1 Motivation

Role-play is a teaching method that has been proved to be successful – more especially, role-play in a virtual environment. While investigating the use of role-play within virtual learning

environments, I found that there are various studies that have focused on this and that many researchers have attempted to develop role-play activities for the virtual world. Gregory & Masters [7] set up a participatory role-play activity within the Second Life environment; this was based on the “Six Thinking Hats” framework, proposed to investigate the enhancement of traditional teaching techniques through the application of virtual worlds. Another study by Cho et al. [18] investigated the influence of several factors, such as age and gender, on physical and social presence; these can affect the interest in, and advancements attained, in virtual role-play. In her thesis, Dracup [19] recommended certain criteria related to role-play design after studying the impact of student engagement in the stories (scenarios) she developed on learning. Jimenez-Diaz et al [20] introduced ViRPlay3D2; which is a virtual environment for role-play activities based on videogame technology. It enables the users to mimic object oriented (OO) objects when interacting with each other - in order to understand the execution of an OO application. Furthermore, several studies have claimed that using computer simulation helps students to understand complex ideas, although implementing simulations that have numerous unnecessary details will overwhelm and confuse the students [3] [21-23]. Smetana and Bell provide a review of such studies, i.e., those that involve computer simulations which support science instruction and learning [24]. Gardner et al. [25] created the +Space application as a simulation tool which supports role-play in 3D virtual environments and is based around a structured template and a sequence of activities that are facilitated by an online moderator. Joshi [26] implemented a system that maps tasks authored in LAMS¹ (a tool for creating collaborative learning activities²) onto a static virtual learning environment. Both projects introduced a way of deploying structured role-play simulation for learning in 3D collaborative environments. However, there are limitations to the work that has been done, so far, in this area. The major outstanding problems associated with creating virtual

¹ Abbreviation for “Learning Activity Management System”

² <https://www.lamsfoundation.org/>

learning environments are: finding simple and practicable ways to model and represent abstract concepts as 3D visual objects; and implementing serviceable facilities that support the interaction between student and student, between students and their instructors, and the represented objects. Also some projects have focused only on one topic: e.g., ViRPlay3D2 is exclusively for teaching object-oriented design.

With respect to the above, this thesis presents an approach to the creation of a role-play simulation in a role-play supporting virtual environment (RPVE). This approach harnesses the advantages of 3D virtual environments in an effective way, in order to benefit the student's learning in terms of their understanding of abstract concepts, and is supported by evidence from my experiments. Moreover, this approach is generalized and thus extends the previous studies by offering a system that can be applied to a wide range of topics involving message-passing role-play scenarios. The approach is presented within a conceptual pedagogical framework.

1.2 The Big Vision

The vision behind this research is to discover a generalized method that facilitates the construction of learning scenarios and renders them as message-passing role-play activities. The first step is to investigate the use of immersive technologies such as 3D virtual environments (3D VEs), a number of different learning designs and teaching strategies (e.g., role-play), and emulations in relation to the structuring of collaborative learning activities in support of the Learning-by-Doing methodology. This is in order to present a generalized pedagogical approach which better harnesses the learning affordances of combining two methods widely used to enhance students' learning: role-play and simulation in 3D VEs.

In relation to this, the next step is to create a novel, conceptual pedagogical framework that will generate role-play activities to simulate message-passing in a virtual environment, wherein mixed-mode simulation, employing both fully automated objects and humans emulating the

functionality of objects, is supported. In other words, these activities can be deployed in a role-play virtual environment (RPVE) in order to assist students to become more immersed in the learning process and to provide the students with an alternative point of view to the one they would naturally have. In this context, each activity involves humanizing a ‘non-human’ object. This means that the students embody and imitate an (often abstract) object that is part of a technological system. The intention is that the students are enabled to actually become (within the VR environment) a part/object of the system that they are studying. This occurs in a virtual world and the aim is to support the student’s ability to imagine and visualize such objects, causing them to be more engaged with their learning, enhancing their conceptual understanding, strengthening their reasoning when solving problems related to the topic area, and reinvigorating their interest in learning.

In addition, the intention behind employing a virtual environment is to use simple metaphors that are more readily accessible to the student’s mind and that are not encumbered by unnecessary details. Including too many details might have a negative effect on the students’ comprehension and possibly distract them. Constructing realistically modelled objects that behave as if they are real world objects would lead to there being no entirely abstract elements [27, 28]. Here, Dalgarno & Lee’s [29] conceptual model concerning learning in 3D virtual learning environments, which includes the characteristics of representational fidelity and learner interaction (believed to enhance the learning benefits of this kind of environment), has been borne in mind when creating our virtual learning environment and attempting to make the most of these learning benefits/affordances.

Furthermore, it was resolved that the research should address some of the questions and hypotheses put forward by Dalgarno & Lee concerning the capabilities and features of virtual learning environments, especially with respect to the following:

“How can learning tasks be carried out within a 3D Virtual World (VW) designed to meet specific, desired educational outcomes: e.g., the acquiring of content knowledge in regard to particular topic domains, or generic skills such as teamwork and problem solving?”

Additionally, for usability purposes and to avoid the problems which can result from the use of learning technology, we embraced the Mayes & Fowler approach [30] when designing our learning tasks. They described the learning process as a cycle of three stages: Conceptualisation, Construction, and Dialog/Application.

With respect to the above, a prototype constructed on the basis of the proposed framework was implemented as a model to support empirical, experimental phases aimed at validating the research hypothesis and the framework.

1.3 Hypotheses

The research hypotheses are divided into two elements: technical and learning. This is because this study was concerned with two distinct areas: Computer Science and learning.

Technical element:

1. It is possible to create a generalized conceptual framework for the creation of message-passing role-play activities which involve mixed-mode roles whereby some of the object-roles are ‘played’ by the system and some are played by the user – that is, they are ‘humanized’. This can be achieved by adopting a data driven approach such that the data:
 - 1.1. supports the creation of a role-play virtual learning environment – the objects of which are rendered on the instant (as required), at run-time; and
 - 1.2. supports the creation of mixed-mode role-play (MMRP) activities and interaction between the environment’s objects.

In particular, the data can be represented for retrieval in such a way that they allow the framework to be reconfigured so that the system can be reused for a number of purposes for which a message-passing scenario is relevant.

This advances the state of the art in the following ways:

1. The addition of the generalization concept.
2. The development of the approach used in order to achieve this aimed-for generalization.

Learning element:

2. Enabling a student to embody an object taking part in a message-passing role-play activity with other objects in a virtual environment leads to better learning outcomes and the gaining of a more thorough understanding than using other computer-based approaches. This is achieved through enhancing the learner's learning engagement:

- being concerned with all the qualities of an experience" [31].
- Association with the role of the embodied object.

This advances the state of the art in the following way:

It introduces the mixed-mode approach to implementing role-play activity tasks - whereby the student, acting as an object, interacts with the automated objects within the 3D virtual environment in order to complete the assigned task.

In summary, we seek to show that it is possible to generate role-play activities via the proposed framework and that this framework can operate across three levels of generalization:

1. Humanized object generalization: The ability to change which object is humanized with respect to the same scenario.
2. Learning task generalization: The ability to change which scenario is 'played' with respect to the same subject.

3. Subject generalization: The ability to change the subject/topic being taught.

And this is all achieved by utilizing a data-driven approach, whereby none of the distinct levels of generalization require changes at the programming level. Only changes to the underlying data and database are made.

1.4 Contributions

The major objective of this research is to investigate the learning effectiveness of message-passing role-play activities offered in a virtual environment. Thus, the contributions made by this research are as follows:

1. The construction of a generalized computational framework (MMRP) that generates message-passing role-play activities within an RPVE using a data-driven approach to support the desired generalizations (Chapter Three).
2. The implementation of a prototype system that deploys the MMRP model in order to generate network role-play activities in an RPVE – in order, in turn, to explore the learning affordances of VR for role-play. This prototype is complemented by learning scenarios scripted to be executed over four different stages – in order to validate the flexibility of the model and its levels of generalization (Chapter Four).
3. The evaluation of the learning affordances of the role-play activities generated for the RPVE, as well as those of the framework's levels of generalization. This was achieved by comparing the MMRP activities of this framework to other computer-based approaches in relation to the various kinds of modifications made to the data-base driving the system (Chapters Five and Six).

Beyond the main contributions, the study also offers one secondary contribution:

4. An enhanced CRC³ card structure for generating role-play activities (Chapter Three).

1.5 List of publications

Some elements of the contributions described in this thesis have been presented in the following publications:

1. **Enas Jambi**, Michael Gardner, and Victor Callaghan. "Supporting mixed-mode role-play activities in a virtual environment." *2017 9th Computer Science and Electronic Engineering (CEECE)*. IEEE, 2017.
2. **Enas Jambi**, Michael Gardner, and Victor Callaghan. "A Generalized Pedagogical Framework for Creating Mixed-Mode Role-Play in Multi-User Virtual Environments." *International Conference on Immersive Learning*. Springer, Cham, 2019.

1.6 Thesis Outline

This thesis is organised as set out below:

1. **Chapter One** (this chapter) introduces the motivation underlying the research, the vision derived from this research, the hypothesis, and the contributions made by this research as well as the publications which have arisen from it.
2. **Chapter Two** presents the learning theories relating to this work and, more generally, the use of virtual reality in education. It focuses on theoretical views on the use of role-play and on the employment of role-play within virtual environments in particular. In addition, this chapter investigates the technicalities involved in deploying role-play activities within a VR environment and the data-driven approach which was employed to support the aimed-for generalizations.

³ Abbreviation for 'Class- Responsibility- Collaborator', introduced in more detail in 2.1.1.

- **Chapter Three** introduces the Mixed-Mode Role-play Framework (MMRP), a conceptual architectural model for generating message-passing role-play learning activities to be deployed in RPVEs. This chapter presents the use of CRC cards as an approach to data organization - to create the data that are employed to generate the message-passing role-play learning activities. The MMRP consists of a number of subsystems; these are: *Instructor GUI, RPVE Generator, Simulator, and Student GUI*.
- **Chapter Four** starts by describing the implementation of the MMRP subsystems in detail; this implementation is based on the conceptual architectural model defined in the previous chapter. Then, it describes the proof-of-concept hypotheses-validation experimental framework, which consists of two main phases: the Network Learning topic and the DB topic. The evaluation of the experimental framework was achieved by a mix of quantitative and qualitative instruments, also presented in this chapter.
- As the research hypothesis consists of two elements (learning and technical), the results and the analysis of these are introduced in **Chapter Five** and **Chapter Six**, respectively. Both chapters describe the data collection, the process of analysing these data and the outcomes (i.e., the results). In addition, in each chapter there is a discussion of the results and findings and their wider consequences on the present study.
- Finally, **Chapter Seven** concludes the thesis by presenting a summary of its achievements and discussing the main educational and technological issues that have arisen from the research. It then highlights future research directions and completes the thesis by outlining an image of the future of the field.

Chapter 2

2 Literature Review

“Condemnation before investigation is the highest form of ignorance.”
- Albert Einstein

The previous chapter introduced the main motivation behind this research, which is to find a method to support students’ understanding of abstract concepts whilst also keeping them immersed and engaged in the learning process. Examining this motivation, role-play can be seen to be one of the most effective learning methods in science education [13]. Moreover, the use of 3D virtual environments benefits student learning and supports their engagement in the learning process [17, 32]. Several studies have sought to deploy role-play activities in 3D virtual environments in order to study the impact of combining these two methods for student learning – one such is that of Jimenez-Diaz et al and more examples are introduced later in this chapter [20].

This chapter provides an investigation of the literature and background studies related to the topics on which this research is focused, such as role-play in science learning, the virtual environment and role-play activities within virtual environments. We explore these technologies from both the technical and the pedagogical points of view. This investigation is followed by a description of the data-driven approach as the intended tool to serve the desired generalizations. This chapter also examines some of the learning theories and views regarding pedagogical drama (another term for

pedagogical role-play) frameworks. Finally, the chapter concludes by identifying the limitations of the related studies, which this research seeks to address.

2.1 Role-Play in Science Education

Even though science educators generally prepare well before embarking on any course of lectures, many have noticed that their efforts to convey the necessary information are often, simply, not sufficient. After a while, students can become disaffected and lose their concentration. Thus, there is a need to make classroom activities more interactive by using active learning methodologies [33, 34]. Role-play is one of the learning methods that has long been used in the educational field to encourage students to become more active in the classroom by solving a task or problem collaboratively in a structured sequence [35]. The collaboration between the students has the potential to enhance the learning outcomes as well [36-38]. In addition, role-play can help students to explore the subject from several points of view, interact from the first-person perspective and grow their cognitive abilities [39]. Role-play (or pedagogical drama) is a participatory method employed as an exercise in many pedagogical fields: e.g. language learning, physical therapy, engineering, social sciences, marketing, accounting [40-46]. All previous studies on the topic emphasize the learning affordances of role-play such as:

- Improving students' attitudes towards the study topic.
- Providing the students with the opportunity to express themselves, share their opinions and use their imagination.
- Supporting the process of preparing the students to become professional in their field and become more ready to deal with real-world situations.

Role-play has also long been used to teach computer science topics [47]. McGuffee's [13] role-play activity for teaching Transport Layer protocols has been mentioned as one example. However, he is not the only computer science educator to use role play in his classes. Andrianoff & Levine

introduced three role-play exercises which could be used to explain the concepts of object-oriented (OO) design [48]. The exercises they utilised included scripts to be performed by students that involved simple (physical) actions and the referring of these actions to concepts or methods within the topic of object orientation (in programming). Several teachers have reported receiving positive feedback after testing these exercises in their classrooms; thus evidencing the effectiveness of this pedagogical technique. A typical comment was “It really humanizes the programming”.

The studies cited above represent examples of the way in which role play can be used to simplify abstract ideas and concepts and make them more concrete, visual and comprehensible. However, whilst each study was focused solely on its own field, they do provide case-study material, including role-play scripts and scenarios that can be applied to the creation of role-play activities in the classroom.

2.1.1 CRC Card Method

One of the techniques employed in role-play activities is the use of Class-Responsibility-Collaborator ‘CRC’ cards. Bellin [49] illustrated the structuring and writing of CRC cards as a problem solving technique. The CRC cards presented in Figure 2-1 were used by Biddle & Noble [50] in defining a role-play environment, specifically to describe the interaction between the user and the system. An approach based on the use of CRC cards was introduced by Beck & Cunningham [51] for teaching the concepts of OO and pre-existing function-rich facilities to programmers. The cards were employed to characterize the objects by class name, responsibilities and collaborators; this approach benefited the learners since it allowed them to explore the objects in a visual way as part of a team activity.

Beck & Cunningham [51] used index cards to distinguish the roles within their role-play system. After splitting a card into two columns, they would specify the user's responsibilities on the left and the system's responsibilities on the right. This format highlights the functional requirements related to the system and its behaviour.

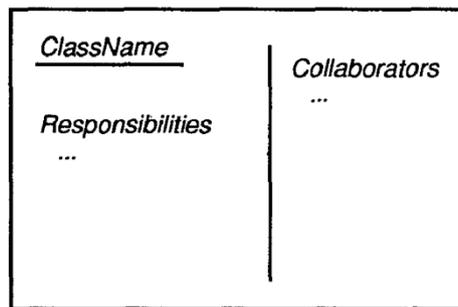


Figure 2-1: A Class-Responsibility-Collaborator (CRC) index card. Reprinted from "A laboratory for teaching object oriented thinking" by Beck, K. and W. Cunningham. in ACM Sigplan Notices. 1989. ACM.

Ambler [52] introduced a simple way to produce CRC cards by following the steps laid out here:

- **Determine the classes;** classes are the fundamental blocks of the application. Preferably there should be three to five main classes. Sometimes cards (classes) that represent actors in the real world are included.
- **Determine the responsibilities;** determine and represent what each class does and the information that the system creator wants to maintain about it. A class's responsibility is represented by specifying the nature of its collaboration with another class.
- **Define the collaborators;** a class must collaborate with other classes in order to get tasks done. Collaboration constitutes either a request for information or a request to perform a task. In the process of determining class collaborators, there is a possibility that new responsibilities which must be taken on by other classes may be discovered along with, perhaps, the need to create a new class or two.

However, Hvam et al [53] introduced a modified CRC card for product modelling, as shown in Figure 2-2. They added more fields to the structure of the CRC cards in order to enhance the

links between the classes and they made it easier for the developer to implement the system because they introduced the use of inheritance and ‘has a’ relations. The additional fields were: aggregation, generalization, and knows/does.

| Class name | Date | Author |
|------------------|------|----------------|
| Responsibilities | | |
| Aggregation | | Generalization |
| Superparts: | | Superclass: |
| Subparts: | | Subclass: |
| Sketch: | | |
| Knows/Does | | Collaborations |
| Knows | | |
| | | |
| | | |
| | | |
| | | |
| Does | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Figure 2-2: The revised CRC card. Reprinted from “CRC cards for product modelling” Hvam, L., J. Riis, and B.L. Hansen, *Computers in Industry*, 2003. 50(1): p. 57-70

In light of this work, my research is intended to extend study into the learning affordances of role-play as specifically rendered in a virtual environment, but in a more generalized way. This present study proposes a generalized method for structuring role-play activities, based on message-passing scenarios, to be deployed across several fields/subject areas. This represents an advance in relation to previous studies that were exclusive to a particular subject. This generalized approach comprises:

- A universal method for structuring the data to be applied to the corresponding structuring of role-play scenarios.
- A tool for rendering this role-play scenario as a role-play activity within a virtual environment and controlling the interaction between this environment's objects.

2.2 Learning Theories & Learning Design

Before looking into one of the main issues involved in the creation of a pedagogical framework - that of determining which is the most efficient learning approach to be used to deliver the best learning outcomes - it is necessary to review the underlying pedagogical theories. According to many educational theorists, instructivism, constructivism, and socio-constructivism are the most significant theories in use today [54]. There is much debate among researchers concerning which of these to employ in pedagogical frameworks. These theories can be defined as follows:

- Instructivism - “The theory of instructivism maintains that knowledge should be transferred directly into the mind of the learner from the instructor. [55]”

Instructivism encompasses the traditional learning approach, where the teacher is the centre of the learning process, not the student [56]. It is the teacher's responsibility to obtain the knowledge, then reinforce it and transfer it to the student via traditional learning approaches, i.e. lecturing.

- Constructivism – “The constructivist theory is rooted in the idea that the learner actively constructs his/her knowledge, not that the latter is passively acquired from without”. [55]

The advocates of this theory believe that personal knowledge is constructed from self-learning to create the learner's own model, not perceiving or understanding the true nature of things. [57]. The learning process is shifted from a teacher-centred process to a student-centred process, where the teacher's role is to create situations (i.e. learning activities) for the students, then to guide them

rather than hand out the information [56] [58]. It is important that the student has the motivation and willingness to learn in order to achieve successful learning and understand the concepts[59].

- Socio-constructivism – “An approach to learning according to which knowledge acquisition is facilitated by the inclusion of the social field of the learner” [60]. It “emphasizes the importance of culture and context in giving meaning to what happens in society and constructing knowledge from this understanding”. [55]

Socio-constructivism is one of the most recent learning theories and is derived from constructivism [60]. Hein [57] emphasized that learning is a social activity, and that interaction with other human beings is recognized as a fundamental aspect of learning. The learners construct their own version of truth, influenced by their environment and their interactions with members of society who have superior knowledge [58]. Wertsch [61] adds that children also learn from their interactions with peers, in addition to adult influence. In this approach, the teacher is replaced by a facilitator who assists the learners to get to their own understanding of the content [61] [62].

Looking at the audience targeted by, and the learning outcomes anticipated for, a framework is the most effective way to determine the best approach to be used. Mayes & Fowler’s framework [30] suggested using all three approaches by means of a cycle. The learning cycle shown in Figure 2-3, introduced by Mayes & Fowler, describes learning as a continuous process of refinement of understanding. The cycle begins with the “conceptualisation” stage that involves a match between the learner’s pre-existing knowledge and new understandings acquired from an exposition. The second stage is “construction”. This involves the process of constructing and combining concepts through employing them in the performance of meaningful tasks. Finally, the last stage is “Application”, which can be best characterised in education as ‘Dialogue’. This stage involves the testing of conceptualisations, i.e. the understandings, of the learner. Each stage can be mapped to three kinds of differentiated courseware in the following order:

- *Primary*, such as the live lecture, or presentations via the traditional media of print and video, to provide the learner with a primary exposition of the subject.
- *Secondary*, such as learning tasks and activities that engage the learner at a conceptual level.
- *Tertiary*, such as the dissections and the mutual offering of opinions that are crucial to the opening up of communication and a dialogue between the teacher and the learner. This also involves the ‘re-use’ of the previous experience of other students.

Mayes & Fowler concluded in their study that the framework they presented supported the use of emerging new technologies in education by providing a tool which could integrate these new technologies into learning tasks.

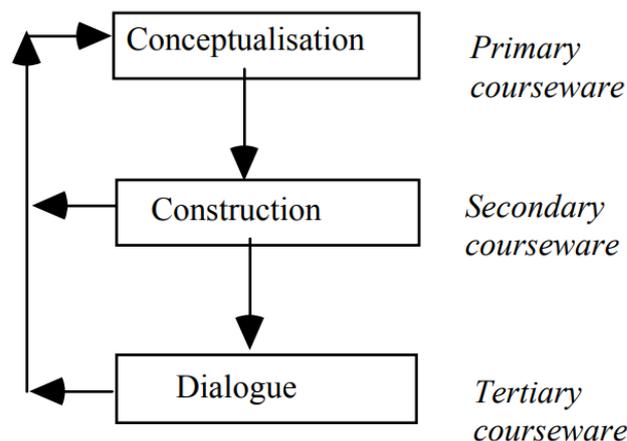


Figure 2-3: Learning Cycle. Reprinted from “Learning technology and usability: a framework for understanding courseware” by Mayes, J.T. and C.J. Fowler, *Interacting with Computers*, 1999, 11(5): p. 485-497

Role-play, which is central to the scope of this research, is an example of *Secondary* courseware because it supports the learner’s task-based learning activity. Role-play has been defined as ‘behaving in accordance with a specified function’ in The Concise Oxford English Dictionary (1978 edition) [63] and is considered to be a powerful tool for learning. Such learning is often based on learners being made to engage mentally and physically in a trajectory activity, acting in interchangeable roles according to a scenario script. However, Braund [6], in his research, points out that there is a lack of role-play activities in science lessons in general. Thus, he introduced his

theoretical model for supporting the use of drama in science education, which is based on Brook's 'empty space' theory of drama [64]. Braund's science learning model can be defined as a process of rationalizing between two worlds of knowing: the learner's world and the scientists' knowledge. This model defines two levels for viewing how differing activities reduce the distance between the learner's world of knowledge and the scientific world of knowledge. The first is the general level, where the empty space between the two worlds is filled with learning activities that are intended to reduce the amount of cognitive dissonance and so close the gap between the two worlds. The second level, and one of the focuses of this research here, is one whereby drama can be seen as a means to help fill the 'empty space' between the two worlds, as shown in Figure 2-4. Braund claimed that his model can proficiently support a 'constructivist approach' to learning by supporting the student's engagement and interest in the subject matter.

Further investigation into the learning theories correlating with the present study's research direction, it can be seen that virtual worlds which engage the learner as a 'player' solving problems and engaging in quests - one of the digital learning game styles - are associated with the new learning theories, including constructivism and social constructivism [65, 66]. Hence, the following section introduces the virtual environments and gives examples of using such spaces for role-play activities.

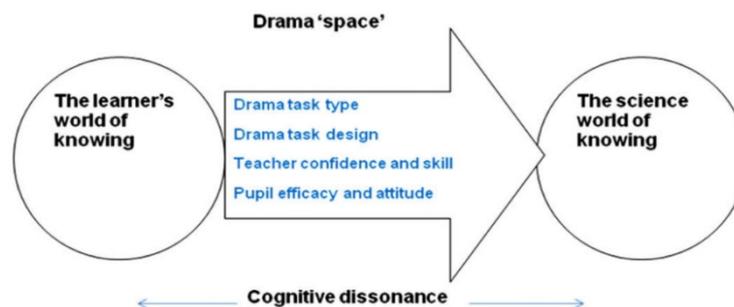


Figure 2-4: A model for learning science through drama. Reprinted from "Drama and learning science: an empty space?" by Braund, M., *British Educational Research Journal*, 2015. 41(1): p. 102-121

2.3 3D Virtual Environments

What does the term ‘Virtual Reality’ actually mean? Milgram [67] introduced a taxonomy notating the virtuality continuum from the completely real to the completely virtual, as shown in Figure 2-5

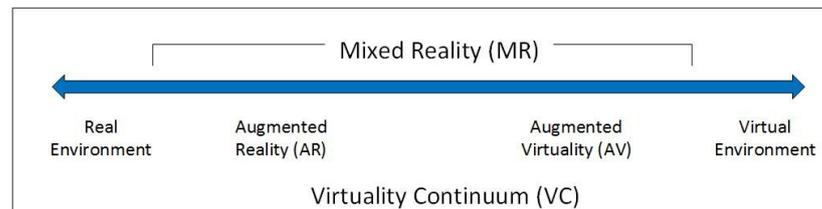


Figure 2-5: Virtuality Continuum. Reprinted from “A taxonomy of mixed reality visual displays” by Milgram, P. and F. Kishino, *IEICE TRANSACTIONS on Information and Systems*, 1994. **77**(12): p. 1321-1329

This shows the virtual environment as the opposite end of the continuum to the real one. The simplest way to describe such environments is that they are ones wherein the objects are represented by graphics and exist in essence or effect, but do not exist corporeally or actually. Bainbridge [68] presents the term ‘virtual world’ which refers to the environments generated electronically by a computer that all visually mimic a complex real environment where people can be represented by avatars that can interact with one another and with virtual objects.

There are many studies which have been directed towards proving how the use of interaction in 3D virtual reality environments has considerable advantages in relation to learning abstract concepts across many disciplines such as computer science, engineering and architecture [69-74]. Mikropoulos & Natsis [75] presented a review of 53 studies related to the educational applications of Virtual Reality (VR) in which one of their findings was the positive attitude of users towards the utilisation of virtual reality in educational settings. Hsin et al. [76] reviewed some empirical studies which were focused on how new technologies impacted children’s learning. They pointed out that these technologies influence children cognitively, socially, emotionally and physically in positive ways. However, most of the reviewed articles did not explicitly address the learning theories underlying these studies.

Dalgarno & Lee [29], investigated the employment of 3D virtual worlds within pedagogical frameworks by reviewing and analysing several applications of such environments. They highlighted the learning affordances of using virtual learning environments (VLEs). A VLE is a virtual environment that is built on a certain pedagogical model; involves one or more educational objectives; aids the users to experience, virtually, the things that they (the learners) could not experience in the real world; and which leads to intended learning outcomes [75]. Dalgarno & Lee's model of learning in 3-D VLEs is presented in Figure 2-6; this indicates the potential learning benefits of these environments, which are: accessible spatial knowledge representation, experiential learning, engagement, contextual learning and collaborative learning.

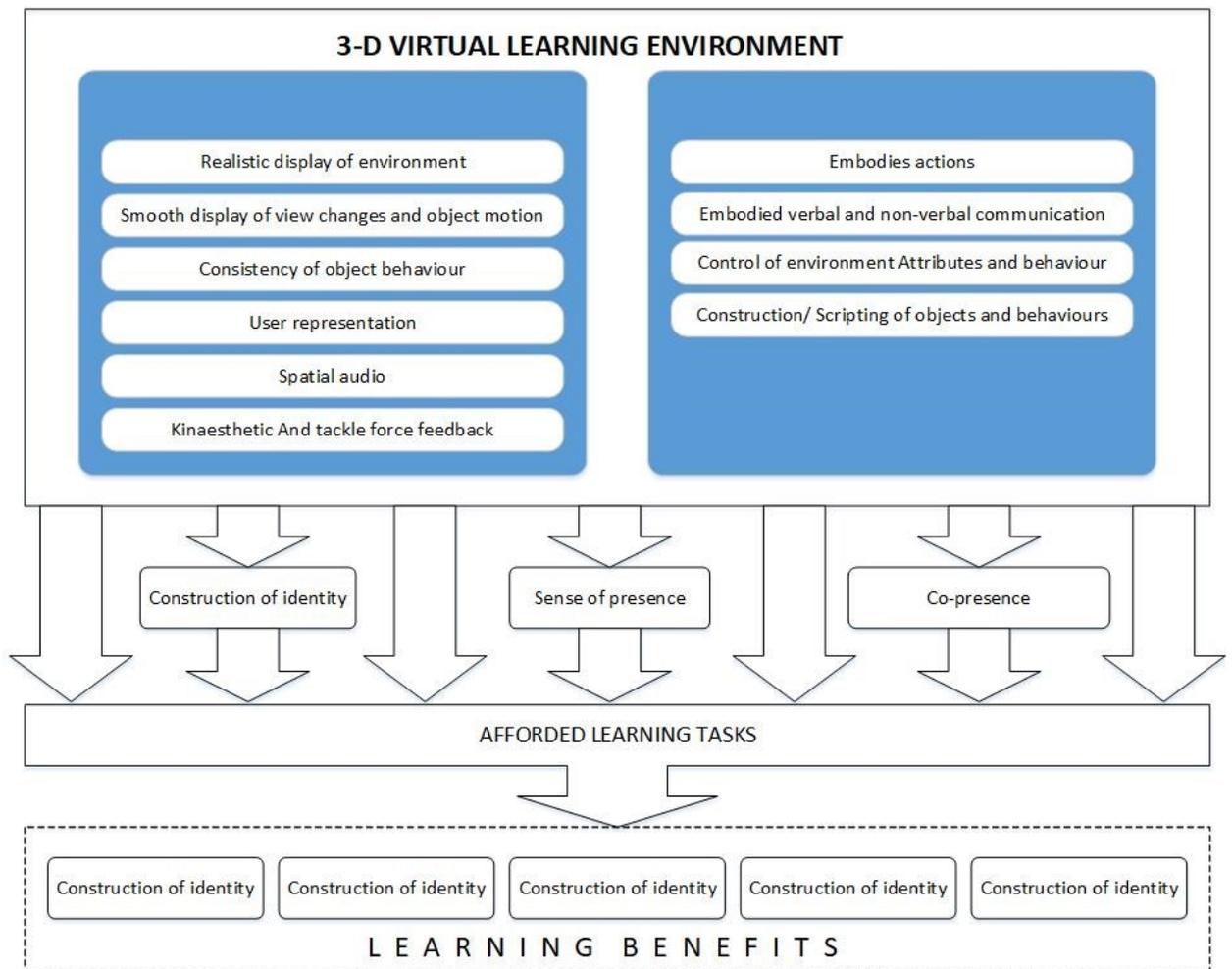


Figure 2-6: Dalgarno and Lee model of learning affordances in 3-D VLEs. Reprinted from "What are the learning affordances of 3-D virtual environments?" by Dalgarno, B. and M.J. Lee, *British Journal of Educational Technology*, 2010. 41(1): p. 10-32

Prasolova-Førland [77] concluded that the advantages of using these virtual environments in education are various and include:

- They can be used in the manifestation of difficult scientific concepts.
- They can enhance the learner's engagement.
- They support e-learning and remote collaboration between students.

To highlight the effectiveness of implementing these virtual worlds and how the educational aspects of the technology can be fore-fronted in these implementations, McCaffery et al. introduced a mechanism for developing virtual worlds platforms [78]. They argued that building in a programmability factor within virtual worlds provides them with the ability to handle modification or extension. Moreover, programmability can provide the users with control of the environment and also control of the interactions between themselves within the environment and with the particular simulation being enacted. A general/universal approach to programming the environment and handling the interactions within it, in accordance with particular role-play scenarios, is what is required to achieve the level of generalization that this study aims for.

Virtual worlds facilitate each and every student being engaged in an activity while the teacher monitors and supervises them all at the same time. Such a situation is likely to bring huge benefits to many educational processes. It also represents an opportunity for distance learners to participate [79]. Additionally, Sooksomchitra [16] showed how utilizing computer-supported collaborative learning (CSCL) provides a shared environment that supports, more effectively, the students in adopting life-long learning. Such a shared environment distributes knowledge among peers and has a great, positive impact on the quality of education provided.

There are many studies regarding the learning advantages offered by the new technologies, Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (XR) as used in education (which can be referred to, collectively, as 'immersive learning' technologies). The Immersive

Education Lab Research Group at the University of Essex have proven some of the benefits of such technologies in several studies [32, 80-86]. Immersive education is defined as giving “participants a sense of ‘being there’ even when attending a class or training session in person isn't possible, practical, or desirable, which in turn provides educators and students with the ability to connect and communicate in a way that greatly enhances the learning experience”[84].

In light of all this positive evidence presented relating to the learning affordances of 3D virtual environments utilized in the learning process, a narrowed investigation focused on deploying role-play activities in such environments is presented in the next section.

2.3 Role-Play in the 3D Virtual Environment

Focusing on role-play learning activities, there have been several attempts to digitize and transpose role-play activities into the virtual world environment [20, 25, 26].

Transposing a role-play into the virtual world allows all the learners to be simultaneous participants in learning activities, and/or to be members of groups performing the same activity in parallel with other groups - instead of there being one group enacting the exercise and the rest of the class observing. For example, +Spaces [25] is a framework developed to focus on political topics and the dynamics of public opinion about these topics, using virtual world communities. The researchers wanted to ‘implement a role-play simulation in 2D and 3D environments based on a structured template and a sequence of activities that are facilitated by an online moderator’. One of the concerns these researchers had was how to make the process visualizable by the users/learners, and this resulted in a focus on the process rather than simply the outcomes. In response to this issue, they came to support the ‘glass-box’ approach to discovery learning. The glass box approach allows learners to examine the underlying assumptions that inform the role-play scenario being used [87]. +Space connects many platforms (Facebook, Twitter, Blogger, and Open Wonderland) to its services (a recommender/reputation system for selecting participants and

a data analysis service) across the integrated applications (polls, debates, simulations) that it supports. These implementations rely, for their 3D virtual world activities, on the tools that are provided by the platform Open Wonderland⁴. The sequenced role-play was facilitated by an online moderator. Included in their future plans is an intention to build on their work by utilizing the snapshot feature provided within Open Wonderland in order to analyse the learning design specifications and map them so that they can be represented within collaborative 3D space.

The learning design is the generative description of the learning process. A comprehensive learning design will involve the learners, the learning objects, the environment and the interactions between the learners and the objects within the learning environment [88]; this is as Britain [89] describes when creating a learner workflow by the Instructional Management Systems (IMS) Global Learning Consortium⁵. IMS-LD provides a model which describes the structure of tasks and activities and their assignment to roles as ‘Learning Design’⁶. Then, the LD is provided as a platform that can be shared and re-used. The complexity of the underlying model employed by the IMS-LD and its requirements has often led educators to use Learning Management Systems (LMSs) such as LAMS to help them author learning strategies [90]. The Learning Activity Management System (LAMS) is an editor based software system for authoring (designing, managing, and delivering) sequenced online collaborative learning activities, according to the Learning Design ‘LD’ specifications, by use of drag and drop facilities [91]. After a model has been implemented, it may then be generalized to become a set of templates that can be reused and modified by other educators for a variety of other courses [92]. There are many shared learning designs offered via the repository of the LAMS Community.

⁴ <http://openwonderland.org/>

⁵ <http://www.imsglobal.org/home>

⁶ “‘learning design’ (small ‘l’, small ‘d’) when we are talking about the general concept and ‘Learning Design’ (Capital ‘L’ and ‘D’) when referring to the concept as implemented in the IMS specification” according to Britain [88].

In 2010, a study was conducted aimed at structuring virtual world educational activities using LAMS as the basis for this structuring, but offering the system so constructed as a separate software tool [93]. LAMS provides an external sequence guideline and instructions for students so that they can progress with their tasks within the virtual world. OpenSimulator (OpenSim)⁷ was the platform that they used for building virtual worlds. There was also learning support through links to external worked example videos. Students could submit their work through the ‘Submit File’ activity for assessment. The usual approaches to assessment were employed, such as teachers walking around the students (using the system) in the classroom. The major challenge the researchers of the study faced with this system was that once the student was engaged in a task in the VW, they would be reluctant to go back and refer to LAMS in order to find out how to proceed to the next task. The researchers provided several solutions to this problem, for example, they integrated Adobe Flash display into OpenSim so that the LAMS sequences could be displayed as a wall within the VW. Joshi [26] in his project in the same area provided another and more practical solution by using the snapshot facility of Open Wonderland to integrate LAMS sequences into the VW.

Joshi [26] focused his work on the field of education and learning design as this relates to virtual worlds. Due to the difficulty involved with authoring learning tasks in the 3D virtual world, he proposed a mechanism for authoring learning activities in a 2D learning management system such as LAMS then importing and deploying the resultant file into a 3D virtual platform - which was Open Wonderland in his project. He succeeded in mapping some of the LAMS tasks into a predefined designed space in a 3D virtual environment. Although his system was claimed to be generally applicable and fully functional, it was built on static predesigned objects and spaces that were the only ones available to be deployed in the virtual environment. There is, therefore, the

⁷ http://opensimulator.org/wiki/Main_Page

prospect of additional work to be usefully undertaken to enhance the effectiveness of that system to make it more dynamic. This work might result in the virtual environment being more comprehensively customised by the learning design creator i.e., the objects and spaces might be created specifically for the learning tasks.

From a didactic point of view, an article in the Australian Journal of Teacher Education [94] criticizes a study conducted with regard to teaching practices related to role-play in virtual classrooms, stating the main limitations of that research and some features of it which could form the basis of improvements/future work. One of the main limitations of the system proposed in the research that the journal article reported on was the use of text-based rather than audio-based communication; this (it was argued) limits the experience of immersion and the degree of realism encountered. Another limitation identified was the length of the experiment (in terms of the time allocated to the experimentation) and the unprofessional illustrations used within the virtual classroom that affected the overall judgment of the experience by the participants.

Although these previous studies have indeed involved the use of role-play in the learning context, the type of role-play they focused on was not that associated with interactive-drama based digital games. In contrast, the type of role-play that this present study focuses on is, indeed, associated with planned digital drama - drama that involves role creation and narrative story generation and which is enacted through technologies and digital spaces [95].

Jimenez-Diaz et al. [20] transposed their pedagogical approach, aimed at using role-play for teaching object orientation design patterns, into a Role-Play Virtual Environment (RPVE) by applying the ViRPlay3D2 platform whereby students could mimic object interactions within a software system via a role-play activity. In that environment, the students visualize problems and situations and play collaboratively in a simulation which represents the interaction among OO objects in the course of an execution of an OO application. The novelty of this work was underlined

by its use of visual metaphors for the fundamental abstract concepts derived from the OO paradigm: classes, objects, and message passing. These researchers utilised a user-driven approach when deploying role-play scenarios. The employment of a user-driven approach implies that the user has control over the role-play script and the actions performed by the students in the activity. In order to test and evaluate it, this model was employed in an OO introductory course in learning activity that was structured as a game of sorts. The students who participated in ViRPlay3D2 showed a high degree of motivation in relation to their learning. These promising results have prompted the idea of utilizing such activities in the teaching of other topics - to enhance the students' learning environments.

Hainey & King [96] reviewed the existing literature and the known empirical evidence in order to propose a number of viable research directions – viable, that is, in terms of moving forward the study of digital games as applied to learning, and in terms of exploring the idea that role-plays are a kind of game. In their investigation, they proposed several such directions, including that of studying the benefits of the use of digital games for learning purposes as compared to traditional teaching approaches by, for instance:

- Comparing the use of digital games/role-play to traditional teaching approaches across a number of different subjects.
- Comparing the pedagogical benefits of single player versus multiplayer collaborative games across a number of different subjects.
- Comparing the pedagogical benefits of 2D versus 3D games used as digital game interventions.

All these directions are taken into considerations within this study and are discussed further in the next chapter.

2.4 The Data Driven Approach

With the new technological trends such as big data, IoT, and cloud computing, the data-driven approach and associated applications have emerged [97]. Anderson [98] defined Data-driven-ness as being ‘about building tools, abilities, and, most crucially, a culture that acts on data’. He adds that the elements required in order to achieve data-driven organization are:

- The right data.
- Data that is joinable, shareable, query-able.
- Data which can be reported.

The data-driven approach can be used in a variety of ways. For example, it has been used in decision-making to improve the general level of achievement at a school – which, of course, affects the educational performance of individual students [99]. This approach has provided teachers with the authority to identify, develop, and implement an intervention strategy for a school’s system based on their analysis of data.

Data-driven learning (DDL) is an inductive learning process for use in language learning [100]. In this process, corpus data is provided to the learner so that they can observe and study the patterns of a language and determine how some words and phrases are used.

In another example, Rivers & Koedinger [101] introduced a data-driven approach for generating feedback for the novice programmer automatically in order to support their learning. For this, they expanded the Hint Factory methodology [102] by addressing its limitations and describing how to overcome the challenges involved and thus eliminate these limitations. The Hint Factory is an approach for tutoring programming that provides the students with predetermined feedback at each stage, based on their prior data. However, Rivers & Koedinger claimed that the provided solutions for solving programming problems were weak and that this complicated the tutor’s task; they introduced their approach in response to this. Their approach automatically

generates solution-states that map onto the student's state in their problem-solving process and provides the nearest accurate solution.

The data-driven approach is used in programming tasks that are concerned primarily with the structure of the data [103]. The data is grouped and matched in terms of patterns or classes. The approach is used to improve the ability of software to be used, refined, tested, maintained, and extended.

The pedagogical examples given previously all utilize data in generating materials related to a particular topic under study via different methodologies and algorithms. However, this study is more interested in utilizing the data-driven approach for generating the objects of a 3D virtual environment and controlling the interactions between these objects according to a topic-specific scenario, where the topic is specified by the data as well.

2.5 Teaching Computer Networks

As mentioned in Chapter 1, my primary motivation for embarking on this research was to help in overcoming the difficulty my students encountered when visualising the abstract concepts relating to networks. With respect to this, an investigation into teaching fundamental computer network methods and techniques is the primary focus. At King Abdulaziz University, where I used to teach, they used both Packet Tracer⁸ and Wireshark⁹ applications for teaching the Network Lab course; indeed, these packages are specified in the teaching manual. Using these two applications together, it is possible to introduce the students to the real world of networking by sniffing the network packets and analysing the sniffed data with Wireshark. This also demonstrates to the students the real activities of a network by using the Packet Tracer simulator to simulate network topologies and the communications involved with various tasks and activities.

⁸ <https://www.netacad.com/courses/packet-tracer>

⁹ <https://www.wireshark.org/#download>

Sarkar et al [34] introduced another modelling tool for teaching networks, called WebLan-Designer. They found that students need to be motivated and engaged in the learning process in order for the objectives of such a course to be met. WebLan-Designer (which uses a table-based representation) was created to assist in teaching networks and the problems these have. This system is a web-based tool developed specifically for the teaching of LAN design fundamentals. It allows students to select network components to model and to configure LANs according to network scenarios provided to the students.

Janitor, J. [104] presents a number of different ways of using Packet Tracer productively and, for the students, enjoyably. He shows how Packet Tracer provides a network simulation with many features and tools that help students and teachers to work with networks; in the case of students, both individually and collaboratively. Shao & Maher [33] adopted an empirical pedagogical approach to teaching networks which was intended to overcome the challenges faced by both instructors and students when engaged with such an advanced topic. One of their methods was to use the Wireshark application in the laboratory; this traces and captures the network packets as they go from/to a computer through a network. Although Wireshark provides the students with an opportunity to discover the real-world networking environment, this system does not help them to visualize the dynamics of data transport.

Another tool which goes step by step through the actions of a network emulation is Nitkit [105]. This tool can be used very effectively to teach networking. The virtual network which is created reproduces (emulates) the behaviour of a real network and all the associated functions and technologies which are appropriate for exploring a wide range of network concepts in a networking course. Network emulation is an effective instrument for examining the student's ability to implement and configure a computer network - which is one of the main learning objectives of most networking courses.

The previous are examples of tools that support the learning and teaching of networking in higher education. However, McGuffee [13] introduced another (alternative) method intended to engage the students to a greater degree in the learning process – causing them to ‘have fun’ with the world of networking. He provides students with an opportunity to be participants in an interactive drama which takes place in the classroom and is focused on networking scenarios. An example of this kind of drama is that of a group of students physically acting as exchanged network packets; this activity can be used to explain the reliability of the data transfer protocol - the rest of the class observes. He (McGuffee) claims that visualizing the inner workings of the protocol provides the students with a better understanding of it. Because of this experience and its result, he strongly encouraged computer science educators to design role play activities around their subjects and engage their students in such interactive drama exercises.

The above summarised the tools and methods used to teach networking which have been widely investigated. In this thesis, I introduce a prototype based on networking scenarios in order to validate an element of the research hypotheses.

2.6 Summary

Throughout the remainder of this thesis, many of the studies and findings looked at in this literature review are drawn on. There are explorations into possible solutions to the difficulties faced by learners when attempting to visualize the abstract concepts of computer science; these solutions involve role-play and the application of 3D virtual environments to pedagogical activities in particular. In addition, there is much strong evidence presented in the above literature regarding the learning benefits of employing role-play activities across many fields. However, each of these studies has focused only on its own subject area. There is a need to generalize the methods used to organize role-play scenarios to be deployed into 3D virtual worlds. Some of the studies looked at examine in detail the fact that there is potential for expanding the methods used and overcoming

their limitations in order to attain improved outcomes. In the subsequent chapters, a conceptual framework is introduced based on the learning and drama theories previously mentioned, as well as the implementation of a system based on this framework. The CRC card method and the data-driven approach are employed in creating this system and to support the intended generalization. A network-focused prototype is produced as a case-study along with experimental undertakings which are used to evaluate the system.

Chapter 3

3 Research Framework

*“The secret of change is to focus all of your energy,
not on fighting the old, but building on the new.”
– Socrates*

The previous chapter provided the background for this research in terms of motivation/vision and also discussed studies related to the present one. The present research is in the field of computer science and immersive learning. It is concerned with investigating the learning affordances of message-passing role-play activities within 3D virtual environments (3D VE). From a wider perspective, this study explores ways by which the data-driven approach employed here can be utilized to generalize the process of generating such activities within 3D role-play virtual environments (RPVEs) so that they can be used in relation to a wider variety of topics. As in the previous chapter, the context of this chapter will be based on an examination of the issues concerned with the teaching of abstract concepts and the technologies and applications that have been applied in this area. More precisely, an investigation into what are the most appropriate computational approaches, theories, and frameworks that can be applied to learning environments and simulations carried out on virtual reality platforms.

We begin by proposing the research framework and this will lead to the further phases - of experimentation and evaluation - that are discussed in successive chapters. Thus, this chapter first introduces the study's conceptual architecture. Then, it describes the data-driven approach and

how this is utilized to serve the generalization of the framework. This description is followed by a justification and an explanation of the MMRP subsystem's architecture. The chapter concludes with a summary of the points that were addressed in terms of related theories and the formation of our conceptual architecture.

3.1 The Conceptual Framework

The realism and engagement offered by an educational game (where role-play is a form of structured game) can have an impact on learning outcomes, according to Tashiro & Dunlap's study [106]. One of the fundamental benefits of using role-play in teaching and learning is to improve the student's engagement in the learning process by causing them to become more immersed - this can enhance their understanding of the subject [39]. Moreover, Winn [107] added in his study that the realism and the engagement experienced can be increased by conducting the role-play activity in a 3D virtual world (3D VW) because of the immersive nature of such an environment. A VE can enhance the user's experience of immersion, allowing them to build their knowledge from direct experience - by being a part of this environment. Moreover, 3D VWs provide a platform from which to observe the participants and the overall activity, as well as offer the ability to record the outcomes.

The affordances of learning derived from 3D VWs as proposed by Dalgarno & Lee [29] (presented in Section 2.3) clearly represent the potential learning benefits of using 3D VWs: spatial knowledge representation, experiential learning, engagement, contextual learning and collaborative learning. In addition, a 3D VW can offer a richer experience for users than simple 2D Web applications, often combining many features together into a single environment. Such an environment may include instant messaging within groups of users, voice chat, rich user profiles, and creative collaboration in online social interaction that involves sharing various objects and services in the virtual world [108]. Virtual Reality (VR) can be used to support students to reach

their desired learning outcomes through constructivist and problem-based learning. Alzahrani [109] presented empirical evidence based on his experiences that participants' performance was improved by using a VR platform as opposed to using a 2D web-based platform. Investing the affordances of a 3D VE into learning, by creating a role-play activity, can therefore potentially positively influence a learning process - especially in terms of the immersion of the student in the activity. Role-play has the potential to not only enable the learner to become more immersed in their learning, it also provides them with the ability to enhance their skills by integrating themselves into a simulation of a real-world problem [39]. Another significant advantage of 3D VEs is that they have shown great potential as regards collaborative learning [106] [39], especially when they are implemented in the form of Multi-User Virtual Environments (MUVES). The collaborative features that are provided by an MUVE, whereby users are represented as avatars that may virtually and simultaneously interact with each other and the environment's other objects, can be used to support group role-play activities [67].

The concept of deploying role-play in 3D VEs was introduced in Section 2.4 and we go further here. The following computational framework, called the Mixed-Mode Role-Play (MMRP) Framework, is now proposed for the purposes of testing the learning affordances of role-play activities in RPVEs, as well as to present an approach for generalization — a key target of this research. In this environment a human user interacts with the system. The instructor is responsible for creating and building the data that will be used by the system for generating the role-play activity. Once the learning activity has been generated in the 3D VE, a student logs into the system to embody one of the environment's objects and interacts with other virtual automated objects, as presented in Figure 3-1. The object directly operated by a human user within this activity is called the "*Humanized*" object. Thus, the nature of the 'play' makes this a mixed-mode framework, the

use of the system. This layer has links to all the other layers. The data is the key element that will be used to support the anticipated ‘generalization’ offered by the MMRP. The means of generalization that this framework offers is that it acts as a template and so is reusable for many different topics. In particular the specific learning scenario rendered and the RPVE are changeable according to the data uploaded into the database; there is no need to refigure or reprogram the framework itself. In addition, the generalization offers variation in the selection of the ‘humanized’ object or the learning task when generating the role-play activity. A data-driven approach is employed in this framework: “Data-drivenness is about building tools, abilities, and, most crucially, a culture that acts on data.”[98].

3.1.1.1 The Data-Driven Structure

Figure 3-2 shows the data-driven process, i.e. how the data is organized in a CRC card structure, stored in the database, and then read to the object containers to be rendered in the RPVE.

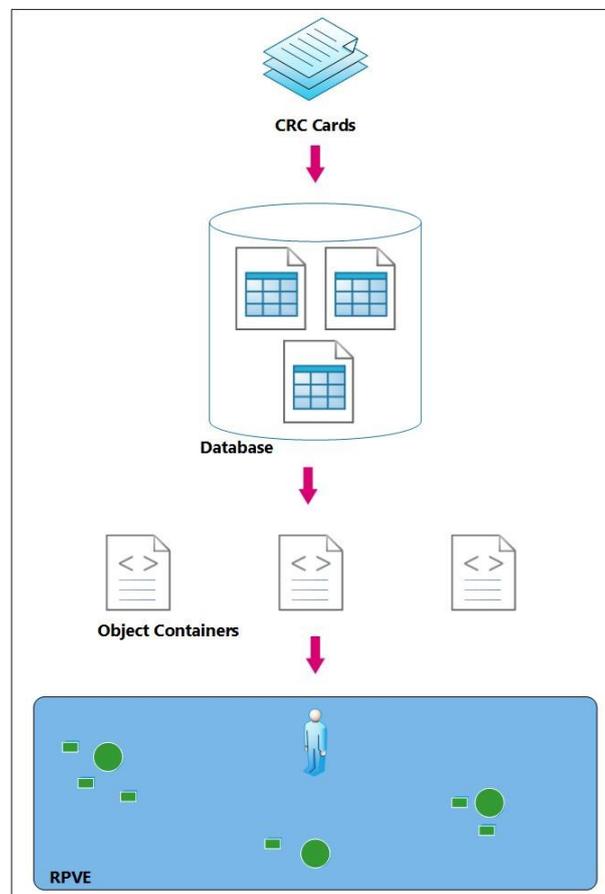


Figure 3-2: The Data-Driven Process

- CRC Cards: Data Organization

A standard way of representing the data is necessary for the data organization and structuring of the database. For these purposes, the CRC card format was utilized for structuring the data to be used for generating both role-play scenarios and the RPVE itself. A specialist in the chosen field, wishing to employ the MMRP framework in one of the courses they teach, is a human actor at this level; they have the responsibility of designing and creating the CRC cards. These structured CRC cards are then stored in the database via object containers (a software structure), with the resultant data being uploaded to the other layers as requested.

CRC cards (Class-Responsibility-Collaboration cards) represent a method that facilitates the definition of objects and can be used to organize data for role-play activities, as presented in Figure 3-3. Generally, this technique is used in teaching various aspects of Object-Orientation (OO) [110] [111] [20]. CRC cards have been described by Beck & Cunningham [51] as a tool for teaching object-oriented thinking to programmers. Defining objects via the CRC card structure means that they are represented as discrete, independent units; this facilitates the creation of a role-play activity.



Figure 3-3: A Class-Responsibility-Collaborator (CRC) index card

However, Hvam et al. [53] introduced a modified way of modelling a scenario using CRC cards. They added more fields to the structure of the CRC cards in order to enhance their use in role-play. The additional fields were aggregation, generalization, and knows/does. These additional fields help to link objects from different classes. They are useful for tracing the roles of

inheritance and ‘has a’ relations. The model thus offered not only enriches the environment’s object population but also supports role tracking.

In our model, the OO classes are structured as CRC cards, each of which consists of a class name, responsibilities, collaboration, aggregation, and knows/does, as shown in Figure 3-4. Using this structure, the data will be retrieved from the database to create and implement the necessary OO objects; these are then rendered as 3D objects in the virtual environment and have the following roles:

| | Field | Description |
|---|------------------|---|
| 1 | ID | the unique identification of the object; this will be used as the primary key within the database. |
| 2 | Class name | equivalent to object names. |
| 3 | Type | there are two types - ‘Main’ or ‘nMain’. - Main: objects that have roles within the learning scenario. They interact with each other to complete a specific task. They are also considered ‘super-parts’. One of these objects is played by the student and thus is called the humanized object. - nMain: these are the support/subpart objects. One of these objects is the answer or the target for its main object, based on its task. |
| 4 | Responsibilities | The general responsibilities of the objects in terms of their contribution to the learning objectives associated with the learning scenarios. |
| 5 | Aggregation | each object has a super-part, and a number of subparts. This structure allows for the collection of different objects into an |

| | | |
|---|----------------|--|
| | | aggregation hierarchy. The structure embeds the associations between the objects which helps link them together. |
| 6 | Collaborations | this indicates what defines the 'next' role in a chain of roles. |
| 7 | Know | the message contained by the object in question. |
| 8 | Does | represents the learning tasks that the object exists to facilitate. |

The additional fields - ID, Type, and Aggregation - are employed to organize the hierarchy and the relationships between the objects (for example, HTTP, FTP, and STMP are subparts that form the Application). The data must be embedded in an organized structure so that it can be readily accessed.

| <u>Class name</u> | <u>ID</u> | <u>Type</u> |
|-------------------------|-----------|-----------------------|
| <u>Responsibilities</u> | | |
| <u>Aggregation</u> | | |
| <u>Superparts:</u> | | |
| <u>Subparts:</u> | | |
| <u>Knows/Does:</u> | | <u>Collaborations</u> |
| Knows | | |
| Does | | |
| | | |

Figure 3-4: MMRP CRC card structure

- The Database: Data Storage

The CRC cards are then transferred into the database. Figure 3-5 shows the Entity–relationship model (ER model) that represents the data model to be implemented by the database. Every scenario has a unique ID; a unique learning objective that the role-play scenarios are created around, and a task. The learning objectives are derived from the responsibilities of the CRC cards that have the type: Main. These learning objectives are set up by an instructor or specialist,

according to the chosen topic, utilising the MMRP. The learning objectives appear on the MMRP instructor interface as options that can be selected according to the topic to be taught. With each learning objective a task record is attached that will appear in the Student's interface to guide them to initiate the role-play activity. Each scenario is mapped to a set of objects of the *type* 'Main' and these will take roles in the message-passing role-play activity.

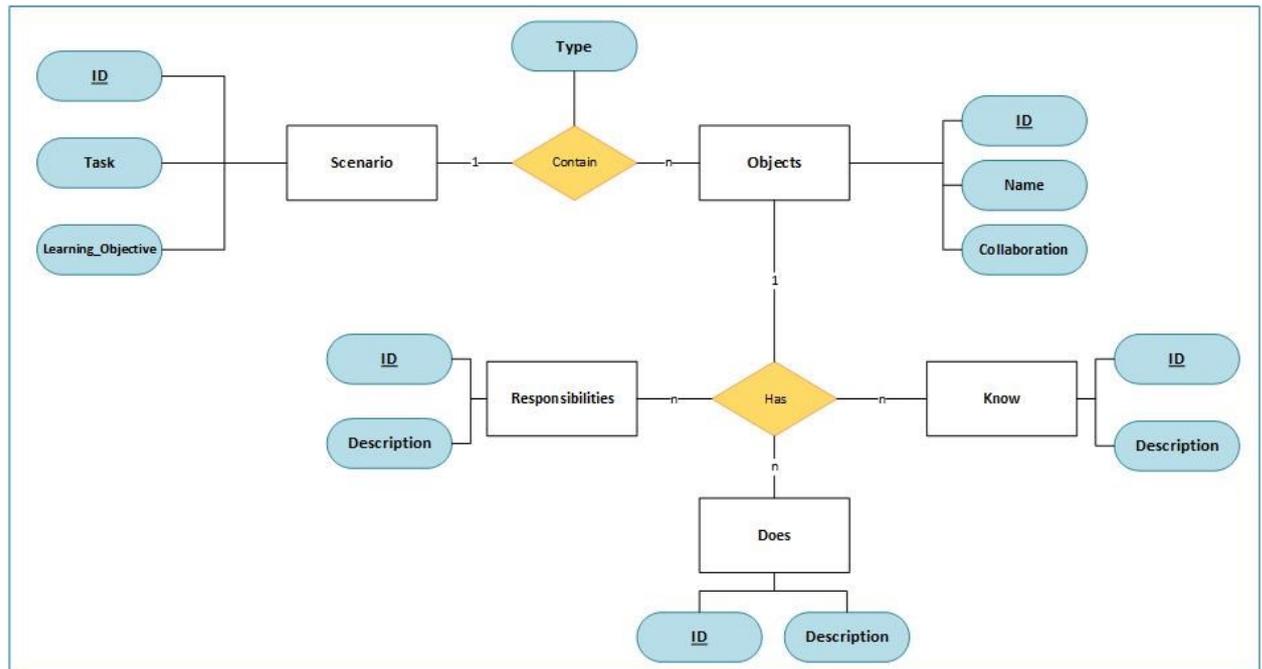


Figure 3-5: ER Model

Each object has a unique ID, Object_Name/Class_Name, and Collaboration. These objects have many Responsibilities, Does, and Know messages.

- The Object Containers: OO Objects

As the environment consists of many objects, all of which take turns to engage in message-passing role-play activity, it is the OO class structures that have the defined constant variables used to upload the required data from the database. These set the values for the variables in order to generate the RPVE's objects and control the interactions between these objects. When the RPVE is rendered, the sub-part objects are rendered around the super-part from which they are derived. In the next chapter, in Section 4.1, this process is explained in detail using a prototype example.

In summary, this layer acts as a general template that facilitates the generation of the OO objects to be used in a role-play scenario.

3.1.2 Task Design Layer

This is the layer in which the role-play activity is initiated, based on the instructor's desired learning objective — as mentioned earlier, we follow the Learning-by-Doing pedagogical theory here. In this role-play activity a task needs to be accomplished. This task will be recorded in the *Scenario* table. When executed, the available learning objectives within the *Scenario* table are loaded from the database via an object container, located in the *Data Layer*, and presented by the GUI interface as options for the instructor. The instructor then selects the desired learning objective — for example, the learning behind what is involved in the process of retrieving a webpage from a server. Based on the selected learning objective, a role-play activity, including all relevant objects mapped to the learning objective, will be rendered into the 3D virtual environment. Via an object container, these objects are then displayed by the GUI interface so that the instructor can choose which of them will be the *humanized* object. The *humanized* object is the object that the student will embody in the RPVE and via which they (the student) will interact with other, automated, objects. All the objects interact with each other according to the selected scenario in the resultant mixed simulation.

3.1.3 Objects Layer

Once the learning scenario and the *humanized* object have been selected by the instructor, the system begins to generate the RPVE and its objects in the Object layer. As displayed in Figure 3-6, the required data are loaded from the *Data Layer* via an object container that is responsible for mapping the 3D representation of the objects to be rendered within the RPVE. Each object can be switched into one of two states: ON or OFF.

- *ON State*: This is the default state for any object. This state indicates that the object will function automatically as part of the simulated system. The required data for constructing each object are uploaded into an object container to create the objects one by one, before being loaded into the memory.
- *OFF State*: This means that the object will be humanized (i.e., its function will be actioned by the student). The required data for constructing the targeted object are uploaded into an object container, as with all other objects, except the switch case will be OFF.

The data in the Responsibilities and Collaborations fields of the CRC cards control the movements of the RPVE objects and their interactions.

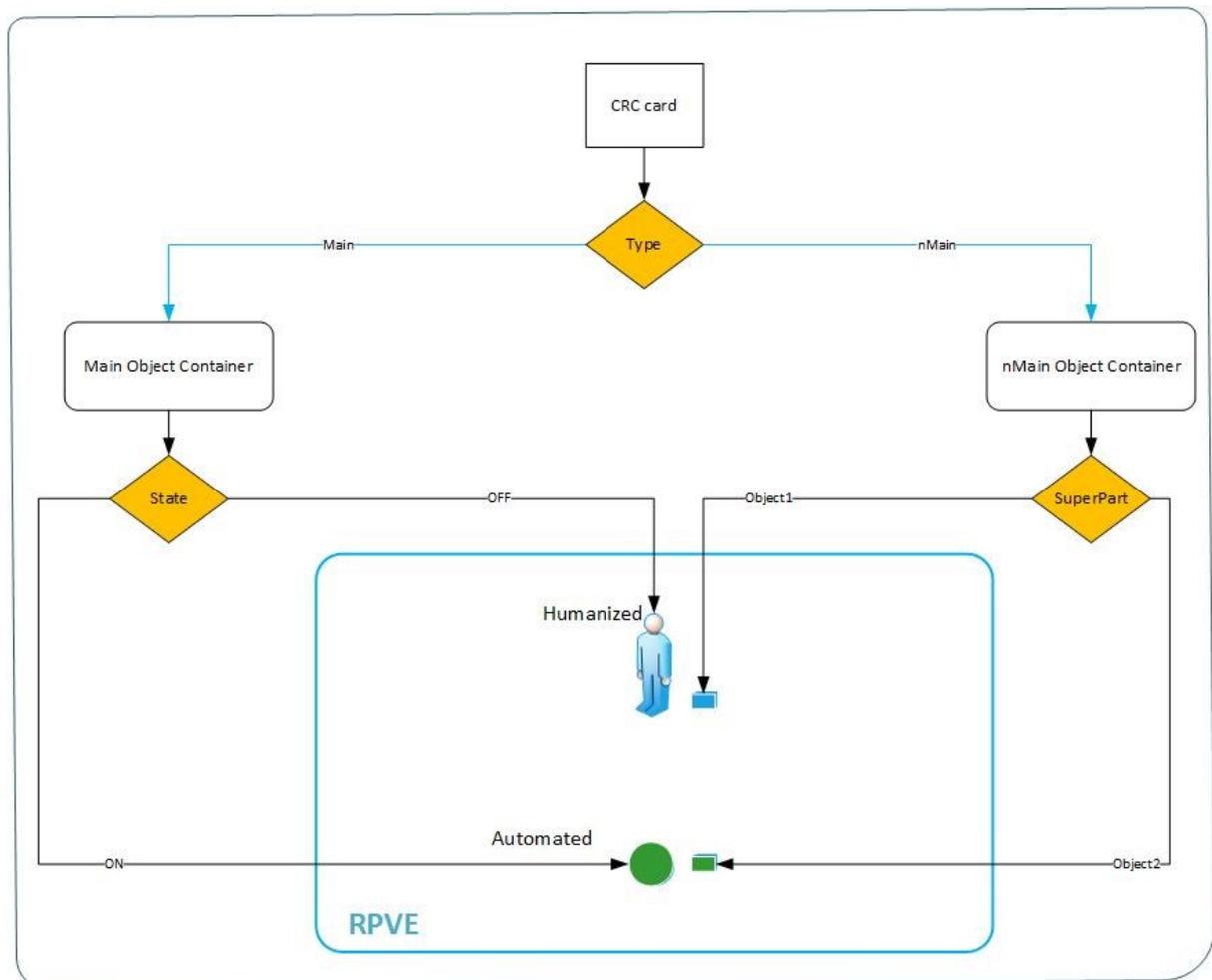


Figure 3-6: Rendering the objects into the RPVE

3.1.4 Simulation Layer

This is the layer wherein the mixed simulation occurs. The RPVE and its objects are generated as follows:

The objects interact with each other based on the selected scenario. The *humanized* object is represented by an avatar that is controlled by the student. The roles' proceeding and interactions are controlled through reading the data from the database. As displayed in Figure 3-7, Collaborations in the Main object indicate the next role, i.e. the one that receives the message from the current role.

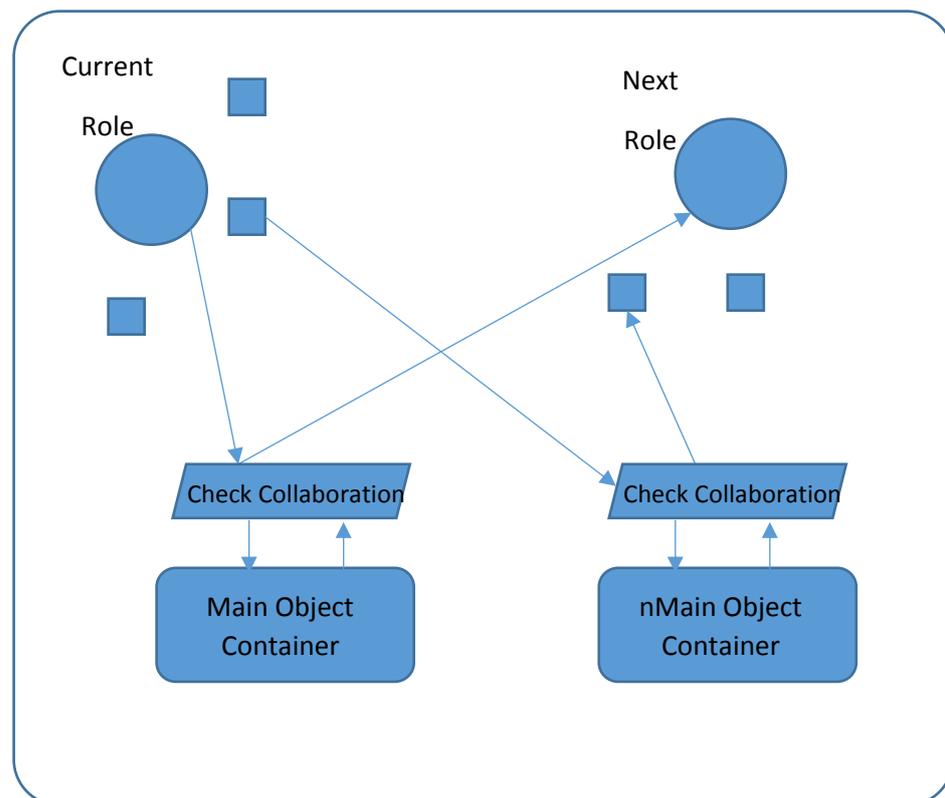


Figure 3-7: Process of interaction between the objects

3.2 Mixed-Mode Role-Play System Architecture

The MMRP system architecture presented in Figure 3-8 consists of distributed subsystems; this simplifies the implementation process and makes it adjustable. The way in which the system operates (as a learning environment) is outlined below. As indicated in the conceptual framework presented earlier, there is mixed-mode interaction between the human and the system. There are two human actors: either the instructor or the student. First, the human actor/user logs into the system with their ID through the GUI; the *User Manager* then retrieves the user's profile from the *User Repository* in order to find the user's access permissions and authorisations. There are two types of permissions: one for instructors and one for students. The system generates the student's role-play activity based on the instructor's preferences.

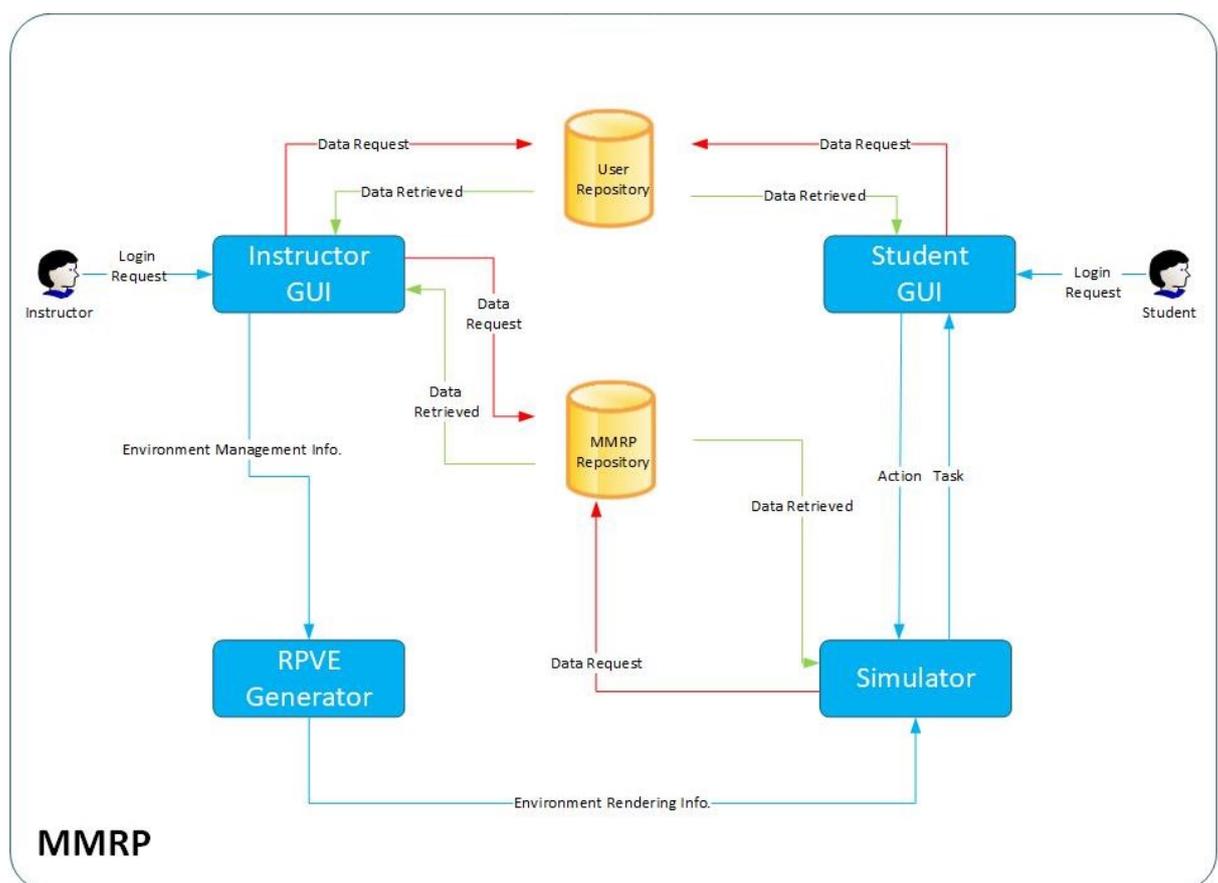


Figure 3-8: The MMRP's System Architecture

3.2.1 Instructor GUI

The architecture of the instructor's interface is shown in Figure 3-9; using this, the instructor can choose the role-play scenario and the humanized object to be 'played' by the student.

After verifying the instructor's ID, the *User Manager*, in accordance with the permissions given to the instructor, pops up a Java tool that allows him/her to specify the task characteristics (as below) after he/she has set the learning objective behind the activity:

- *Scenario Generator*: all the scenarios are uploaded from the database and displayed as a list of options. The instructor can then choose from these according to the desired learning objective.
- *Object Selector*: all the main objects of the selected scenario are uploaded from the database and displayed as a list of options. The instructor can then choose the humanized object.

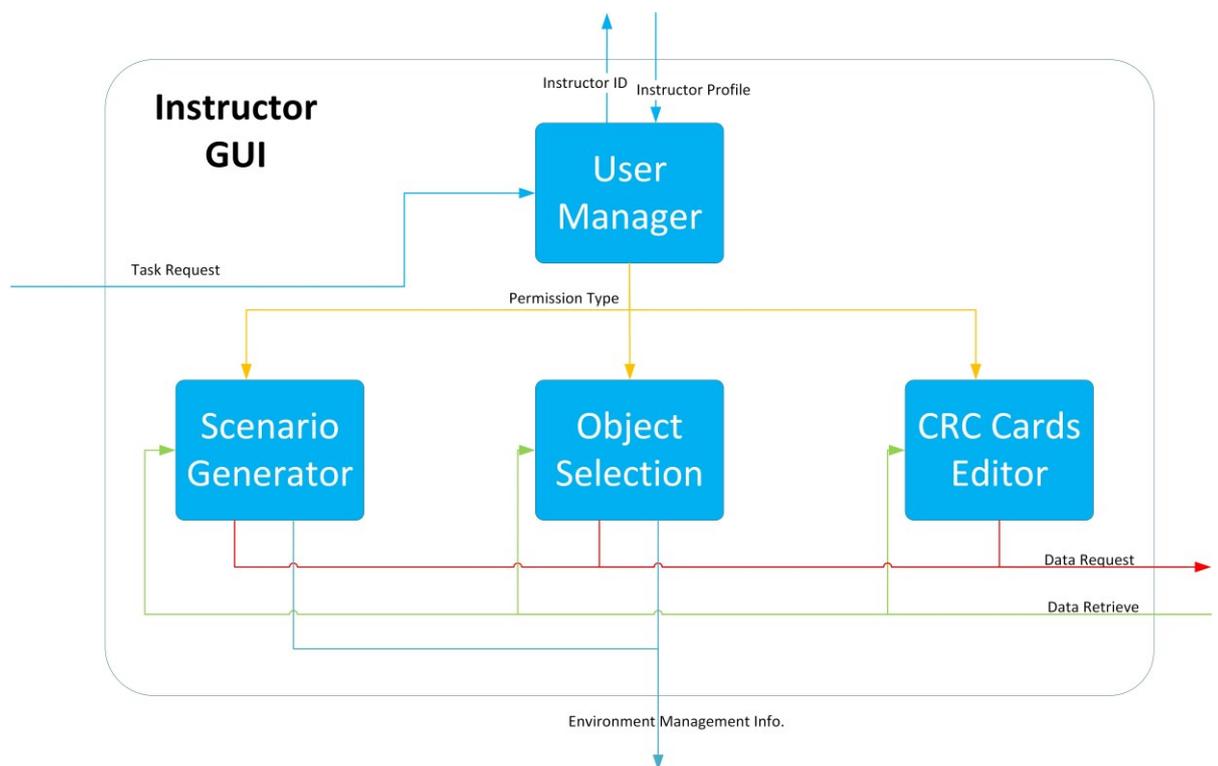


Figure 3-9: The Instructor GUI subsystem

- *CRC Cards Editor*: This edits the pre-existing cards (i.e., adds/deletes responsibilities, collaborators) or generates new cards for new objects that are required for the learning objective.

3.2.2 RPVE Generator

This system is responsible for generating the RPVE for the mixed simulation, as presented in Figure 3-10. After the scenario and the humanized object have been selected, the associated data are uploaded from the database to the appropriate object container:

- *Main Object* container: all the data associated with the main objects of the learning scenario are uploaded to this object container. They (the main objects) are then rendered into the RPVE. The humanized object is represented by an avatar, with the rest represented by simple shapes distributed within the RPVE, based on the object's state.
- *Subpart Object* container: this container renders the subparts of each main object around it.

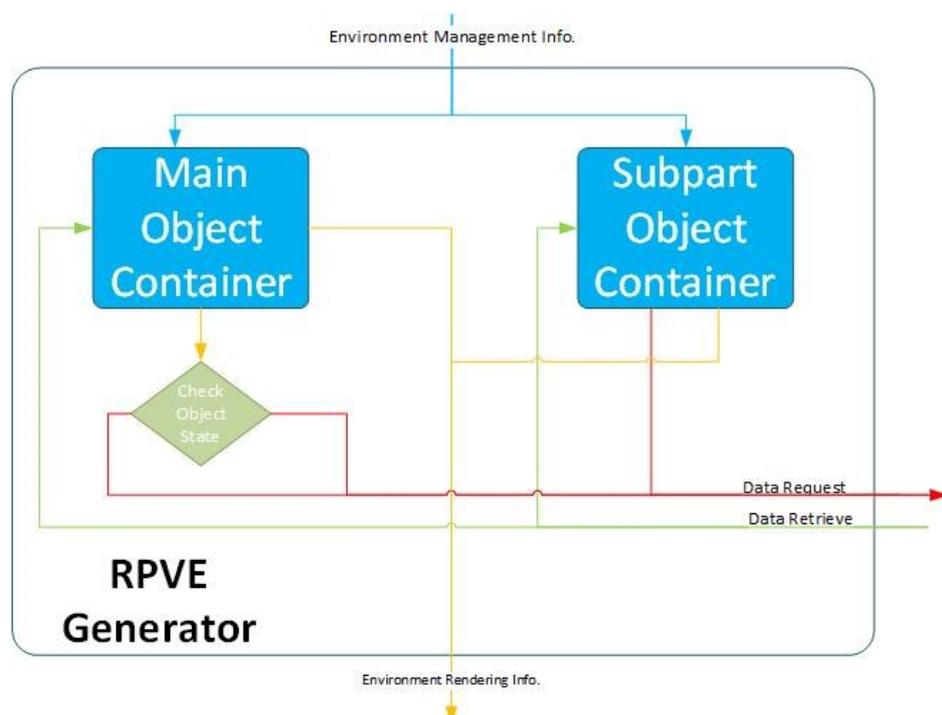


Figure 3-10: RPVE Generator subsystem

3.2.3 Simulator

The mixed simulation proceeds as shown in Figure 3-11.

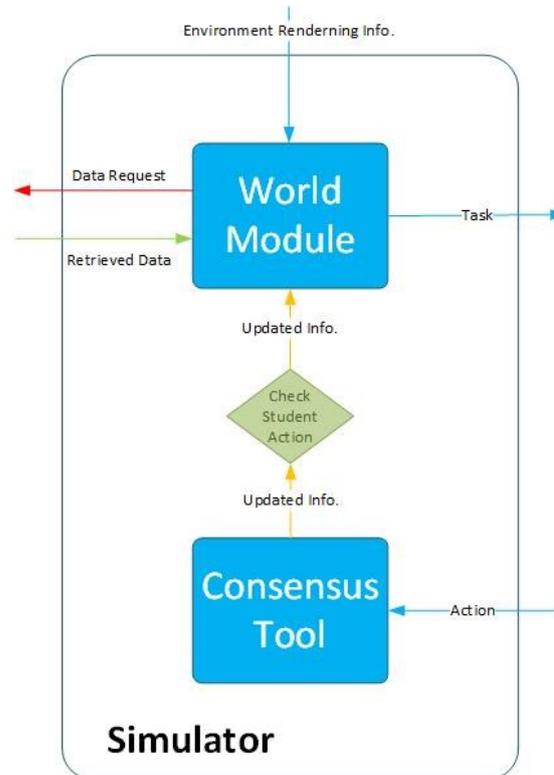


Figure 3-11: Simulator subsystem

- *World Module*: the data uploaded for each object contain the specified responsibilities and collaborations to control the objects' behaviours. If the learning task matches one of the subpart objects' responsibilities, this signals that this is the subpart holding the message to be delivered to the next role. The collaboration specification determines the object to receive the message and perform the next role.
- *Consensus tool*: The inputs from the student will be translated into commands received. These are queued to be transferred to the *World Module*.

3.2.4 Student GUI

The user/student begins their interaction with the RPVE through a display screen. Via this they can also view the simulation in progress and receive the task in which they will interact as an object, as shown in Figure 3-12. The object's actions are first received as commands from the student's input hardware device and are then contained in the *Hardware-dependent Module*.

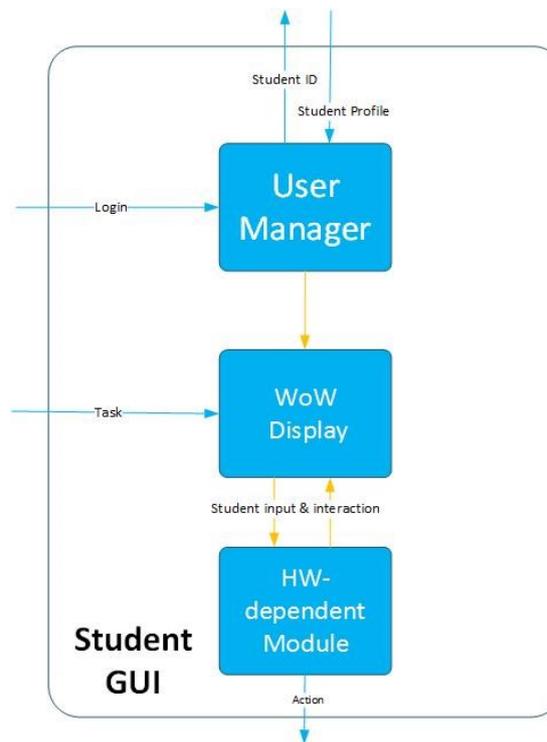


Figure 3-12: Student's GUI subsystem

3.3 Summary

In this chapter, following the introduction of some noteworthy learning theories and after examining the effectiveness of role-play activities in education, the Mixed-mode Role Play (MMRP) framework was presented. The name of the framework was coined as a result of the mixed mode simulation carried out in the RPVE. The student embodies one of the environment's objects and interacts with the other automated objects by exchanging messages according to a learning scenario. The MMRP framework's four layers: the Data Layer, the Task Design Layer,

the Object Layer and the Simulation Layer form a conceptual framework that is intended to harness the effectiveness of role-play in the VR. This framework is generalized via a data-driven approach employed in the implementation. “Generalization” here means that the framework can be reused for different topics simply by changing the database; i.e. different data generate different RPVEs. The CRC card system unifies the organization of the data to be uploaded by the Object container class in order to generate the role-play activity.

The MMRP concepts are then translated into a system architecture with four subsystems: the instructor interface, the RPVE generator, the simulator, and the student interface.

In the chapters that follow, a prototype is presented in detail, including:

- The implementation of the subsystems.
- An example of data held in a CRC card and its representation in the database.
- A learning scenario.
- An experimental framework for validating the research hypotheses.

Chapter 4

4 Experimental Framework

“Observation is a passive science, experimentation an active science.”
– Claude Bernard

Revisiting the research hypotheses from Chapter 1:

Technical element:

1. It is possible to create a generalized conceptual framework for the creation of message-passing role-play activities which involves mixed-mode roles whereby some of the object-roles are ‘played’ by the system and some are played by the user – that is, they are ‘humanized’. This can be achieved by adopting a data driven approach such that the data:
 - supports the creation of a role-play virtual learning environment – the objects of which are rendered on the instant (as required), at run-time; and
 - supports the creation of mixed-mode role-play activities and interaction between the environment’s objects.

In particular, the data can be represented for retrieval in such a way that this allows the framework to be reconfigured so that the system can be reused for a number of purposes for which a message-passing scenario is relevant.

Learning element:

2. Enabling a student to embody an object taking part in a message-passing role-play activity with other objects in a virtual environment leads to better learning outcomes and the gaining of a more thorough understanding than using other computer-based approaches. This is achieved through enhancing the learner's:

- Learning engagement: “being concerned with all the qualities of an experience”
- Association with the role of the embodied object.

The overall claim is that the data-driven approach used in MMRP has benefits relating to generalization. The MMRP acts as a template framework for the creation of message-passing role-play activities in the 3D virtual environment. In the created activity, the student takes the role of one of the objects in the environment and hence interacts with other objects - as a means to achieve a specific learning task that will lead to a better learning of the topic in question. To examine the feasibility of MMRP and its generalization capabilities, this chapter presents a specific framework configuration designed for experimental purposes as a proof-of-concept in order to validate the research hypotheses. This experimental framework configuration will support experimentation phases plus evaluation instruments. The architecture of the MMRP was presented in Chapter 3. This fourth chapter is concerned with the evaluation of the research model and the approach in relation to validating the research hypotheses. But first we introduce the MMRP system implementation.

4.1 The MMRP System Model

In order to implement the model, the following subsystems, introduced in the previous chapter, must be considered:

- *Instructor GUI*
- *RPVE Generator*

- *Simulator*
- *Student GUI*

However, due to the limited time frame within which this research had to be conducted and various other practical challenges that this study has faced, I have been forced to consider carefully the scope of the implementation process. This research focuses on the learner rather than on the teacher role. Thus, keeping in mind the research hypotheses, the focus on the student's learning and the generalization levels, instead of implementing the *Instructor GUI*, I decided to use fixed role-play network scenario tasks that could only be changed via the C# code. The other subsystems are representing the core of the system via which the hypotheses can be experimentally validated.

As for the technical aspects, the research investigated different models and technologies to build the role-play prototype. In the first stage, the learning environment will be created by extending on the system architecture of ViRPlay3D2, as well as by combining elements of previous efforts from Gardner's and Joshi's projects [25] [26].

Being a member of the Immersive Education Lab Research Group at the University of Essex has provided me with many sources of insight. One of the most authentic and novel models for collaborative learning is the MiReSL model that was introduced by Pena Rios in her PhD thesis [112]. MiReSL has the ability to connect environments and learners around the globe in collaborative activities via the InterReality Portal. The InterReality Portal is a human-computer interface (HCI) that was one of the tangible results from Pena Rios' work. Thankfully, I was granted access to InterReality Portal's source code and this was used as the basis of the MMRP system implementation. The Unity game engine¹⁰ is the platform that was used to implement this 3D virtual environment.

¹⁰ <https://unity.com/>

4.1.1 Student GUI Implementation

The GUI screens of the InterReality Portal were redesigned and programmed so as to be a fit with the MMRP model's objectives. Figure 4-1 (a, b) shows the differences between the InterReality Portal and the MMRP Login screens. Although I decided not to continue with implementing the instructor interface, I left an option on the login interface ostensibly for use by teachers, though it is currently inactive. I did this because I am planning to continue to develop the system in the future. Figure 4-2 shows the screens that appear once the student option is selected. After selecting the desired avatar, the user may then click on the new session button to enter the 3D environment. The option, "2. Join one of these sessions" also represents a facility to be put in place in the future, and is discussed in more detail in the last chapter of this thesis.

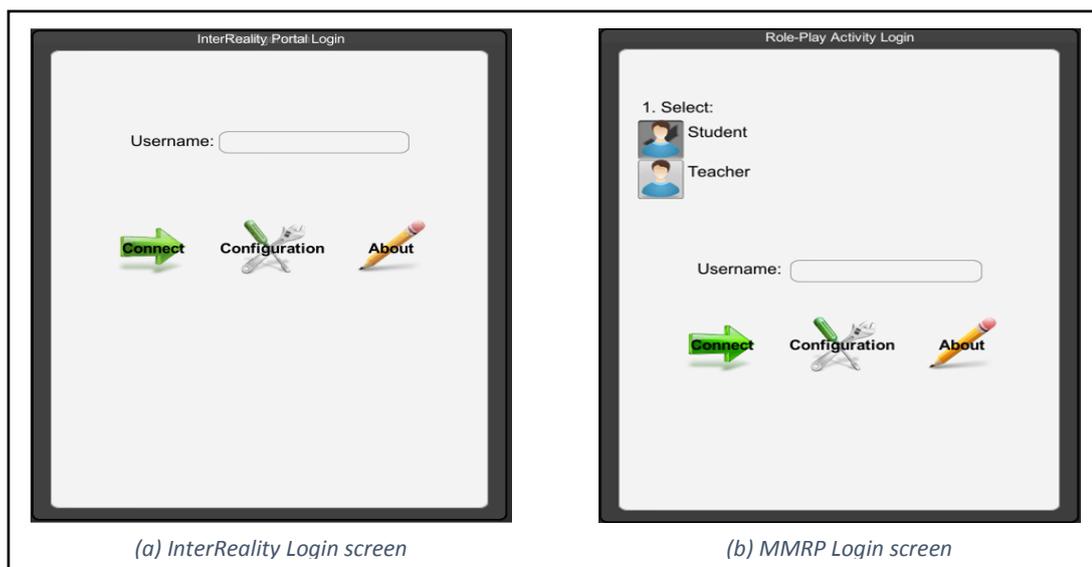


Figure 4-1: The changes in the MMRP login screen

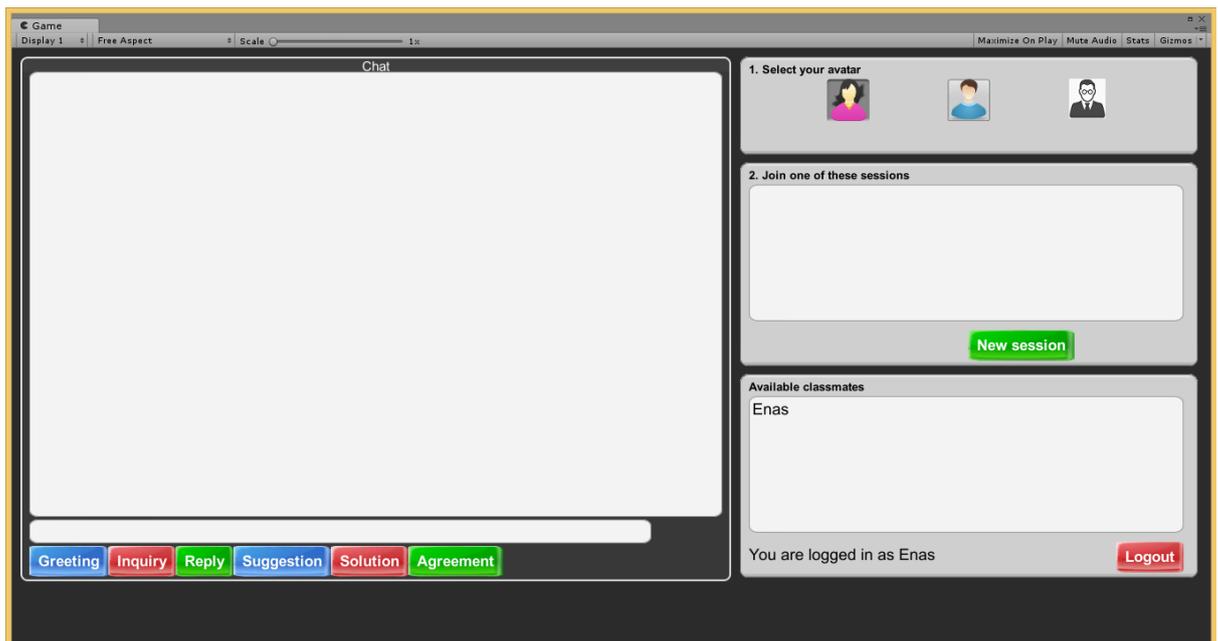


Figure 4-2: Student screen

4.1.2 RPVE Generator Implementation

The role-play virtual environment, the RPVE, is the 3D virtual world in which the user's avatar operates and interacts with other 3D virtual objects. As the InterReality Portal was developed using the Unity game engine, developing the MMRP client platform had to be carried out using Unity as well. Unity is a flexible platform and has a strong developer tool set. In addition, the Unity platform supports C# and JavaScript routines for creating interactive 3D content (i.e. when building the *Object Container* of this subsystem - a structural OO class used to generate the OO objects in role-play scenarios). The platform is also key in allowing for the generalization of the data-driven approach adaptation that this study strives for. After coding the *Object Container* class, the data must be uploaded so that the 3D world may be rendered.

4.1.3 Simulator Implementation

Looking at the application of the data-driven approach, it is evident that the data used for rendering the *RPVE* and for generating the role-play activity is organized via CRC cards, introduced in

Chapter 3. The CRC cards are created by the instructor, or other specialist, to be topically specific to whichever learning activity is being carried out. The database then follows the instructions contained within these cards. There are three main database tables: the learning scenario table, the table representing the ‘main’ objects, and the table containing the subpart objects. These tables are created through *USBWebserver*¹¹, which is an online database server supporting MySQL, see Figure 4-3. PHP pages constitute the links between the database and the JavaScript routines in Unity.

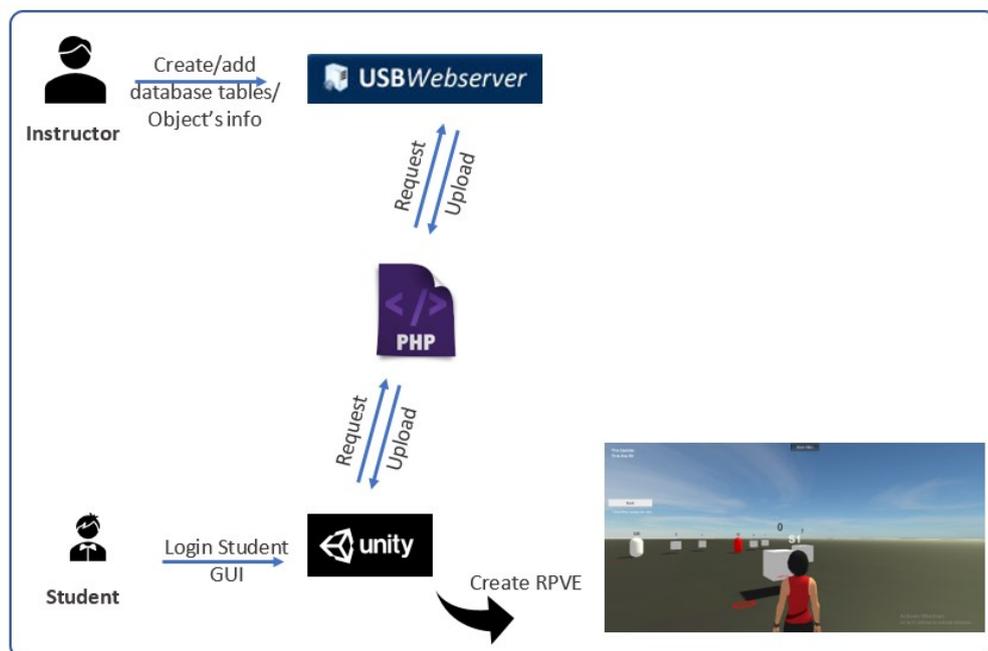


Figure 4-3: Using USBWebserver to create the RPVE

As explained previously in 3.1.1, the data for the role-play activities are organised in a modified CRC card structure. The CRC card fields are: ID, Class, Type, Responsibilities, Aggregation, Collaborations, Know, and Does. As an example, Figure 4-4 shows the CRC card for the Application layer, displaying the following:

¹¹ <http://www.usbwebserver.com/>

- ID field - the unique identification for each object.
- ‘Type’ - the type, Main or nMain, indicates what role the object will have within the role-play activity. This card indicates the object is of *type* Main.
- ‘*Responsibilities*’ - hold the definition of the card’s object and ‘*Does*’ holds its jobs within the system that will be presented in the 3D virtual environment.
- ‘*Collaborations*’ - represent the communication link from object to object, i.e. the “next role” in the task
- ‘*Subparts*’ - the objects that are derived from the Main object. In this example, the Application layer card, the *subparts* are: HTTP, FTP, and SMTP. They also hold the messages that will communicate the next role in the role-play scenario.
- These subparts are defined in other cards with the *type*: nMain. This denotes that they are ‘*Helping Objects*’. They are rendered around the *Superpart* object from which they are derived.

| Class name | ID | Type |
|--|----|-----------------------|
| Application | 1 | Main |
| <u>Responsibilities</u> Serves as the window for users and application processes to access network services. | | |
| <u>Aggregation</u> | | |
| <u>Superparts:</u> | | |
| <u>Subparts:</u> HTTP FTP SMTP | | |
| <u>Knows/Does:</u> | | <u>Collaborations</u> |
| Knows | | Transport |
| | | |
| <u>Does</u> | | |
| <ul style="list-style-type: none"> • Makes sure that the other party is identified and can be reached • Determines protocol and data syntax rules at the application level | | |

Figure 4-4: Application Layer CRC Card

- The messages held in the ‘*Helping Objects*’ are recorded in the ‘*know*’ fields of that object. This field remains empty in the Main cards/*Superpart* objects.

are the main database tables after de-normalizing the entity relations that were introduced in 3.1.1 to simplify and reduce the time of the implementation. There are three main tables:

- The Scenario table, Table 4-1: this contains all the possible learning objectives that the role-play scenarios are based on. The learning objectives are displayed on the MMRP instructor interface as options to be selected according to the desired learning activity. The learning objectives are derived from the Responsibilities section of the CRC cards that have the type: Main. With each learning objective, a task record is attached that will appear in the Student's interface to guide them to initiate the role-play activity. Each learning objective is mapped to a set of main objects that will take roles in a message-passing role-play activity. These main objects are contained in the Main object table.

Table 4-1: Scenario Table

| <u>ID</u> | <u>Learning Objective</u> | <u>Task</u> |
|-----------|--|------------------------|
| 1 | To learn protocols of web browsing | web browsing |
| 2 | To learn protocols for uploading a file | upload a file |
| 3 | To learn protocols for sending Electronic mail | Send email |
| 4 | To learn protocols for remote terminal access | Remote terminal access |
| 5 | How to track an input | 01110 |

- The Main object table, Table 4-2: the principal attributes in this table are: ID, Object_Name/ Class_Name, Responsibility, and Collaboration. The data in this table is drawn from the CRC cards with *type*: Main. These are the required data to render the 'main' objects that have roles in the role-play activity.

Table 4-2: Main Object Table

| <u>ID</u> | <u>ObName</u> | <u>Responsibility</u> | <u>Does</u> | <u>Collaboration</u> |
|-----------|---------------|---|-------------|----------------------|
| 1 | Application | Where a communication originates | | Transport |
| 2 | Transport | Where the data encapsulation begins | | Network |
| 3 | Network | Where packets are prepared for delivery | | Link |
| 4 | Link | Where framing takes place | | Physical |
| 5 | Physical | Where frames are sent and received | | Last |

- The Subpart table, Table 4-3: the principal attributes in this table are ID, Object_Name/Class_Name, Does, Message/Know, and Collaboration. The data in this table is drawn from the CRC cards with *type*: nMain. These are the required data to render the objects that have no roles in the role-play activity.

Table 4-3: Subpart Table

| <u>ID</u> | <u>Oname</u> | <u>Superpart</u> | <u>Does</u> | <u>Message</u> | <u>Collaboration</u> |
|-----------|--------------|------------------|--|----------------|----------------------|
| 1 | HTTP | 1 | web browsing | Get URL | 4 |
| 2 | FTP | 1 | upload a file | Get File | 4 |
| 3 | SMTP | 1 | Send email | Get email | 4 |
| 4 | TCP | 2 | reliable transport | Port Number | 7 |
| 6 | UDP | 2 | unreliable data transfer | Port Number | 7 |
| 7 | IP | 3 | addressing conventions | IP address | 8 |
| 8 | Ethernet | 4 | sending adapter encapsulates IP datagram | Mac Address | 0 |

4.2 Hypotheses Validation

This section discusses the experimental framework designed to validate the research hypotheses introduced previously. Two main aspects were identified: learning and technical. The following questions, which I will seek to answer through the experimental framework, are derived from the research hypotheses:

- Does imitating the action of a technical object in its interaction with other objects in message-passing role-play activity in VEs positively affect learner engagement?
- Does employing the data-driven approach support the framework concept of three levels of generalization which are:
 - Humanized object generalization: The ability to change which object is humanized with respect to the same scenario.
 - Learning task generalization: The ability to change which scenario is ‘played’ with respect to the same subject.
 - Subject generalization: The ability to change the subject/topic being taught.

With respect to these, the experimental work was carried out over two phases: **Network Learning** and **DB**, which are described in more detail in the following sections.

4.3 Network Learning Topic

My experience of teaching network technologies to undergraduate students was the primary motivation behind this research. Moreover, the Internet Protocol Suite (TCP/IP) layers in Figure 4-5 the (TCP/IP) layered networking scenario - represents a typical and common learning scenario for Higher Education computing and networking students [113]. In light of this, the first case study used to validate the learning part of the hypotheses was inspired by these network concepts.

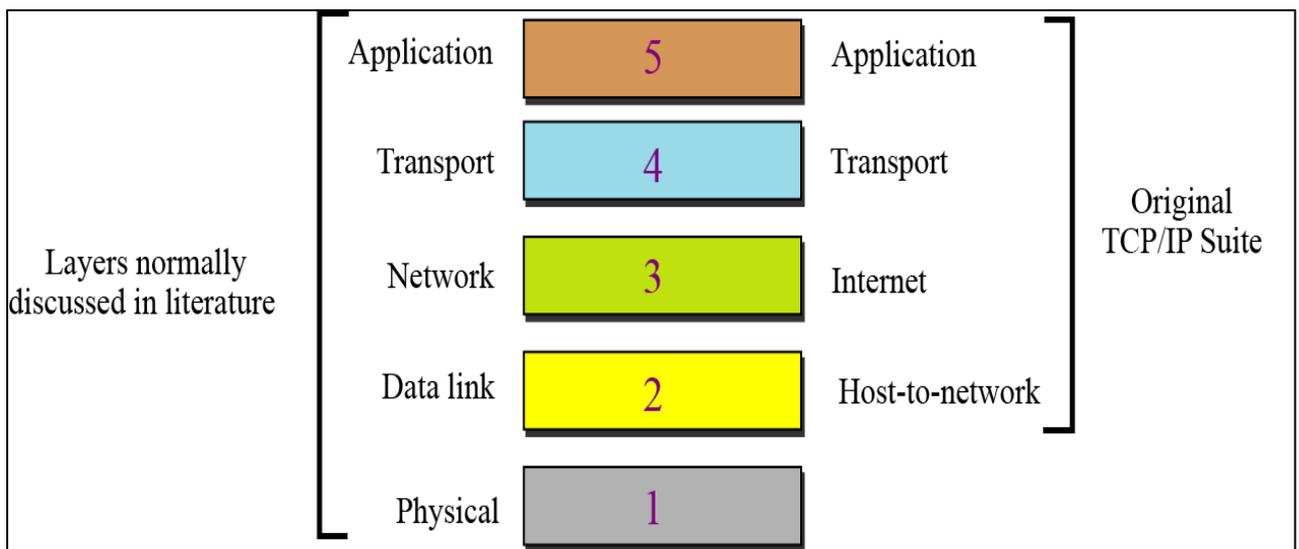


Figure 4-5: The Internet TCP/IP Layers. Reprinted from Kurose, J.F. and K.W. Ross, *Computer networking: a top-down approach*. Vol. 5. 2010: Addison-Wesley Reading.

There are two sub-phases of the learning focused experiment: the **conventional learning group** and the **MMRP groups**, both involving human participation.

The computer lab equipment necessary for the carrying out of the learning experiments, shown in Figure 4-6, was set up with Internet access and all the required software:

- Unity.
- USBWebserver.
- WIRESHARK (the software used in the conventional learning group. More detail follows in 4.3.1.)



Figure 4-6: The lab software

The learning activities were all designed around the Mayes & Fowler learning phases [30], introduced in 2.2. These emphasize the importance of both the instructive and the constructive

approaches in conceptual learning and goal achievement. They describe the learning process as a cycle of three stages:

- ‘*Conceptualisation*’: where the learners will be introduced to the targeted subject through educators or experts in the same field.
- ‘*Construction*’: the learners will apply what they have learned in the last stage through learning tasks and activities.
- ‘*Dialog/Application*’: the learners will discuss among themselves to reflect on what they have learned.

As such, all participants were first briefly introduced to the network protocols in class, to adhere to the first stage of the learning cycle, and then required to fill out a pre-survey, see Appendix A.2, before they engaged in the learning activities. Then, they were divided up and assigned to groups to participate in the learning activities as the second stage of the learning cycle. Pre test-post test instruments were used to measure their knowledge gain.

- Does imitating the action of a technical object in its interaction with other objects in message-passing role-play activity in VEs positively affect learner engagement?
- Does employing the data-driven approach support the framework concept of three levels of generalization which are:
 - Humanized object generalization: The ability to change which object is humanized with respect to the same scenario.
 - Learning task generalization: The ability to change which scenario is ‘played’ with respect to the same subject.
 - Subject generalization: The ability to change the subject/topic being taught.

More detail regarding the participants and the experiments is presented in the next chapter. Questionnaires were used (also explained in detail in the next chapter), alongside verbal

discussions with each participant about the role-play, to obtain subjective feedback and to provide assessments of the students' achievements. An answer was sought to the following research question:

- Does imitating the action of a technical object interacting with other objects in message-passing role-play activity in 3D VW positively affect learner engagement?

To apply the third stage of the learning cycle, a brief discussion with each participant took place after achieving the task to discuss their roles and their overall task achievement.

4.3.1 The Conventional Learning experiment

The conventional learning activities were applied at the control group, *CG*, phase. This phase was implemented to compare the differences in learning affordance and engagement levels between a conventional learning activity and the MMRP role-play activity in order to measure the learning gain and the user engagement. I decided to conduct this phase using the lab software Wireshark [114] as this is one of the tools used to teach network protocols at the University of Jeddah (UJ)¹². Wireshark is a tool that captures the incoming/outgoing packets going to/from the installed device. Figure 4-7 shows the packets captured via a Wireshark interface. A modified lab manual was prepared from the original one used in the network module¹³. The students were instructed to analyse the captured message packets and the operation of the protocols in each layer and record their observations in the manual's response sheet (read more about Wireshark on Wireshark wiki

¹² UJ where the experiment phases took place

¹³ See Appendix for both manuals, the original and the modified.

[115]). After completing the activity, the participants took an online test and filled out the research survey.

4.3.2 The MMRP experiments

MMRP is a tool that generates message-passing role-play activities to be participated in by a user of the RPVE. A student takes on one role among a number of other roles automated by the system

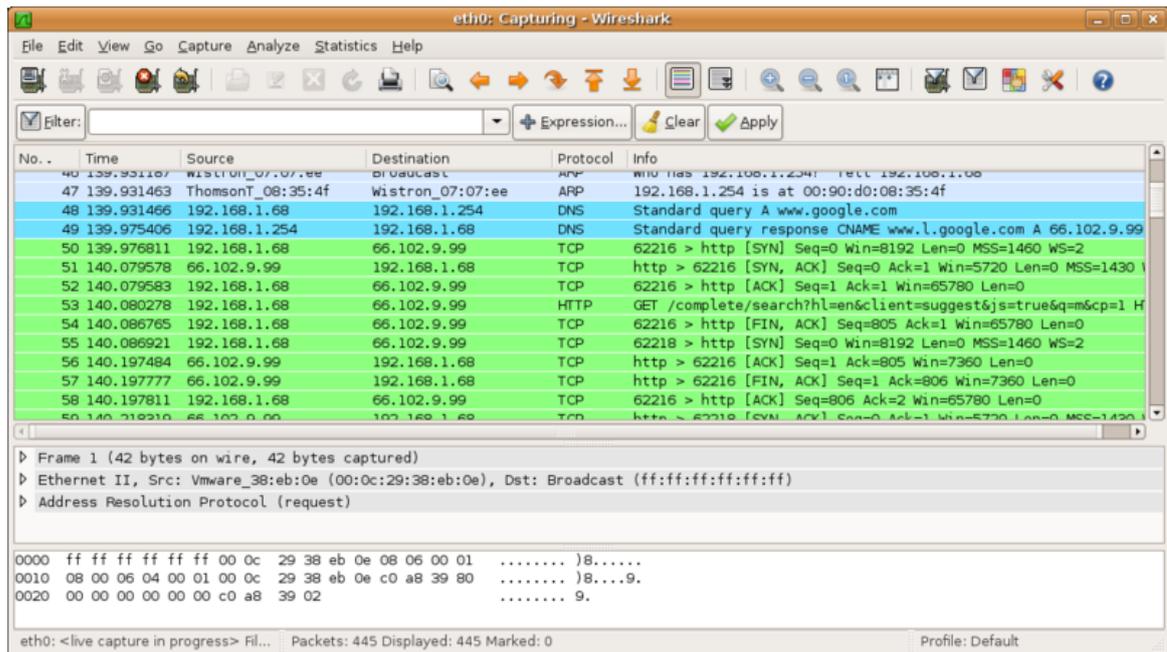


Figure 4-7: Wireshark interface

within a particular learning role-play scenario and then takes turns in sending/receiving messages. The student's role is to imitate an object that exists within the learning scenario and collaborate with the other system objects in the environment to complete a task. In other words, the student's task is to respond to a received message and then send a message to the next object with the next role in the scenario. In this network case study, network layers are the main actors/objects/roles involved in the learning scenarios. The network layer protocols exchange messages with each other to complete a specific given task.

Network Virtual Environment. In a virtual environment, the network layers populate as 3D capsules. These represent the main objects of the learning scenario and interact with each other by passing protocol messages in accordance with a given task. Every layer capsule is surrounded by

boxes representing the protocols of that layer, as displayed in Figure 4-8. As the Internet Protocol Suite (TCP/IP) has five layers in its structure, these are rendered into four capsules plus the avatar that represents the humanized object being controlled by the user. The user is able to change the camera view; this brings greater fidelity to the 3D environment and results in a greater sense of presence [116]. The available view-types are the entire environment's view, Figure 4-8; the user's view, Figure 4-10; and the current object's view Figure 4-9.

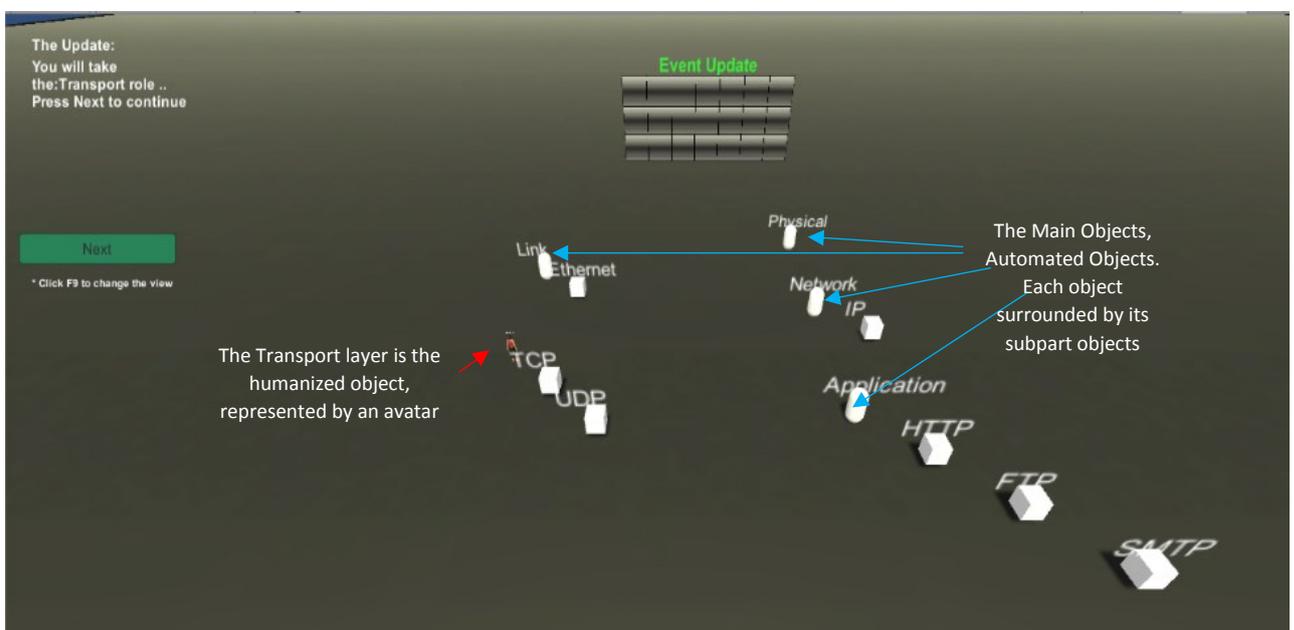


Figure 4-8: The overall environment view. The humanized object is the Transport layer represented by an avatar. The other automated objects (Application, Link, Network, and physical layers) are represented by capsules. Each layer is surrounded by its protocols represented by cubes.

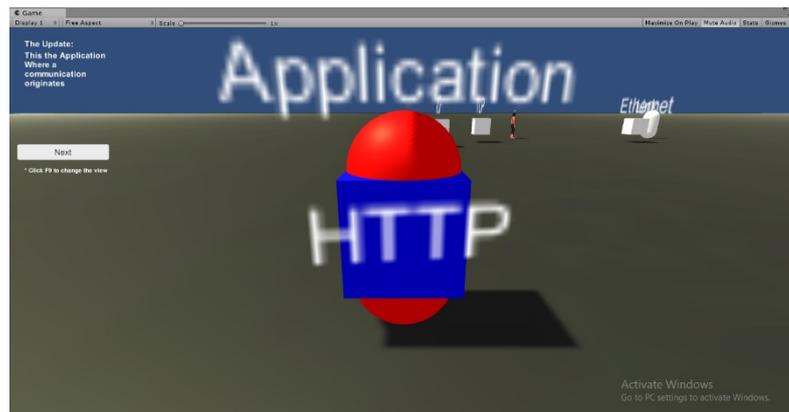


Figure 4-9: The object's view where the Application role is in action and it is automated and controlled by the system.



Figure 4-10: The user's view where the Transport Layer is the humanized object (i.e. the student's role is to imitate the Transport layer).

The Learning Activity

The kind of activity supported by the humanizing of a 'non-human' object, whereby the student imitates a technological system's objects in a virtual world, bolsters their (the student's) imagination and ability to visualize the abstract objects/concepts. The ability to enable the user to observe their role from the point of view of an active avatar in a virtual environment and to change their environment along with the other, automated, objects/roles gives them the impression of embodying the actions of 'their' object; this is one of the 3D environment's learning affordances [29].

In each learning activity, a participant sends and receives messages as part of a role-playing scenario. In the scenarios, the network layers, represented by 3D capsules in the RPVE, interact with each other by passing messages to each other in order to complete selected tasks (such as, to retrieve a web page from a server). A participant takes on the role of one of the layers, and is thus represented by an avatar that is controlled via the keyboard (the layer then becomes a humanized object, as seen in Figure 4-10). This user-controlled layer then interacts with the other layers (which remain under the control of the system, as shown in Figure 4-9). Figure 4-11 shows the life cycle of such a ‘humanized’ object.

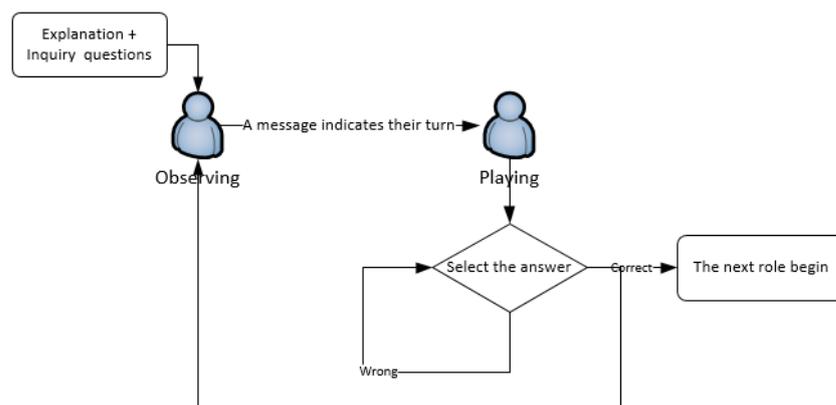


Figure 4-11: The Humanized-object's life cycle

The Unit of Learning

To plot the learning scenarios and the objects' roles and related actions within these scenarios, the role-play activity was rendered into interoperable Units of Learning (UoLs), as shown in Figure 4-12, in accordance with IMS Learning Design (IMS-LD) [117].

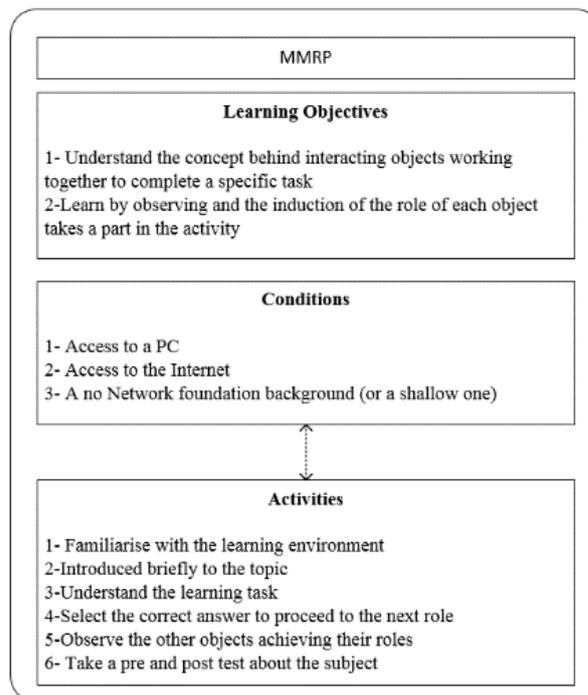


Figure 4-12: UoL

The user actions:

- Observe the other objects undertaking the actions appropriate to their roles.
- Receive messages from the previous layer.
- Choose the correct protocol, based on the received message.
- Deliver the message to the next layer/object.

The return:

- Completion of the role-play activity.
- Achievement of the learning objectives.

If the student merely observes the other objects, they may not obtain the maximum learning benefit from the activity. To deepen the learning benefits, further explanations and questions are displayed on the screen (see Figure 4-13) concerning the student's current role and their predictions of the



Figure 4-13: An example of the update info.

right answers/actions to take; this helps the student to enhance their learning and develop a deeper understanding of the current situation by increasing their engagement [118]. This is also a proven method for improving student learning as it implements the redundancy effect [119] where Mayer & Clark [120] stated, based on the redundancy principle, that learners have better understanding from graphics and on-screen narrations than from relying on just one of them.

This MMRP phase involved three stages and three different groups of participants, *HG*, *SG* and *MG*. These were intended to validate the effectiveness of the MMRP's learning activities, as well as that of the first two generalization levels. The three stages were:

– **Fixed scenario, varying humanized object - *HG*:**

The participating students each took part in three MMRP generated role-play activities that shared the same scenario, but in which the object to be “humanized” varied, as displayed in Figure 4-14. This validated the first generalization level of the MMRP:

“Humanized object generalization: The ability to change the humanized object with respect to the same scenario.”

In addition, this phase was intended to evaluate the effectiveness, in terms of the student's learning, of changing the humanized object across three runs of the same scenario.

The learning scenario was based on the protocols used, at each layer, for “web browsing”. The humanized objects were the transport layer, the application layer, and the network layer of the client side (the sender).

The task was “to choose the correct protocol and compose the messages to be passed between the layers based on the requested task.”

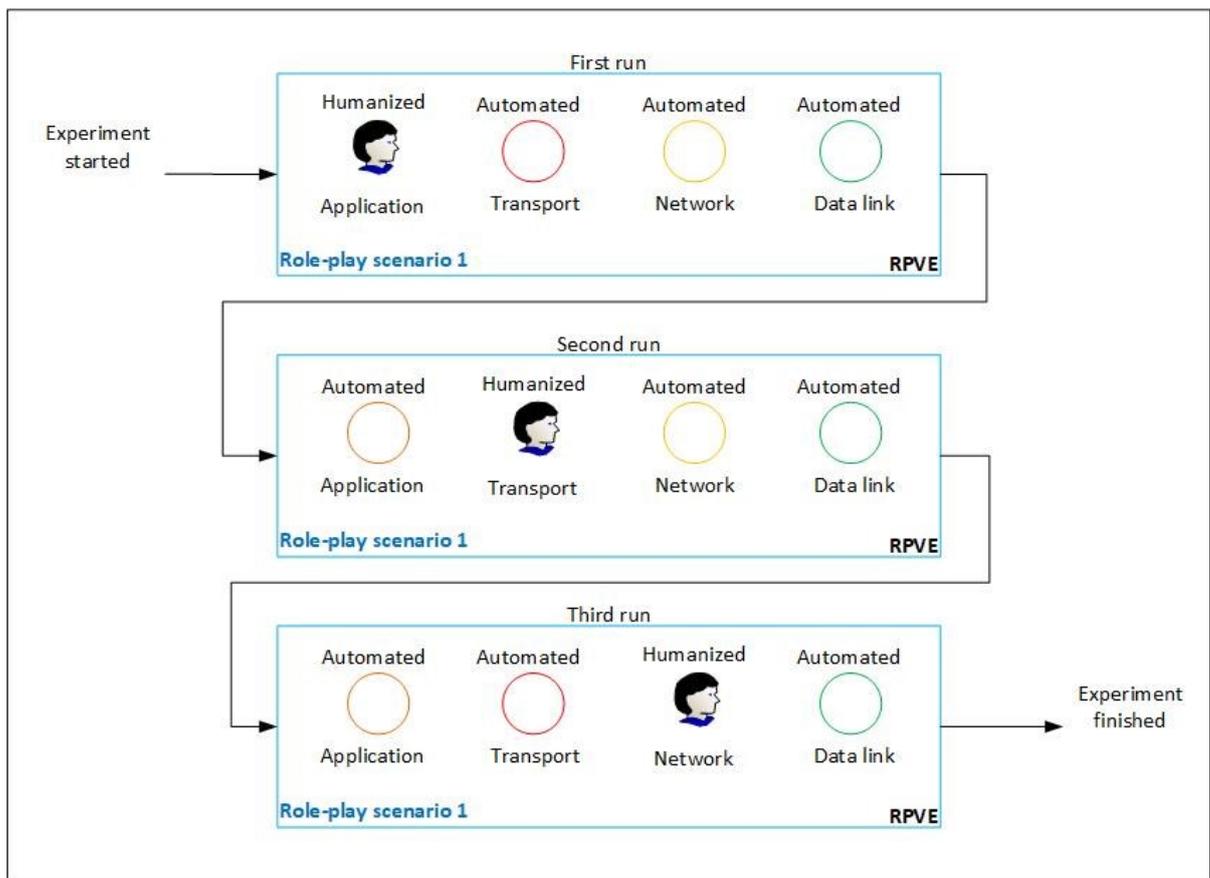


Figure 4-14: The three runs for the HG participant

– **Fixed humanized object, varying learning scenarios - SG:**

Each participant played the same humanized object role across three different scenarios, as displayed in Figure 4-15. This was designed to validate the second level of framework generalization:

“Learning task generalization: The ability to change the scenario simulated with respect to the same subject (i.e., the same database).”

Three sessions were participated in by each student. Each session represented a different scenario, but in each, the user/student took on the role of the same object.

The different learning role-play scenarios used were, respectively: the protocols for web browsing; retrieving a file; and retrieving an email. The humanized object each time was the transport layer.

The task was “to choose the correct protocol and compose the messages to be passed between the layers based on the requested task”.

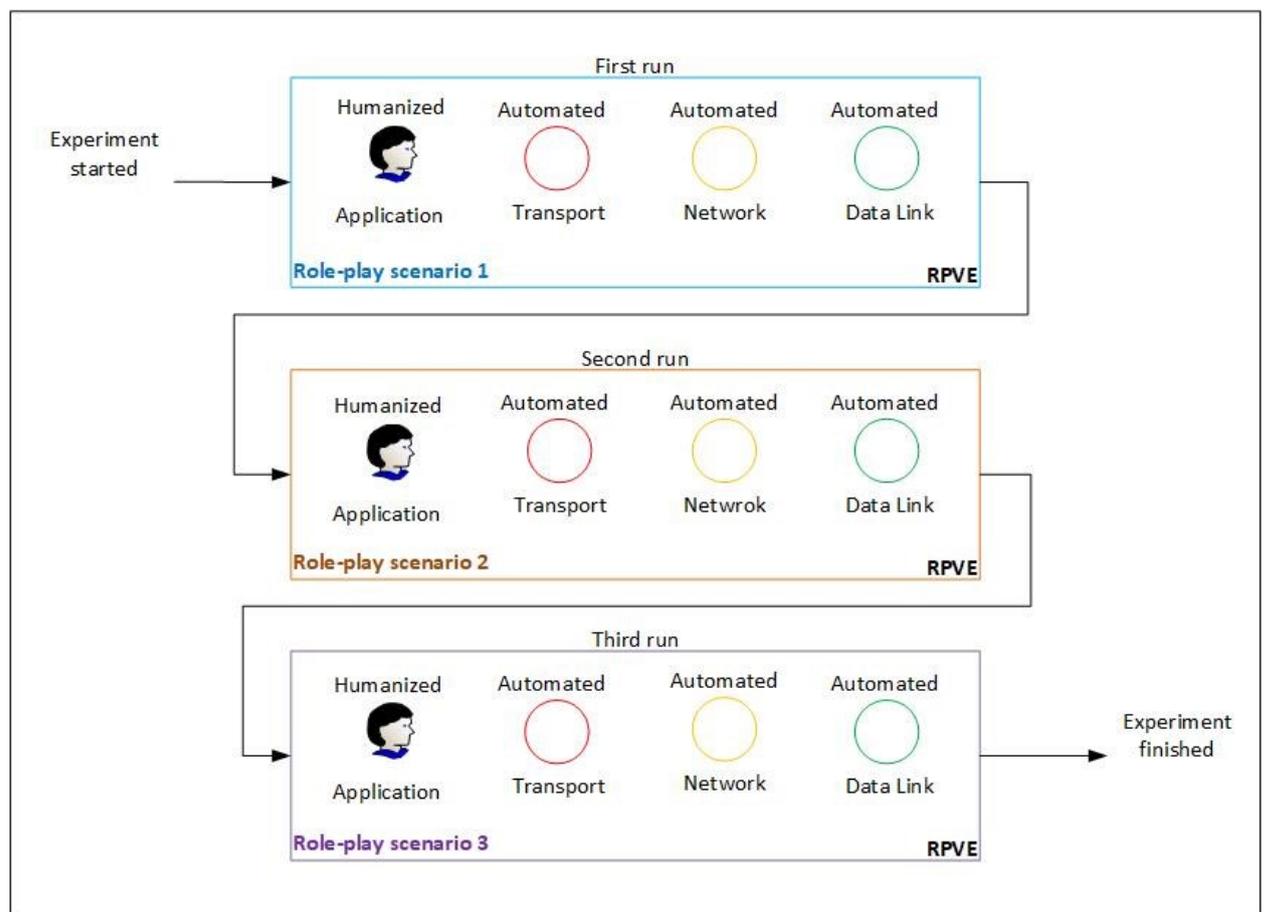


Figure 4-15: The three runs for the SG participant

– **Mixed: varying the humanized object and varying the learning scenario - MG:**

In this stage, each participant took three different humanized object roles across three different scenarios, as displayed in Figure 4-16. The ability to support this endorses the flexibility of the MMRP framework in terms of generating role-play activities.

Again, the learning scenarios were concerned with the protocols for web browsing, retrieving a file, and retrieving an email. The humanized objects “inhabited” by the user in each of these scenarios were the application layer, the transport layer, and the data link layer. The task was “to choose the correct protocol and compose the messages to be passed between the layers based on the requested task”.

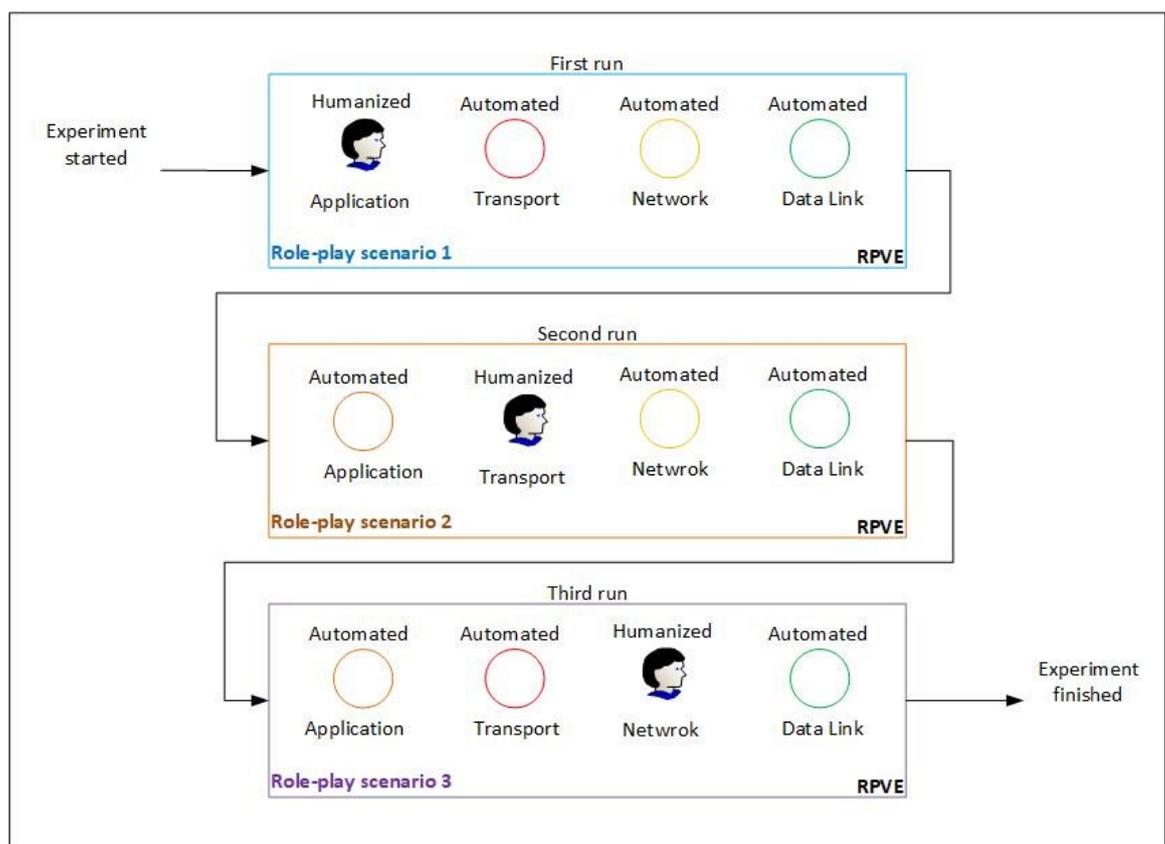


Figure 4-16: The three runs for the MG participant

4.4 FSM Topic: Change the database to deal with a new subject

MMRP is relevant for any subject or topic which can be taught via message-passing role-play scenarios. The third generalization level of the framework, subject generalization, was validated in this phase.

“The database is alterable, under specific guidelines, such that it can be configured to generate role-play simulations other than the one (prototype simulation) related to networking.”

Thus, MMRP was used to generate an entirely different set of role-play scenarios. The pedagogical subject of these scenarios was that of finite-state machines. It could be said that computational theory is grounded on the concept of the finite state machine (FSM), and as it is possible to implement an FSM as an object (humanized and otherwise) by the use of the facilities already present in MMRP, the teaching of the nature of FSMs represents a natural target for this technology. An FSM is, as the name suggests, a machine that can exist in only one of a finite number of predetermined states. An FSM, at a particular point in time, can only receive an input symbol and then, depending on this input, output a symbol (which may be null) and then transit to another (or back to the same) state.

“A finite-state machine $M = (S, I, O, g, s_0)$ consists of a finite set S of states, a finite input alphabet, I , a finite output alphabet, O , a transition function, f that assigns to each state and input pair a new state, an output function g that assigns to each state and input pair, an output, and an initial state s_0 ” [121].

4.4.1 MMRP Implementation of FSMs

The only subsystem requiring modification for this implementation was the *Simulator*, and then only in terms of the data in the attached database. To build the FSM database, the CRC cards were first filled-in as follows:

- The FSMs' various *States* were represented as main objects.
- The elements of the *Input alphabet* $\{0,1\}$ became the subpart objects, with message passing occurring between the main objects and the subpart objects.
- The *Outputs alphabet* was represented in the "Does."
- The *transition function*, f , represented the collaboration
- The *Outputs function*, g , became the responsibility of each object or what that object knows.

For the simulation, the data was retrieved by the MMRP to generate FSM-focused activities; this resulted in an FSM-focused virtual environment. Figure 4-17 shows the FSM RPVE. It shows the humanized object (the student's role) is represented by an avatar. The other states of the FSM are automated and controlled by the system and represented by capsules. Each state is surrounded by cubes labelled (0, 1).

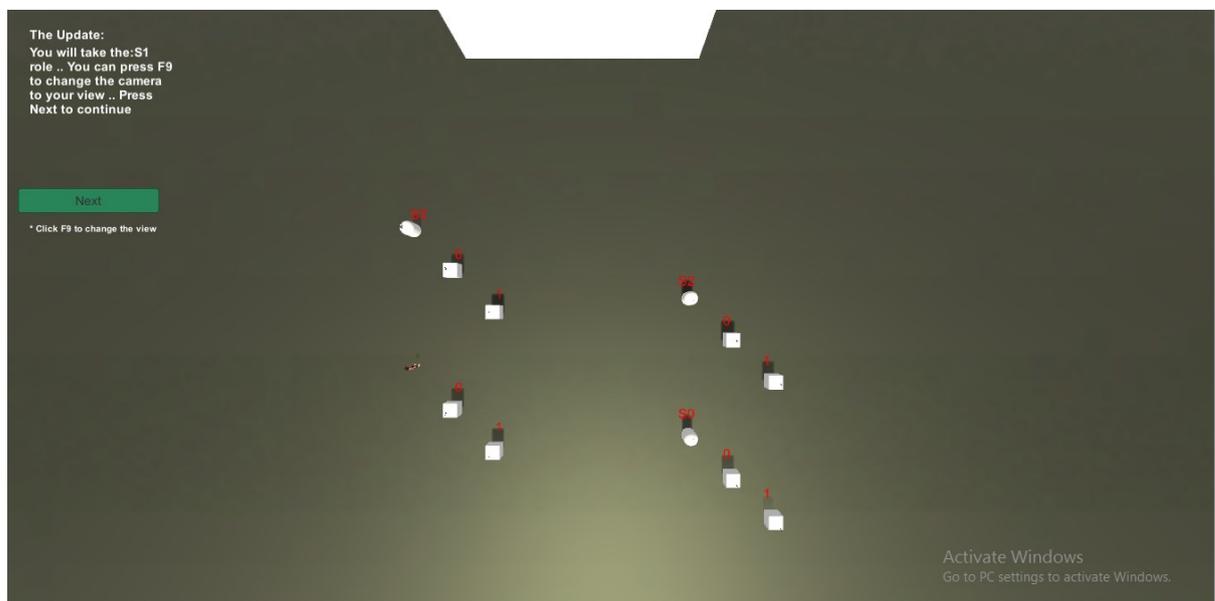


Figure 4-17: The FSM RPVE.

Figure 4-18 shows one of the nMain object's CRC cards. It is one of the subpart objects derived from the S0.

| <u>Class name</u> | <u>ID</u> | <u>Type</u> |
|--------------------------|-----------|-----------------------|
| 1 | 5 | nMain |
| <u>Responsibilities</u> | | |
| <u>Aggregation</u> | | |
| <u>Superparts:</u> S0 | | |
| <u>Subparts:</u> | | |
| <u>Knows/Does:</u> | | <u>Collaborations</u> |
| Knows | | S1 |
| 0 | | |
| | | |
| Does | | |
| 0 | | |

Figure 4-18: An example of an FSM CRC card

This time, the student acts as one of the states. Figure 4-19 shows that the state S1 is the 'Humanized' object controlled by the student. Figure 4-20 shows an automated object controlled by the system. All the objects interact to find the output generated from the input string according to the FSM table.

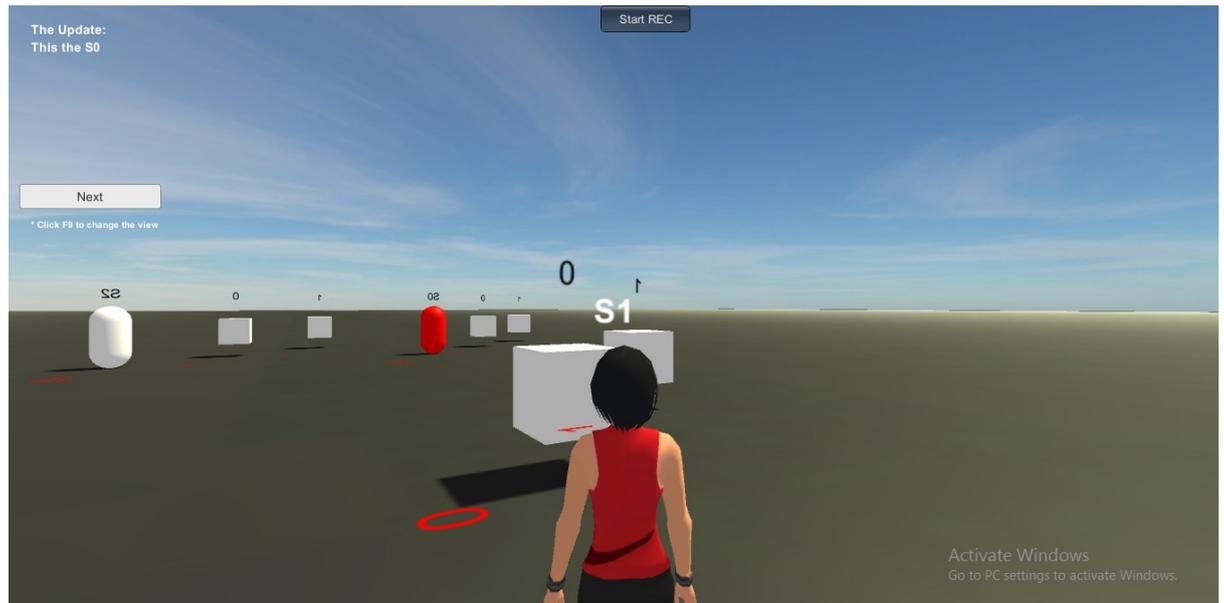


Figure 4-19: S1 is the 'Humanized' object played by the student

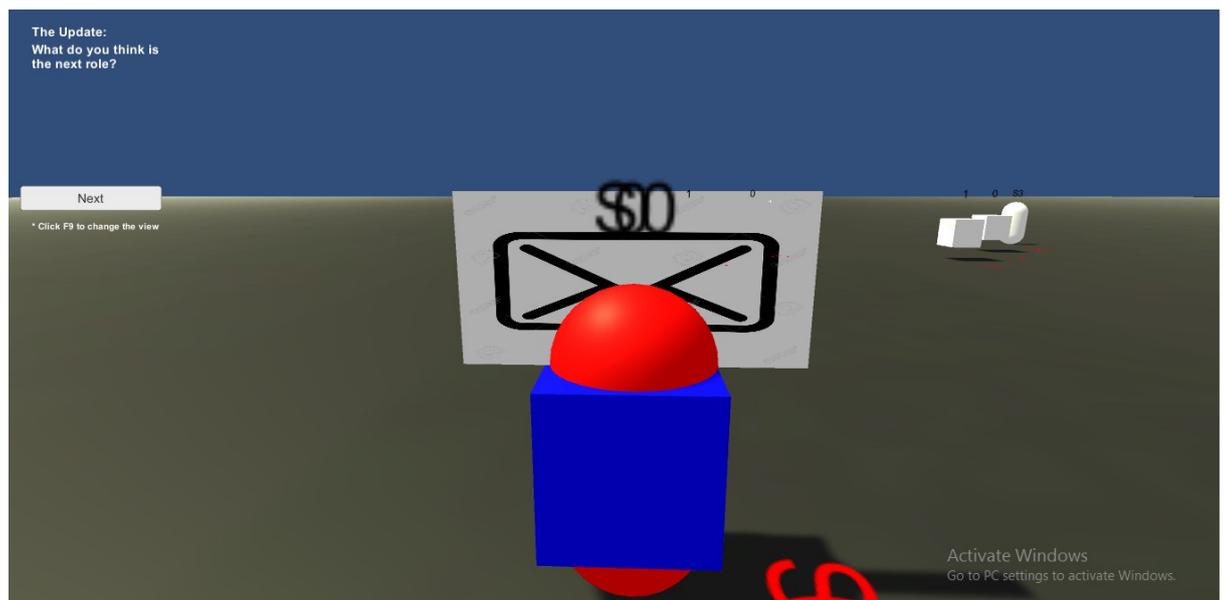


Figure 4-20: An automated object

4.5 Summary

This chapter described the experimental framework used to validate this work's research hypotheses - both the technical and the learning focused elements. The implementation process was introduced and the justification for not implementing one subsystem, the *Instructor Interface*, in terms of the limited time available for completing this PhD, was discussed. Then, in order to

validate the first two levels of the generalizations underlying the MMRP framework, as well as the learning effectiveness of this framework, the network learning case-study was conducted using two main phases:

- The conventional learning phase.
- The MMRP phase with three stages:
 - Fixed scenario, varying humanized object – *HG*
 - Fixed humanized object, varying learning scenarios – *SG*
 - Mixed: varying both the humanized object and the learning scenario – *MG*

The final level of generalization, the subject level, was validated by replacing the network database with the FSM database. In the next two chapters, analysis and results are presented as empirical evidence as to the claims of this study.

Chapter 5

5 The Learning Focused Pilot Experiment: Method and Results

*“You don't learn to walk by following rules. You learn by doing,
and by falling over.”
— Richard Branson*

The pilot experiment that was conducted constitutes a crucial preliminary step towards providing an empirical means of evaluating the study claims as to the instructional merits of the novel role-play learning (MMRP) which was implemented. This chapter is therefore dedicated to describing in detail the empirical measures and procedures that were trialled, and the findings that were obtained (which of course must be taken as provisional, since this is a pilot study). It ends with an account of what was learned from that experience that would inform anyone undertaking this type of validation in the future.

The pilot experiment was designed to support our learning-focused hypothesis and to answer the associated research questions:

Hypothesis:

“Enabling a student to embody an object taking part in a message-passing role-play activity with other objects in a virtual environment leads to better learning outcomes and the

gaining of a more thorough understanding than using other computer-based approaches. This is achieved through enhancing the learner's: Learning engagement "being concerned with all the qualities of an experience"

Learning with MMRP, where the learner embodies the role of a network object through role-play in a virtual environment (VE), will result in better understanding of network concepts and better engagement than learning through other VEs. That engagement is instrumental in the achievement of better understanding.

Research questions:

- Does imitating the action of a technical object in its interaction with other objects in message-passing role-play activity in VEs positively affect learner engagement?
- Does employing the data-driven approach support the framework concept of three levels of generalization, which are:
 - Humanized object generalization: The ability to change which object is humanized with respect to the same scenario.
 - Learning task generalization: The ability to change which scenario is 'played' with respect to the same subject.
 - Subject generalization: The ability to change the subject/topic being taught.

The pilot experiment conducted to test the research hypothesis and answer the previous questions took the form of exposing four different groups of students to the same network information in differing stages, as explained in detail in the following sections. Students in one group (the control group, *CG*) performed a study task not involving role play, while students in the three other groups (experimental groups, *EGs*) participated as human objects in one of three variant MMRP role play implementations to test the generalization levels.

A network knowledge test was administered, along with self-report questionnaires regarding the student's network knowledge and attitudes to the learning methods experienced; I also observed every task session. The pilot research method is described in detail in the next section, followed by a discussion of the results from the experiment.

5.1 Method

5.1.1 Location and Participants

The pilot experiment took place at the College of Computer Sciences and Engineering – Girls' campus (CCSEG), of the University of Jeddah (UJ) in Saudi Arabia (see Figure 5-1). This location was chosen because of the ease of access that it afforded me, in terms of the required resources and the number of students available for participation in the experiment.



Figure 5-1: CCSEG

The 47 participants who volunteered were female undergraduate students studying at the College of Computer Sciences and Engineering – Girls' campus (CCSEG), i.e. all majoring in Computer Science. 51% of them were at their third level of study; 12% were at their fourth; and 37% were at their fifth. It should be noted that one level corresponds to one semester of study. In Saudi Arabia, the students must complete a foundation year (i.e. two levels of their studying)

before majoring. All scientific modules are taught in English. It is worth mentioning that male participants were excluded due to the cultural restrictions prevailing in Saudi Arabia. Males are taught separately, and it was not possible for me, as a female researcher, to access them. Nor was it practicable for me to attempt to train a male assistant to conduct the experiment in the male section of the university on my behalf.

At UJ, the module "Introduction to Computing" is one of the required modules for all CCSEG students at their third level of study (during their first semester as CCSEG students). In this module, a duration of one semester (i.e. thirteen weeks), the students are introduced to fundamental computer science topics (such as: Number Systems, Data Storage, Operation on Data, Computer Networks, and Computer Organization) that will be taught more fully in advanced levels later. One of the set topics of this module is "Network and Internet Protocols", which is given in 6 hours of theory lecturing and 3 hours of practical labs scheduled over two weeks. They are taught the advanced network module only when they are at their sixth level.

The network role-play activities used in the research experiment are concerned with understanding the basic messages passed between the network layer protocols of the Internet Protocol Suite (TCP/IP). For this experiment, therefore, the participant sample had to include students only from levels three to five. Students at higher levels would already have covered this topic in full detail. The experiment started at the end of a fall semester, November-December 2018. By that time all participants had already been briefly introduced to the concept of network layers and protocols in "Introduction to Computing". As I have previously been one of the instructors for this module, and had talked to the current instructors about what the students are taught, I know that time would have been devoted to explaining this topic by the instructor in both lectures and practical lab sessions. The latter are typically spent on exploring the students' understanding and constructing their knowledge by practically addressing problems and questions on the topic. In

addition, for about half the participants, considerable time had passed since they had taken the Introduction to Computing course, allowing forgetting to have occurred.

5.1.2 The Pilot study overall Procedure

Prior to the pilot research study, permissions were obtained from the University of Essex and the University of Jeddah (UJ) to conduct the experiment. Ethical approval of the consent forms and questionnaires (see Appendix) was also achieved.

In UJ, many of CCSEG's instructors, in particular the ones who teach third level students, were contacted and asked to encourage their students to take part in the study's activities. As described earlier in Section 4.3, one of UJ's labs (Figure 5-2) was prepared so that it could provide the required software environment for the learning experiment, including:

- Unity.
- USBWebserver.
- WIRESHARK.



Figure 5-2: UJ Lab

The tasks of the experimental intervention essentially focused on the second stage of the Mays & Fowler model. This pedagogical framework [30], previously introduced in 2.2, emphasizes the importance of both the instructive and the constructive approaches in conceptual learning and goal achievement. They describe the learning process as a cycle of three stages:

- ‘*Conceptualisation*’: where the learners will be introduced to the targeted subject via educators or experts in the same field.
- ‘*Construction*’: the learners will apply what they have learned in the last stage through learning tasks and activities.
- ‘*Dialog/Application*’: the learners will discuss amongst themselves to reflect on what they have learned.

The intervention period was therefore timed near the end of a semester, so as to ensure that all the learners, including those at the third level, had been previously introduced in lectures to the concepts of network layers and protocols - via the module, "Introduction to Computing".

The forty-seven participants were divided randomly into four groups — the Control Group (*CG*) to perform traditional non-role play tasks, and the three experimental groups (*EGs*) to experience different variants/phases of MMRP: the Humanized Group (*HG*), Scenario Group (*SG*) and Mixed Group (*MG*), as detailed earlier in Chapter 4.

First, I presented to each participant a summary of the study topic, the aim of the study, the participant’s role, their rights and what was expected from them.

Next, each one was asked to sign a consent form and complete the pre-questionnaire about their demographic background and prior network knowledge. Next followed the lab activity, which differed depending on which group the student was in. This was administered and observed throughout by me. Subsequently, a self-reported measure of network knowledge was administered so as to enable the researcher to assess the 'learning outcome' mentioned in the research hypothesis.

Finally, a post-questionnaire was completed by each participant, in which they were required to record their attitudes to the activities. The questions were designed to evaluate participants’ 'learning engagement', as mentioned in the research hypothesis, and to answer the question:

- Does imitating the action of a technical object in its interaction with other objects in message-passing role-play activity in VE positively affect learner engagement?

5.1.3 The learning stage of the experiment

Care was taken to ensure that all elements of the activities that were not part of what was to be compared were the same for all stages with all groups. This included what was to be learned:

- Understanding of the layering concept in the network structure of the Internet Protocol Suite (TCP/IP)
- Identifying the network layers and main protocols contained in each layer
- Distinguishing some of the roles of each layer and its protocols.

It is worth mentioning that all incidental features of the experimental stages were also kept the same in all conditions, including CG. That included:

- Same time allowed for learning, both in terms of preparation and familiarization time before doing the tasks and time spent on the tasks.
- All students worked individually not in pairs/groups.
- All tasks had clear written instructions, and a clear goal so that it was clear when the task was completed.
- All tasks had the same number of subtasks: three.
- All tasks involved understanding and practice of use of the same content: network concepts (layers, protocols).
- I was present at all times to assist if required and to observe their reactions to the activities.

Therefore, the differences between conditions/phases concerned only what I wanted to test, i.e. the benefits of imitating an object in role-play activities in the virtual environment and the

generalization concept that applied in the MMRP sessions. All good experiments control for factors that are irrelevant to the aim of the experiment but might interfere with the result if not controlled.

5.1.3.1. The conventional learning stage

Twelve participants, the control group (*CG*), engaged individually in a Wireshark [114] activity whereby they were required to detect the captured incoming/outgoing packets on their device. The students' task was to analyse a captured packet message and the actions of the protocols in each layer and record their findings in a lab manual that they had been given beforehand. The manual gave the instructions for how to run Wireshark, and a test run for the Wireshark software (see Appendix A.4). Figure 5-3 shows one of the *CG* participants. It is worth mentioning that the *CG*'s task was designed to use Wireshark in a limited way — observing those incoming/outgoing packets that matched to what had been implemented in the MMRP system and the *EG*'s tasks. This was to ensure that the comparison was as fairest as possible.

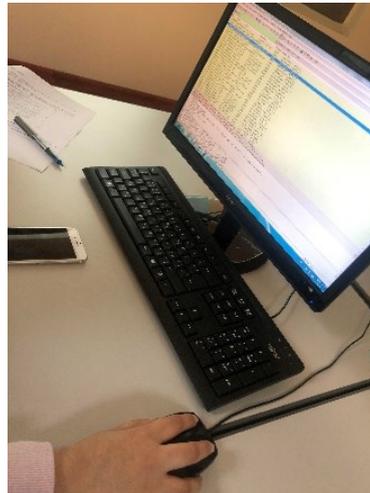


Figure 5-3: Screen as seen by *CG* participant

5.1.3.2. The MMRP experimental stage

As mentioned earlier in section 4.3.2 of the previous chapter, there were three versions of this, relating to the three phases of MMRP, to test the generalization of the MMRP framework and to answer the question:

2. Does employing the data-driven approach support the framework concept of three levels of generalization which are:
 - Humanized object generalization: The ability to change which object is humanized with respect to the same scenario.
 - Learning task generalization: The ability to change which scenario is ‘played’ with respect to the same subject.
 - Subject generalization: The ability to change the subject/topic being taught.

The three experiment versions were administered to one *EG* group and proceeded as follows.

— Fixed scenario, varying the humanized object, *HG*:

Thirteen undergraduate students participated, each individually, in three MMRP generated role-play activities. All these activities had the same, fixed role-play scenario, but in which the humanized object, operated by the student, was varied. This therefore implemented the first generalization level of MMRP: *“Humanized object generalization: The ability to change which object is humanized with respect to the same scenario.”*

The purpose of this stage was to evaluate the effectiveness, in terms of the student’s learning, of changing the humanized object across three runs of the same role-play scenario. Three devices were loaded with the MMRP platform. Each held the same role-play scenario, which here was imitating the three network layer protocols responsible for “web browsing” in message passing. However, the object to be humanized, out of the Application Layer, the Transport Layer, and the Data-Link Layer, differed between each.

Three students took part in the activities simultaneously then swapped places so that each participant eventually took part in all three versions of the activity.

– **Fixed humanized object, varying learning scenarios, SG:**

The eleven students in this group took part, individually, as the same humanized object, but across three different role-play scenarios each; this was so that the second level of framework generalization could be evaluated: *“The learning task generalization: The ability to change the scenario presented with respect to the same subject”*.

These students undertook three role-play activities, each time embodying the same humanized object, the Transport layer, but within different scenarios. These scenarios simulated the protocols used in each layer for “web browsing”, “retrieving a file”, and “retrieving an email”.

– **Mixed: varying humanized object and varying learning scenarios, MG:**

The eleven students in this group took part, individually, as three different humanized objects, namely the Application Layer, the Transport Layer, and the Data-Link Layer. As each object, they operated across one of three different role-play scenarios, involving the protocols in each layer for “web browsing”, “retrieving a file”, and “retrieving an email”. This was done to test the effect of using the full flexibility of the MMRP framework in generating role-play activities. Each participant therefore undertook just three role-play activities (and so ran the system three times), with a different humanized object and a different role-play scenario each time.

5.1.4 The Pre-questionnaire

As already mentioned, this was administered first. It provided demographic information to allow the researcher to check that the participants belonged to the targeted population, e.g. were not above the fifth study level. Importantly, it also contained a question asking them to rate their network knowledge on a three-point scale, see Table 5-1. It is normal in any learning experiment

experiment was based. I used the self-report of knowledge and post-test as two measures that, together, can be used to assess the learning effectiveness of any intervention.

Table 5-2: The Post-test

| | | | | |
|--|--|---------------------------------------|--|---|
| Student number: | | | | |
| Q1. The TCP/IP model has five layers: | <input type="checkbox"/> True | | <input type="checkbox"/> False | |
| Q2. The _____ layer of the TCP/IP protocol suite provides services for end users. | <input type="checkbox"/> data-link | <input type="checkbox"/> transport | <input type="checkbox"/> application | <input type="checkbox"/> physical |
| Q3. The _____ layer of the TCP/IP protocol suit transmits a bit stream over a physical medium. | <input type="checkbox"/> data-link | <input type="checkbox"/> transport | <input type="checkbox"/> application | <input type="checkbox"/> physical |
| Q4. Which of the following is an internet application? | <input type="checkbox"/> electronic mail | <input type="checkbox"/> remote login | <input type="checkbox"/> file transfer | <input type="checkbox"/> all of the above |
| Q5. _____ is a protocol for e-mail services? | <input type="checkbox"/> FTP | <input type="checkbox"/> SMTP | <input type="checkbox"/> TELNET | <input type="checkbox"/> HTTP |
| Q6. _____ is a Transport layer protocol? | <input type="checkbox"/> HTML | <input type="checkbox"/> IP | <input type="checkbox"/> UDP | <input type="checkbox"/> Ethernet |

5.1.6 The Post-Questionnaire

The post-questionnaire measured the students' engagement through both closed and open response items after the tasks were completed. It was administered via an online survey using *Google Forms*¹⁴, an online application provided by Google that allows for the creation of questionnaires using a range of question-type options, from multiple choice to drop-downs to linear scales. The responses to such surveys are automatically collected by Forms, with statistics concerning the responses displayed as a chart in real-time.

The post-questionnaire drew on two areas of previous research for its items and variables: user acceptance and user engagement. We describe each of these in turn.

- User acceptance

It is common in the development of any new software to assess user acceptance (UA) in some way, as a means of validation [122]. This is no less true for validating the fidelity of MMRP as a pedagogical RPVE. The role-play activities generated by the MMRP act as visualization tools in the virtual environment that are claimed to assist in learning. However, we need to tap the opinions of users as part of any evaluation of the actual benefits that this tool affords. Perceived usefulness and perceived ease of use are the two factors that influence acceptance according to the

¹⁴ <https://www.google.com/forms/about/>

Technology Acceptance Model (TAM) [122]. In order to evaluate this study's learning tool, I therefore utilized part of the same UA evaluation measures, see Table 5-3, that were used for evaluating VirPlay3D2 [20] (a visualization tool for learning Object Orientation) as it is one of the foundational works that this project is built on. The other engagement scales used are explained below. Focusing largely on the ease of use of the application, the survey went as follows:

Table 5-3: User Acceptance items

| CODE | QUESTION |
|------|--|
| UA1 | I understand the interaction between the environment's objects very well |
| UA2 | I enjoy playing my role alongside the other objects |
| UA3 | The MMRP platform was easy to use |
| UA4 | Access to the information was easy |

The three experimental groups (*HG*, *SG*, and *MG*) were asked to respond to these items so as to measure the acceptance of the software. They did so via a five-point Likert scale which asked the participants to rate the system in relation to their experience of using it (1 = 'Strongly disagree' and 5 = 'Strongly agree').

- **User Engagement**

The User Engagement Scale (UES) (Table 5-4) proposed by O'Brien & Toms [24] was extended by Wiebe [23] into a new self-reporting instrument for measuring the level of engagement experienced by the user of a game-based environment. This (Wiebe's) extended instrument was used here since the simulation is indeed game-based and it seemed an appropriate measure of learning engagement and role association, which our hypothesis requires us to assess to answer the question "*Does imitating the action of a technical object in its interaction with other objects in message-passing role-play activity in VEs positively affect learner engagement?*"

It consists of four subscales:

Table 5-4: The Engagement Subscales

| CODE | CONSTRUCTS |
|------|---------------------|
| FA | Focused Attention |
| PU | Perceived Usability |
| AE | Aesthetics |
| SA | Satisfaction |

Every participant in the present study was required to respond to this part of the questionnaire once they had completed their learning, using whichever environment they had been assigned to. This part of the post-questionnaire included 23 items as follows:

- The Focused Attention (FA) items (Table 5-5) measure how absorbing the task was, in terms of a positive emotional effect.

Table 5-5: FA items

| CODE | QUESTION |
|------|--|
| FA1 | When I was doing the activity, I lost track of the world around me |
| FA2 | I was absorbed in my task |
| FA3 | I blocked out things around me when I was doing my task |
| FA4 | I was so involved in my task that I lost track of time |
| FA5 | The time I spent participating in the activity just slipped away |
| FA6 | I was really drawn into doing the tasks |
| FA7 | This activity experience was fun |

- The Perceived Usability (PA) items (Table 5-6) measure how difficult the task was, in terms of a consequently negative emotional effect.

Table 5-6: PA items

| CODE | QUESTION |
|------|---|
| PU1 | The experience was demanding |
| PU2 | Many times during the task I just wanted to give up |
| PU3 | Using the software was mentally taxing |
| PU4 | I felt annoyed while doing my task |
| PU5 | I found the software confusing to use |

- The Aesthetics (AE) items (Table 5-7) measure how pleasing the visual aspects of the task were.

Table 5-7: AE items

| CODE | QUESTION |
|------|---|
| AE1 | The screen layout of the software was visually pleasing |
| AE2 | The software interface appealed to my visual senses |

- The Satisfaction (SA) items (Table 5-8) measure how interesting and so how motivating the task was.

Table 5-8: SA items

| CODE | QUESTION |
|------|---|
| SA1 | I felt discouraged many times while on the activity |
| SA2 | I would continue doing this activity out of curiosity |
| SA3 | This experience did not work out the way I had planned |
| SA4 | The content of the software incited my curiosity |
| SA5 | My experience participating in the activity was rewarding |
| SA6 | Doing the activity on this software was worthwhile |
| SA7 | I felt interested in doing my task |
| SA8 | I would like to do another task again using this software |

All of these items employed a five-point Likert scale (i.e., 1 = ‘Strongly disagree’, 3 = ‘Neutral’ and 5 = ‘Strongly agree’) to measure how the participant perceived their experience of computer-based learning. The items were modified slightly for use in this study context (for example: original FA item, “When I was playing the game, I lost track of the world around me,” was modified to “When I was playing my role, I lost track of the world around me.”).

5.1.7 The Observation

During the study I observed all the learning task sessions. I made notes, particularly focusing on the degree of apparent interest and engagement shown by the students. These were used in conjunction with the students’ post-questionnaire responses to determine the results of the study.

5.1.8 Reliability of instruments

Internal reliability, assessed using Cronbach's alpha, was measured for the network knowledge test, as well as in relation to each of the five subscales of the post-questionnaire. Within each of

these, given that each survey item is designed to essentially assess one central aspect, reliability should be high (ideally 0.7 or better, on a 0-1 scale).

The internal reliability check of the six network knowledge test items yielded a Cronbach alpha of .550, which is middling rather than excellent. If we look in detail at the SPSS output¹⁵, we can see that this is because items 1 and 4 were rather different from the others, in that they were much easier to answer correctly (as evidenced by the mean score: if 0 is wrong and 1 is correct then a mean/average of .87 for item 1 is quite high). However, we judged that it was still appropriate to retain these easier items, since they were definitely measuring network knowledge.

We move now to the post-questionnaire. First, items such as SA1 and SA3, which were worded in an opposite way to the other SA items, as shown in Table 5-8, had their scores reversed so that a higher number on this subscale always indicated a greater degree of satisfaction.

Next the internal reliability of each subset of items was checked using Cronbach's alpha (Table 5-9). This showed that all four of the engagement scales exhibited high reliability ($>.7$), thus confirming that, as their designers had no doubt planned, the items within each scale were worded so as to tap into one consistent idea or construct representing that scale as a whole.

By contrast, the user acceptance (UA) scale showed only moderate reliability ($<.7$), see Table 5-9, having been weakened in particular by the item, UA1. This was possibly because this item concerned understanding, whilst the other three UA items asked about ease of use and enjoyability. Thus, this scale could not measure 'one thing' as clearly as the engagement scales could. Omitting that item, however, would have only raised the alpha to .543, so we left it in. A further aspect that differentiated the UA from the other scales and perhaps damaged its reliability was that it was only used with the *EG* participants, since two of its items were worded specifically in relation to features of the MMRP experimental stages. Hence fewer responses were available.

¹⁵ See appendix

Table 5-9: Reliability of the attitude scales

| SCALE | CONCEPTUAL FOCUS | N OF RESPONDENTS | N OF ITEMS | CRONBACH ALPHA |
|-------|---|------------------|------------|----------------|
| PU | How difficult the task was, with consequent negative emotional effect | 47 | 6 | .720 |
| FA | How absorbing the task was, with positive emotional effect | 47 | 7 | .712 |
| AE | How pleasing the visual aspects of the task were | 47 | 2 | .821 |
| SA | How interesting and so motivating the task was | 47 | 8 | .730 |
| UA | How understandable and easy to use the MMRP task was | 35 | 4 | .514 |

Overall the reliability is good, so in that respect I trust the findings from these scales. I believe that the lower reliability from the UA scale is explicable from its nature, i.e. that its items are designed to measure complementary constructs rather than one single construct. That sufficiently explains its low reliability as measured by Cronbach's alpha. In essence, it is a limitation of Cronbach's alpha that it cannot fairly measure reliability in such a case.

5.1.9 Data analysis

For the network knowledge test we calculated an overall score for each person by adding up their scores for each of the six items, displayed in Table 5-2, and later compared the groups based on these individual sums. In the post-questionnaire we calculated each participant's mean score for each of the five subscales, across all its component items. This was then rescaled from a 1-5 to a 0-4 scale.

The distributions of these summary scores for each attitude scale were then checked for normality of distribution. The Kolmogorov-Smirnov test showed that one third of the data departed significantly from what would be expected in a normal distribution. Given that, in addition, the agreement response scale used was arguably more ordinal than interval in nature, we therefore chose to employ non-parametric statistics for all inferential tests, since normality of distribution is not a prerequisite for these. The implication of this is only that there is a slight increased likelihood

of a type II error, which is where a difference that is actually significant is reported as non-significant.

5.2 Results

5.2.1 Learning effectiveness

Outcome scores

Our hypothesis requires us to assess whether 'better learning outcomes' were indeed obtained with MMRP, as predicted, or with the non-role play method used by the *CG*. The scores from the network knowledge post-test are the best measure of final knowledge and we can see (Table 5-10) that the control group did worst, as we had expected, with an average score of less than half the test items correct (3) and with no individual scoring full marks. The *HG* does best, with a mean of 4.6 out of 6 (or 77% correct), and with no individual getting less than three items correct.

Table 5-10: Descriptive statistics for the four groups on post-test network knowledge

| | | N | Maximum | Minimum | Mean | Standard Deviation |
|-------|----|----|---------|---------|------|--------------------|
| Group | CG | 12 | 4.00 | 1.00 | 2.42 | .90 |
| | HG | 13 | 6.00 | 3.00 | 4.62 | 1.12 |
| | SG | 11 | 6.00 | 1.00 | 3.73 | 1.68 |
| | MG | 11 | 6.00 | 1.00 | 3.45 | 1.69 |

In order to assess whether the differences in knowledge between the groups were marked enough to be unlikely to be due simply to sampling error, we then applied the appropriate significance tests. The overall comparison of the four groups was found to be significant in terms of the non-parametric Kruskal-Wallis test ($H=13.16$, $p=.004$); which means that at least one pair of conditions differs significantly (= we can reject the null hypothesis that there is no difference). However, the post-hoc paired comparisons between each pair of groups, treating the three experimental groups separately, revealed that this was entirely due to the *CG-HG* difference in

score (= on average 2.2 items) being significant (Mann-Whitney test, with Bonferroni adjustment, $z = -3.72$, $p = .006$). Thus, we can say definitely only that the version of MMRP experienced by the *HG* was more effective than the tasks performed by the *CG*. The extent of the difference was not something that was likely to have been caused simply by the fact that these were small samples of participants. We cannot say that the three runs of the role-play activities, which the *SG* and *MG* took part in, were significantly more effective than those participated in by the *CG*, and descriptively the differences in mean scores were considerably lower than the *HG-CG* difference of 2.2 — *SG-CG*: 1.31; *MG-CG*: 1.03. Had more participants been involved, however, it could have been that more pairs of instructional stages could have been found to be significantly different.

We had not, in fact, expected to find differences between the MMRP groups; *HG*, *SG*, and *MG*. If we treat the MMRP groups as all one group, the experimental group *EG*, we get the result shown in Table 5-11, and the difference between the (now only two) groups is highly significant: Mann-Whitney $z=-3.05$, $p=.002$. That again means that the difference is not just due to the fact that our participants are samples of students and not the entire population of students that we wish to refer to. There is a better than 95% chance that a difference would be found if we were able to test this on the entire population of computer science students that we have sampled. However, this conceals the fact we have just presented above, that it is the *HG* runs that brought about this overall result. It remains necessary therefore to explain why the *HG* version of MMRP might have had such a markedly better effect, which could be a direction for future study.

Table 5-11: Descriptive statistics for the two groups in terms of post-test network knowledge

| | | N | Maximum | Minimum | Mean | Standard Deviation |
|-------|--------------|----|---------|---------|------|--------------------|
| Group | Control | 12 | 4.00 | 1.00 | 2.42 | .90 |
| | Experimental | 35 | 6.00 | 1.00 | 3.97 | 1.54 |

5.2.2 Learning gain

Our hypothesis also predicted that 'gaining.... of understanding', i.e. learning, would be greater in the *EGs* than the *CG*. In order to assess differences in the students' learning, as opposed to their final knowledge states above, we included in the analysis their self-reported levels of knowledge prior to the intervention, rather than just their post-intervention network knowledge scores. The first of these concerned the way in which learning was measured. Normally, in relation to assessment of educational activities, the same test or an equivalent one is used as both the pre-test, before any teaching or other intervention, and the post-test, afterwards, so as to measure the learning gain [123]. In the present case, however, that did not happen in the pilot. First, at the baseline stage before the students had taken any computer courses, I in effect made the assumption that students' knowledge of the network matters that were the target of the research would be zero. It is not unusual for studies to make such an assumption, but it would be more prudent to actually measure student knowledge at that point in case in some way some students had gained prior knowledge. Second, it was important to measure students' knowledge of the targeted information after the students had taken the basic Introduction to Computing course, but before the researcher's intervention with her experiment (more explanation follows in Section 5.3).

First, on their claimed pre-knowledge alone, as expected the four groups did not differ significantly: Kruskal-Wallis ($H=2.40$, $p=.493$). Their overall mean score was 1.79 (on a 1-3 scale). Thus, before the intervention, they were generally claiming, based on their learning from the Introduction to Computing course, to only possess about 40% of the knowledge that they would need for full understanding of network layers and protocols, etc.

Second, we used the ordinal option within the Generalized Linear Model to make comparisons between the post-test knowledge scores, with these self-reported pre-scores included as a

covariate, so that the post-score differences between groups could be assessed taking the pre-scores into account.

With respect to the comparisons between the post-test scores of the four groups, if we control for students' pre-intervention reported knowledge, we obtain a similar overall significance in the differences between the four groups to that obtained above without the inclusion of this control: Wald chi squared = 12.74, $p=.005$. However, once again, a post hoc comparison between the pairs of groups shows that this is entirely due to the difference between *CG* and *HG*: Wald chi sq. = 12.38, $p=.006$. None of the other pairs of groups differ significantly.

If we undertake just a two-group comparison (*CG* (12) vs *EG* - across all 35 students), controlling for the pre-intervention knowledge as reported, we obtain Wald chi squared = 9.28, $p=.002$. This means that even when we take into account that the students reported different levels of prior knowledge of relevant network concepts before the intervention, we still find a significant difference in post-intervention knowledge between *EG* and *CG*. Again, this is similar to the result without the control, and again prompts explanation as to why the *HG* stage should be mainly responsible for this *EG* superiority.

In order to obtain a clearer, if somewhat approximate, picture of the gains in each group we can rescale both the pre-intervention self-reported knowledge and the post-intervention knowledge score to a % relative to their respective scales and display them as in Table 5-12.

Table 5-12: Descriptive statistics for network knowledge, rescaled to percentage

| | | Estimated % of knowledge of network layers, protocols etc. | | | | |
|-------|----|--|---------------------------|---|---------------------------------|------------------------------------|
| | | N | Assumed before the course | Self-reported after the course, before the intervention | Measured after the intervention | Tentative Gain during intervention |
| Group | CG | 12 | 0 | 29.17 | 40.33 | 11.16 |
| | HG | 13 | 0 | 46.15 | 77.00 | 30.85 |
| | SG | 11 | 0 | 40.91 | 62.17 | 21.26 |
| | MG | 11 | 0 | 40.91 | 57.50 | 16.59 |

This shows that all groups possibly learned more about networks from the initial lectures than from the practice in the intervention. That suggests in turn that the conceptualisation/instructive stage of the Mays & Fowler model of learning is perhaps more crucial for learning than the construction stage.

The figures also show that, descriptively, the *CG* happened to have the lowest level of knowledge before the intervention and the *HG* the highest. However, far greater gains were made by the *HG* than the *CG* during the intervention, even though the *CG* on average had more left to learn, given its much lower self-rated pre-intervention knowledge (average 29% versus 40% or more in the *EG*). Indeed, the order of the four groups on pre-intervention knowledge is matched by that for size of gains during the intervention: $HG > SG$, $MG > CG$. If we look separately at the correlation between pre-intervention reported knowledge and estimated knowledge gain across all participants on an individual basis, however, we find that there is a very strong negative relationship: Spearman $\rho = -.717$, $p < .001$. This negative relationship exists also within the *CG* and *HG* groups separately: *CG* Spearman $\rho = -.918$, $p < .001$; *HG* Spearman $\rho = -.842$, $p < .001$. In other words, students with less knowledge before the intervention regularly make greater gains during the intervention than students with better (self-reported) initial knowledge. Thus it seems that, against a background where, as in many studies of learning, those with less initial knowledge learn more, the *HG* version of MMRP still succeeds in getting *HG* participants to end up with even greater improved knowledge than *CG* participants.

Overall, we can say that the different learning environments did indeed affect the students' learning about network layers and protocols, but in particular the form of learning experienced by the *HG* was significantly more effective than that experienced by the *CG*. Thus, our hypothesis (5.1) is partially confirmed in that it predicted a learning benefit from the three MMRP conditions,

but did not suggest that there would be an exceptional benefit specifically from the stage varying only the humanized object.

5.2.3 User Engagement and User Acceptance

We next consider the results that will potentially support the hypothesis that learning through MMRP enhances 'learning engagement' and 'association with the role of the embodied object'.

The descriptive statistics for the four user engagement (UE) variables and the one user acceptance (UA) variable are displayed in Table 5-13, and Figure 5-4. We consider the three *EG* groups as one in these analyses, since they did not produce significantly different results from each other. Two kinds of inferential test were performed (Table 5-14). The binomial test was employed to assess, for each group and in relation to each variable, whether the group yielded a significantly positive (higher than 2) or negative (lower than 2) response rating in relation to the practice stage that the students had experienced. This was deemed useful to know so that we can assess not just if one group showed greater engagement or other positive attitude than another, but also whether any group exhibited definitely positive engagement or other positive attitude in absolute terms. The Mann-Whitney test was employed to compare the two study groups (*EG* and *CG*) and so assess whether the differences between the *CG* and *EG* are substantial enough to conclude that it is unlikely that they could be due just to sampling error, but more likely that they indicate a real difference in attitude between the groups. Note that the PU variable had items asking about difficulty, so that a negative attitude value indicates a positive attitude concerning the experimental activity.

Table 5-13: Descriptive statistics for the attitude scales

| | | | Maximum | Minimum | Mean | Standard Deviation |
|-------------------------|--------|----|---------|---------|------|--------------------|
| Perceived usability PU | Groups | CG | 3.00 | .83 | 1.89 | .66 |
| | | EG | 3.00 | .33 | 1.52 | .71 |
| Focused attention FA | Groups | CG | 3.00 | 1.43 | 2.39 | .50 |
| | | EG | 3.86 | 1.57 | 2.64 | .63 |
| Aesthetics AE | Groups | CG | 3.50 | .00 | 1.25 | 1.08 |
| | | EG | 4.00 | 2.00 | 2.89 | .71 |
| Satisfaction SA | Groups | CG | 3.88 | .88 | 2.45 | .74 |
| | | EG | 4.00 | 2.00 | 2.94 | .52 |
| User acceptance UA | Groups | CG | . | . | . | . |
| | | EG | 4.00 | 1.75 | 3.23 | .49 |

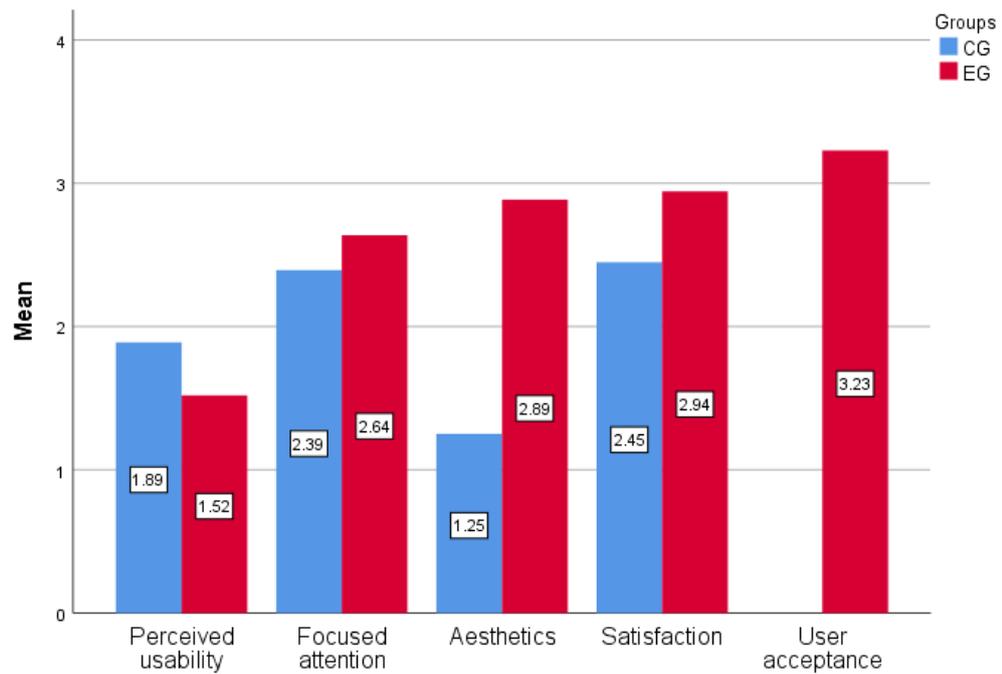


Figure 5-4: Overall attitude scores of the two groups

Table 5-14: Inferential statistics for the attitude scales

| | | | Binomial test | | Mann-Whitney test | |
|---------------------|--------|----|---------------|-------|-------------------|-------|
| | | | higher/lower | p | z | p |
| Perceived usability | Groups | CG | L | .774 | -1.52 | .129 |
| | | EG | L | .001 | | |
| Focused attention | Groups | CG | H | .039 | -1.09 | .276 |
| | | EG | H | .001 | | |
| Aesthetics | Groups | CG | L | .039 | -4.02 | <.001 |
| | | EG | H | .002 | | |
| Satisfaction | Groups | CG | H | .039 | -2.35 | .019 |
| | | EG | H | <.001 | | |
| User acceptance | Groups | CG | . | . | . | . |
| | | EG | H | <.001 | | |

We can see at once that the most positive response of all, and highly significantly above the scale midpoint, was provided by the students in *EG* with respect to the attitude labelled User Acceptance (UA). This attitude focuses on the ease of use and ease of comprehension of the MMRP activities as experienced by the *EG*. The result therefore testifies to this environment's advantages in terms of student approval. However, we do not have a comparable measure yielded by the *CG*. Thus, direct comparison is impossible.

Among the UE attitude subscales measured across both groups, SA and AE were the next highest in positive *EG* response, and again were significantly positive (above the scale midpoint 2). The difference between the *EG* and the *CG* was also significant. As regards SA, which concerns interest and motivation, the *CG* returned a significantly less positive evaluation than the *EG*, though it was still positive. As regards AE however, which concerns visual attractiveness, the *EG-CG* difference was far greater as the *CG* expressed a significantly negative view of the visual aspects of the onscreen displays that they had had to work through. Indeed, this represents the largest difference between *CG* and *EG* in our findings. This is possibly due to the fact that the Wireshark interface that the *CG* worked with was simply the normal output of a utility program generated for use by computer experts to track network activity, and not specially made with any

pedagogical purpose in mind. MMRP, by contrast, had been constructed by the researcher specifically for educational purposes with respect to the Dalgarno & Lee specification to utilize the learning affordance of the 3D virtual environment [29].

Some further evidence of SA and AE arose from the observations of the sessions. It seemed that the students were excited to be taking part in the MMRP activities and looked forward to the next opportunity to do so. In the optional open question field, where the student was asked to add any additional comments regarding their experience, the students commented as follows:

- Five students stated that “More explanations and details should be added to the student’s interface”.
- Five students felt they would have preferred the system to have had better object representation (in terms of more attractive visual appearance).
- Seven students commented positively about their experience. They described how much fun they had had, and that they would not forget the information that they had learnt; one of them said, “It is like we are playing a game!”
- One of the students asked me if she could capture her screen so that she could show people how much fun she had had, as shown in Figure 5-5.
- The other students preferred not to make any additional comments.

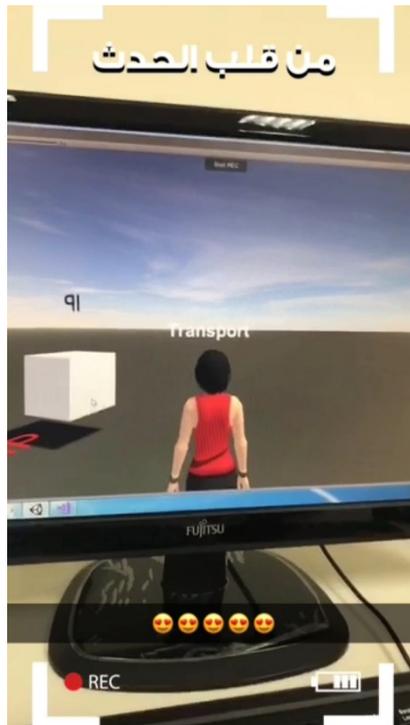


Figure 5-5: A screenshot of an MMRP participant's screen

Finally, as regards FA and PU, the *EG* yielded evaluations which were significantly higher than 2 for FA (the ability to be absorbing) and lower than 2 for PU (difficulty), both of which indicate that this group were positive about the MMRP generated environment that they experienced. However, in these respects, the differences between the *EG* and the *CG* were not significant.

In general, then, the results predominantly but not totally support our hypothesis. With respect to 'learner engagement', the *EG* groups which had experienced MMRP were indeed significantly favourable with respect to all the four UE attitude subscales, and significantly more favourable than the *CG* on two of them (interest and visual attractiveness). Participants were not of the view, however, that the experimental stages were definitely easier or more absorbing than the control stage. With respect to 'association with the role of the embodied object' the *EG* was significantly favourable in UA, one of whose component items refers specifically to playing an embodied object role ("I enjoy playing my role alongside the other objects").

5.2.4 Correlation results concerning the relationships between UE, UA and network learning and knowledge

Finally we return to the fact that our hypothesis (5.0) does not just predict that the MMRP practice phase, using 3D VE, will yield (a) better learning about, and outcome knowledge of, networks than only observing the network conditions using 2D interactive learning resources, and (b) greater engagement and association with the role of the embodied object, but that the former (a) will be 'achieved through' the latter (b). In other words, there should be a relationship between these two types of variables.

First, from what we have already seen (in Sections 5.2.1; 5.2.2 and 5.2.3), there is a broad connection between (a) and (b). However, there is also a mismatch. In this pilot experiment, while MMRP in general (across the three *EGs*) was, in contrast with the *CG*, associated with high scores (especially for three attitudes, *SA*, *AE* and *UA*), it was only the version of MMRP experienced by the *HG* that had a significant impact on learning and outcome knowledge of network concepts¹⁶. The findings therefore suggest that while *SA*, *AE* and *UA*, as produced by MMRP, may have some impact on learning, there is something else, especially present in the *HG* stage, that we did not separately measure but which has a key impact on learning the network concepts.

We would speculate that this relates in some way to the extra separate attention that an *HG* participant pays to network activity and protocols, due to the fact that she is required in the *HG* stage to practice the same role-play scenario but operating different Humanized objects.

It is also informative to consider whether, for all the participants regarded as one group, there is any evidence of relationships between the extents to which they have positive attitudes to learning in whatever stage they experienced, and how well they learned. If so, then we can consider

¹⁶ As it mentioned in 5.1.3.1, that the *CG*'s task was designed to use Wireshark in a limited way — observing those incoming/outgoing packets that matched to what had been implemented in the MMRP system and the *EG*'s tasks to ensure that the comparison was as fairest as possible.

whether the attitudes that show this correlation are the ones prominently positively endorsed by the *HG* participants.

Simple Spearman correlations (Table 5-15) show that FA and AE both had significant positive correlations with performance in the network knowledge test, and SA came very close to being significant in relation to this. This proves how engaging the task was, and hence how much fun it was, along with how visually attractive it was; thus seeming to have had a positive effect on learning. It is notable that perceived ease of use and ease of understanding, as measured by UA, was quite unrelated to learning, but that could be in part because this was only measured for the higher scoring *EG* and not for the *CG*.

This result does not help explain the markedly greater impact of the *HG* stage on learning, however, since the *HG* descriptively had very slightly lower levels of FA, AE and SA than the *SG* and the *MG* and so was virtually the same as them on all three attitudes.

Table 5-15: Correlations between attitudes and post intervention network knowledge

| ATTITUDE | N | SPEARMAN RHO | p |
|----------|----|--------------|------|
| PU | 47 | -.183 | .217 |
| FA | 47 | .335 | .021 |
| AE | 47 | .311 | .034 |
| SA | 47 | .286 | .051 |
| UA | 35 | .060 | .734 |

Finally, it is possible to look to the students' responses to the open questionnaire items for assistance. One of the *EG* students for example stated that she wished she had been introduced to the subject before via the MMRP activities because then, she believed, she would have understood the material more clearly and earlier. However, she did not elaborate on what it was about the MMRP that she thought had the beneficial effect.

Overall then, the part of the hypothesis that predicts what will be responsible for the *EG* superior learning is not fully supported and there remains an open question about what really caused *HG* to do so well.

5.3 Lessons from the pilot experiment

As was stated at the start of this chapter, the research reported here was conceptualized as a pilot study, from which lessons could be learned about the experimental design and the instruments used, so that a fuller and better constructed main study experiment could follow. The results that were obtained from the pilot study about student success and engagement with respect to MMRP (5.2) were very significant and supported my learning claims about the MMRP prototype. However, there are some points should be addressed as the following:

As it materialised, time did not permit me to proceed to a main study stage. However, I report here what I learned from carrying out the pilot, for the benefit of anyone undertaking such a study in future. In particular, as the pilot progressed through data gathering and analysis, I came to realise, with the help of feedback from experts, that there were two areas in which it was non-optimal and which would need to be improved in any follow up main study.

The first of these concerned the way in which learning was measured. In this pilot study, as declared in Section 5.2.2, the learning gain measurement relays the comparison between self-reported knowledge and the post-test, instead of using the same test or an equivalent one as both the pre-test and the post-test. I did perform the comparison but with what, in hindsight, was a rather weak measure: relying on self-report of any relevant courses they had taken and a single item where they estimated what they knew on a three-point scale. Importantly, it was not comparable in a simple way with the instrument used for the post-test. After the end of the experiment, knowledge was assessed with a post-test containing six multiple-choice items which I feel provided reasonable coverage of what they were expected to learn, although the small number of

items may well have contributed to its only moderate level of reliability. Furthermore, it proved rather easy for the participants, due to the fact that it tested only recognition knowledge of the targeted information (through multiple choice items), rather than recall knowledge (through open response items). I would therefore recommend anyone in future to construct a longer test, not entirely consisting of multiple-choice items, and use that test on all three occasions (baseline, post-instruction, post-experiment).

The second area that emerged as in need of improvement concerned the experimental design, specifically with respect to the comparison between the control and experimental groups, and the need to control for 'novelty effect' and the like. A key requirement in any classical educational experiment is that what will differentiate experimental groups receiving a treatment of special interest, from a control group receiving some other treatment (or no treatment), whose effect is not expected to be so great, should be the only targeted difference between the two treatments, and not any other associated feature that would 'confound' the comparison [123]. In the present case a potential unwanted feature was novelty, which for example has often been found to affect how well students learn from, and rate, learning tasks involving new technology versus traditional paper-based materials. For example, Burke & James [124] found that students who perceived PowerPoint to be very novel recorded better learning and more positive attitudes compared with those who regarded PowerPoint as not very novel.

In the pilot study, the researcher had hoped to control novelty through the fact that students would not have had prior experience with either Wireshark (used in the control condition) or MMRP (used in the experimental condition), and that both involved, in a sense, new technology. I was not, for example, making a crude comparison between learning from lectures and learning from MMRP. Nevertheless, two points came to my attention during the study. The first was that possibly a virtual world application has inherently more potent novelty effect than a non-

pedagogical utility program such as Wireshark in ways that were not the focus of the study to assess, so the comparison was from the start loaded in favour of MMRP. The second was that although students all had to run the MMRP program three times to perform the three subtasks required, they were doing this all on one occasion so there was no chance for the researcher to assess how any novelty effect might wear off over a realistic period of time [125].

Moreover, in the pilot it could be argued that my MMRP differed from Wireshark in at least four ways: it involved a virtual environment simulation, it was 3D, it involved role-play, and that role-play had the user take on the role of an object representing an abstract concept. None of those were the case in Wireshark, yet my claim really is not that my MMRP is superior for learning in all of those ways; only the last. As I showed in my literature review (Chapter Two), other studies have already shown one or more of the first three features to be beneficial for learning (i.e. use of VEs, 3D, and role play). Rather, my novel claim is that it is role-play, where the student takes the role of an object that represents an abstract concept in some system, which is superior to role-play of other types in VEs. Therefore a fairer comparison would be of my MMRP with, for example, an implementation using the same virtual environment and scenarios, but where the student took on the role in the virtual environment of simply being an onlooker as the transfer of various packages occurs, not taking on the role of any part of that process. In that case it could be no longer argued that any greater benefit or more favourable attitude might be associated with my MMRP simply because, in comparison with Wireshark, it involved a VE or role-play, or was 3D etc. and might have nothing to do with my specific novel kind of role-play.

Lastly, with respect to the passage of time, I would recommend that a future experiment with my MMRP, in contrast with a control condition as just described, would need to take place repeatedly over a period of some weeks to allow for novelty effect to wear off. In other words, in order to be convinced that my MMRP is indeed superior, we need to be shown that any advantage

of MMRP over the control condition is in fact maintained over a period of time and does not disappear after four or five sessions using the two methods on a variety of content.

5.4 Chapter Conclusion

The analysis of the network knowledge test results showed that there were statistically significant differences in learning and outcome knowledge between the *CG* as opposed to the *HG* - specifically, the students in the *HG*, on average, did far better in the post-tests and acquired three quarters of the target knowledge. However, it was also shown that whilst better results were yielded by the other MMRP groups (*SG*, *MG*), as compared to those yielded by the *CG*, these differences had no statistical significance. By contrast, on the attitude variables it emerged that all the experimental MMRP groups exhibited higher user acceptance of MMRP. Furthermore, they were significantly higher than the *CG* on two of the engagement variables: approval of the aesthetic features and satisfaction/interest. Yet they did not judge the activities to be significantly different from the *CG* in terms of how difficult or absorbing they were. Nevertheless, the positive comments from the *SG* and *MG* participants as well as the *HG*, and the enthusiastic attitudes observed in the students while undertaking the role-play activities, along with the positive statistical results, support the claims of the research hypothesis with respect to the engagement benefits of MMRP. Hence, subject to the caveats described in 5.3, we can suggest that role-play imitating the action of a technical object in its interaction with other objects in message-passing role-play activity in VE does positively affect learner's engagement.

However, it was not possible to find anything in the variables that we measured to explain the higher learning performance of the *HG* above the other experimental groups. As the results showed, contrary to our hypothesis, the *HG* experienced the most effective pedagogical environment out of those experienced by the experimental groups; this was not expected or planned for. The students in the *HG* undertook the same role-play task three times in the same

scenario but embodied a different humanized object (i.e., imitated a different network layer) each time. Assuming that this result re-appeared in a main study experiment conducted with all the improvements described in 5.3, this would need further examination.

5.5 Summary

In this chapter I presented the method used for the pilot experiment to evaluate the learning and engagement elements of the following research hypotheses (and associated questions). The pilot findings were also presented and discussed. Furthermore, limitations of the pilot study method were identified and suggestions made for an improved future experiment.

“Enabling a student to embody an object taking part in a message-passing role-play activity with other objects in a virtual environment leads to better learning outcomes and the gaining of a more thorough understanding than using other computer-based approaches. This is achieved through enhancing the learner’s:

- *Learning engagement: “being concerned with all the qualities of an experience”*
- Association with the role of the embodied object.

In the next chapter, evaluation and validation of the technical element of the hypotheses is presented in detail:

“ - It is possible to create a generalized conceptual framework for the creation of message-passing role-play activities which involve mixed-mode roles whereby some of the object-roles are ‘played’ by the system and some are played by the user – that is, they are ‘humanized’. This can be achieved by adopting a data driven approach such that the data:

- *supports the creation of a role-play virtual learning environment – the objects of which are rendered on the instant (as required), at run-time;*
- and*

- *supports the creation of mixed-mode role-play activities and interaction between the environment's objects.*
- In particular, the data can be represented for retrieval in such a way that this allows the framework to be reconfigured so that the system can be reused for a number of purposes for which a message-passing scenario is relevant.”*

Chapter 6

6 The Technically Focused Experiments: Analysis and Result

*“You can’t use up creativity. The more you use, the more you have.”
- Maya Angelou*

There are two sections to the research hypotheses specifications: the learning and the technical. The previous chapter describes a prototype that was built for the purpose of validating the study claims relating to learning; this chapter describes the process of validating the technically orientated claims:

“The proposed framework acts as a generalized tool for generating message- passing role-play activities which operate within a virtual reality environment; it employs a data- driven approach.”

Specifically, this chapter discusses the validation of the third level of framework generalization, which is:

“The database is alterable, under specific guidelines, such that it can be configured to generate role-play simulations other than the one (prototype simulation) related to networking”

6.1 The Evaluation

After changing the associated database, as explained in Section 4.4, so that it contains information related to the new topic - i.e., after replacing the network database with one focused on FSMs - as introduced in Chapter 4 - three role-play activities generated for the purpose of detecting FSM outputs were tested by three instructors from UJ. These three instructors were chosen to participate in this part of the experiment specifically because of their experience in teaching modules that cover Finite State Machines (FSMs). They participate individually in a role-play activity.

The role-play learning activity:

Looking at the FSM table, Table 6-1, it can be seen that the main task in each activity has the form: “Find the output generated from the input string for the finite-state machine with the specified state table. ‘F’ represents the *transition function*. ‘g’ represents the *Outputs function* ”.

Table 6-1: FSM table

| State | F Input | | G Output | |
|-------|------------|----|-------------|---|
| | 0 | 1 | 0 | 1 |
| S0 | S1 | S1 | 0 | 0 |
| S1 | S2 | S0 | 1 | 1 |
| S2 | S0 | S3 | 0 | 1 |
| S3 | S1 | S2 | 1 | 0 |

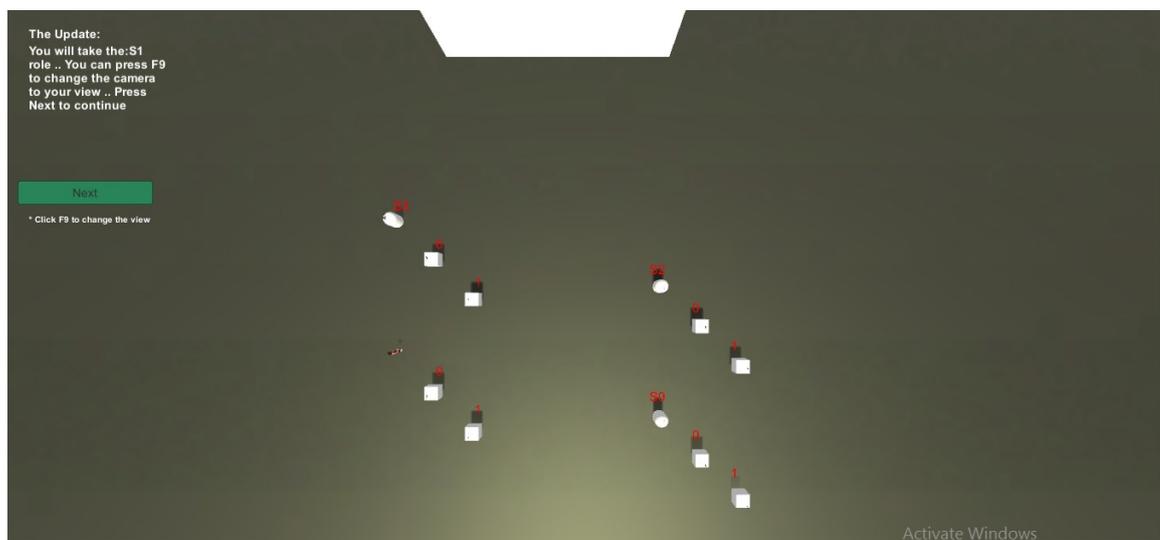


Figure 6-1: The overall view of the FSM RPVE

Following the pattern of the previous unit-of-learning for the network learning case study, the student's actions can be listed as:

- Observe the other objects undertaking their roles.
- Receive the messages from the previous object (state of the machine)
- Choose the correct protocol alphabet element $\{0, 1\}$ based on the received message.
- Deliver the message to the next object (state of the machine).

The return:

- Complete the role-play activity
- Achieve the learning objective.

After achieving the tasks qualitative data was used for this phase because I needed the points of view and relevant insights from experts. Subjective interviews were conducted in order to obtain their observations and reflections concerning the role-play activity generated for teaching the detection of FSM states and outputs, Figure 6-1 shows the FSM RPVE. Questions were asked of the participants to test for the criteria: user acceptance, metaphors, and the usefulness of the information represented in the role-play scenario. They (the questions) were designed to be bases for discussion rather than investigatory, so that the participants were able to feel more relaxed and to talk more freely; this approach provided better subjective information and so ensured the quality of the gathered data [126]. The interviews, which each lasted around 15 minutes were all audio recorded.

6.2 Data Collection

In the main, the transcripts proceeded as follows:

- Brief introduction to the research and the MMRP learning activities.
- The participant enrolled for the role-play activities.

- While they were engaged in such an activity, I conversed with them about their roles, whether they enjoyed carrying out the tasks, the ease of use of the system, the environment and the objects' layout, and any additional comments that they might make.
- Once they had finished, they were asked whether, from their experience, there might be other topics/scenarios which could be transposed into role-play activities generated by the MMRP framework.

Instructor 1

The initial concern that the first instructor had was with regard to the design of the environment: she was strongly of the opinion that more explanatory popups should appear above each state. However, on the positive side, she did believe that the concept behind the learning activities would be very useful in relation to student learning, especially for her 'compiler' module, which was taught, at least partly, in terms of states, similar to those used in FSMs. She also strongly suggested that such learning activities could be used to teach scheduling, as it related to her operating systems module. "The students have so many difficulties in understanding the usage of memory (operating system). If they played role-play scenarios like this (pointing to the FSM ones), it would be much easier for them". She also agreed that the students would have fun while taking part in these activities, "it is a trend that the whole world is obsessed with: using the VR." This instructor was a supervisor for undergraduate students' projects focused on the field of immersive learning. To summarise, the only negative comments she had were that the system could be improved in terms of design and would benefit from the addition of more explanations.

Instructor 2

To start with, this instructor had a bit of difficulty in understanding the concept behind the environment and the interactions between the environment's objects. After these issues and the abstractions employed were clarified she started to use the first activity and had a great many questions about the environment, the role of each object and the other elements of the VR. As she

continued with the activities, she become more familiar with the common steps involved and the VR environment itself. In time she became very passionate about the experiment; she explained about the job scheduler topic relating to operating systems, already mentioned as a difficult topic to teach, and how this could be translated into a learning scenario which would be possible to represent as a role-play activity generated by the MMRP system. At the end, her most pressing suggestion was: “It is better to have multi users playing the roles in the FSM scenarios due to the simplicity of the played tasks.” I took the opportunity to ask the interviewee questions while observing her take part in the role-play activities. She confirmed that she believed that there could be learning benefits from participating in such activities, especially if the improvements that she suggested were taken into consideration.

Instructor 3

This instructor found it relatively straightforward to engage in the first activity because she had a background in gaming and 3D virtual platforms. As with the other two instructors, she recommended that a more visually attractive virtual environment be created. The interactions between the objects were comprehensible, but more explanation could have usefully been included. Overall, however, she was positive about the learning activities, stating that they could help her in her teaching practice. She said, “playing part of the learning scenario gives the student a clearer aspect to envision the abstract concept in a more fun way”. As she became more expert in the field of immersive technology, she asked if it was possible to modify the platform so that it could be used via a headset - to make the students even more immersed in the 3D environment. She suggested the use of the technology employed in the teaching of OO (Object Orientation) as a basis wherefrom other topics could be taught via related role-play activities, generated via MMRP. As, she opined, there are many scenarios that can be arranged into the CRC card structure.

6.3 Discussion, Finding and Results:

The collected data was categorized into meaningful analytical units, as Chenail suggested [127].

The main keywords that were looked for were related to:

- The participants' feelings while they underwent the experiment.
- What their expectations would be, were I to involve students with the same activities.
- Other applications for MMRP generated activities.

These concepts are significant because they are related to user acceptance and satisfaction, and were measured when validating the fidelity of MMRP as a pedagogical RPVE. Moreover, the enthusiasm of the instructors in relation to re-applying the MMRP to create role-play activities focused on scenarios which they, themselves, considered important further demonstrates the capabilities of MMRP as a Pedagogical RPVE.

In terms of the above, all three instructors emphasized how the generated role-play activities could affect student learning in a positive way, in terms of enjoyment - which could support their learning and understanding. They (the instructors) suggested more than one application for role-play scenarios in the computer field. The fact that the three instructors made numerous suggestions for role-play scenarios that could be implemented via the MMRP system supports the idea of that the MMRP framework can be generalized.

However, the major concern raised by the above participants was the design of the VR and its objects. They also advocated that the interface should be enhanced and that the environment should have more informative/explanatory resources added, so that the written lab manual would not have to be used. The weakness of the RPVE was reported by the instructors to be that the objects and sub-parts were confusing in the way they were represented. As the environment of the MMRP platform was introduced for the purpose of validating the thesis hypotheses and not for commercial use, the attractiveness of the design was not one of the priorities of this research. However, one of

my future plans is to research what the most appropriate design would be to render a variety of object representations in a way that would enhance the layout of the 3D environment.

Reading through the transcripts and the findings, it would seem that in the future, there will be a need to interview, and use more role-play scenarios from, outside the computer science field.

The instructors' suggestions can be considered as possible bases for future plans aimed at enhancing the framework and the VE. In their opinions, the MMRP learning activities would support them in delivering the information if they were to be used as per their suggestions. This argues that the third level of generalization has indeed been validated.

Summary

In this chapter, the technically focused experiments, along with their results and the analyses of these, were discussed. The data collected were the qualitative results obtained by interviewing CS instructors from the UJ, as experts. Having been pleased with their trial of the FSM MMRP version, they suggested more examples of learning activity scenarios. This in turn suggests that it is possible to create a generalized conceptual framework for the creation of message-passing role-play activities that involve mixed-mode roles whereby some of the object-roles are 'played' by the system and some are played by the user – that is, they are 'humanized'.

Chapter 7

7 Conclusions and Future Directions

“A lifelong learner is a lifelong winner.”
— *Matshona Dhliwayo*

This research has sought to explore the learning affordances of message-passing learning scenarios rendered in RPVEs - by measuring various factors associated with activities taking place within virtual environments, in particular engagement and user acceptance. Such activities are undertaken here via a mixed-mode process whereby the student embodies one of the environment's objects, subsequently labelled the *Humanized* object, and interacts with other automated objects while engaged in a learning task. In the course of pursuing this goal (of exploration), another goal emerged; namely, that of searching for a novel and simple method of generating such activities (i.e., role-play activities in RPVEs) and then generalizing this method. By ‘generalizing’ what is meant is that the method should not remain limited to only one topic or subject; it should be capable of being adapted to any number of other topics to which message-passing role-play learning scenarios are relevant. This goal was achieved by developing and implementing an architectural model which supports the generation of role-play activities in RPVEs and allows three levels of generalization: *Humanized Object*, *Learning Task*, and *Subject Generalization*. Also, the framework could be employed to prove the learning affordance of such (role-play) activities by measuring related factors such as engagement and user acceptance. In order to achieve these

objectives, first, an investigation of relevant earlier research was conducted (Chapter Two). Then, related pedagogical and technical theories were explored in order to be in a position to correctly structure the architectural model required, MMRP, as detailed in Chapter Three. Chapter Four presented the experimental framework that contained the subsystem implementation, along with network and FSM prototypes. The latter chapter also included a description of how we adapted the necessary learning activities in order to meet the requirements of our experimental design as a means of validating the research hypotheses. In Chapters Five and Six, our findings concerning all the factors measured in relation to both the learning and the technical aspects of the project were described - this involved a description of the experimental phases. Finally, Chapter Seven (this chapter) summarises the overall findings of the thesis and discusses its achievements and the possibilities that exist as regards future studies.

7.1 Summary of Achievements

In this research, the hypotheses posed could be placed into two categories: technical and learning.

Technical element:

1. It is possible to create a generalized conceptual framework for the creation of message-passing role-play activities which involve mixed-mode roles whereby some of the object-roles are 'played' by the system and some are played by the user – that is, they are 'humanized'. This can be achieved by adopting a data driven approach such that the data:
 - supports the creation of a role-play virtual learning environment – the objects of which are rendered on the instant (as required), at run-time; and
 - supports the creation of mixed-mode role-play activities and interaction between the environment's objects.

3. In particular, the data can be represented for retrieval in such a way that this allows the framework to be reconfigured so that the system can be reused for a number of purposes for which a message-passing scenario is relevant.

Learning element:

2. Enabling a student to embody an object taking part in a message-passing role-play activity with other objects in a virtual environment leads to better learning outcomes and the gaining of a more thorough understanding than using other computer-based approaches.

This is achieved through enhancing the learner's:

- Learning engagement: “being concerned with all the qualities of an experience”.
- Association with the role of the embodied object.

To validate all the hypotheses, the theoretical model was constructed to address the gaps in the literature; this literature was found to be generally centred around frameworks which served only one topic in terms of generating role-play activities in VR. The model proposed here is generalized so that it is capable of supporting topics that involve message-passing role-play scenarios - by simply modifying the attached database. Moreover, the generalization capabilities also include the ability to change which object is humanized and the learning task to be undertaken by the student. Applying a data-driven approach is the key factor in the attainment of the required generalizations. In order to apply a data-driven approach, a modified CRC card structure was used as the unifying structure for organizing the data required to generate the learning activities. To render the data into the RPVE, an object container, which is an object-orientated (OO) class structure, is used. Based on the virtuality continuum taxonomy [67], the activity is thus represented in virtual reality. The MMRP activities are generated and rendered in a virtual environment wherein the student role-plays with the environment's objects by sending and receiving messages based on a selected learning scenario. These activities can be used as coursework, thus supporting the student's

learning. To validate the learning affordances of such activities, and the generalization levels of the model, the learning experiments conducted with on different topics: network knowledge and FSM. As the teaching of networking was the fundamental motivation for pursuing this study, a network case study was implemented for validating the learning category of the hypotheses. Both quantitative and qualitative data were collected over these experiments in order to measure the participants' knowledge gain, engagement and acceptance. Although the analysis of the collected data validated the research claims, there were some weaknesses identified as to be avoided in further studies.

7.2 Revisiting the Contributions

The major novel contribution of this research results from its investigation of the learning effectiveness of message-passing role-play activities made available in a virtual environment. At first, our investigation focused on finding an appropriate educational tool for supporting the student learning of abstract concepts; this led to the finding that role-play is a highly effective motivational tool for engaging students in the learning process. Moreover, combining this tool with the affordances of 3D virtual environments leads to additional beneficial outcomes on the student's learning coming into play, as discussed in Chapter 2. However, it was found that there was a lack of studies looking at the conducting of such activities in virtual environments, using structural learning designs. Furthermore, the studies that did cover this area were all exclusive to only one learning topic (each).

In relation to this, one of the primary contributions of this study is the definition of the MMRP model - a conceptual architectural model for technology-enhanced learning methods that embrace role-play within learning-based virtual environments - generalizable in terms of learning topic, learning task and the student's role.

This thesis not only presents evidence to support claims regarding the learning affordances of role-play in virtual environments, RPVEs, it also introduces a novel approach to the generalization of such environments so that an environment can be reused for any number of differing topics – which can be presented via learning scenarios rendered as virtual role-play activities. The generalization capabilities of the MMRP framework are a consequence of the data-driven approach it is based on.

In more detail, the major contributions made by this present thesis can be classified as relating to either technical or learning hypotheses, as follows:

1. The construction of a generalized computational framework (MMRP framework) which generates message-passing role-play activities within an RPVE using a data-driven approach to support the desired generalizations (Chapter Three).
2. The implementation of a prototype system that deployed the MMRP model in order to generate network role-play activities in an RPVE – in order, in turn, to explore the learning affordances of VR for role-play. This prototype was complemented by learning scenarios which were scripted to be executed over four different stages – in order to validate the flexibility of the model and its levels of generalization (Chapter Four).
3. The evaluation of the learning affordances of the role-play activities generated for the RPVE, as well as those of the framework's levels of generalization. This was achieved by comparing the MMRP activities to other computer-based approaches in relation to various kinds of modifications to the database driving the system (Chapters Five and Six).

The first, technical, contribution was the construction of a generalized computational framework (the MMRP framework) which facilitates the generation of message-passing role-play activities within an RPVE and which uses a data-driven approach in order to support the desired generalizations. As part of the data-driven approach, an enhanced CRC card structure for

generating role-play activities was introduced. This MMRP framework was complemented by the implementation of prototype systems, the network and FSM prototypes, which deployed the MMRP model in order to generate fundamentally differing role-play activities for an RPVE – in order to validate the flexibility of the model and the levels of generalization available (Chapter Four).

Other contributions are learning focused and relate to the empirical evidence from a pilot experiment that validated the benefits of this framework and explore the learning affordances of VR for message-passing role-play activities. The implemented network prototype was complemented by learning scenarios which were scripted to be executed over four separate stages. An evaluation of the learning affordances of the role-play activities generated for the RPVE then took place. This was achieved by comparing the MMRP activities to a conventional teaching approach in relation to various kinds of modifications to the database driving the system (Chapters Five and Six). Lessons were learned and suggestions were introduced to ensure the conducting of a more robust subsequent experiment avoiding the limitations of the current one.

Based on the aforementioned contributions, in this thesis we focus on the learning affordance of, specifically, message-passing role-play activities in RPVEs, and more specifically, of mixed-mode role-play activities wherein the student embodies one of the environment's objects and then exchanges messages with other objects in order to complete a particular task. Thus, this investigation should fill the discovered gaps in the literature in this area – relating to the fact that there are few studies concerned with structured learning role-play activities in virtual environments and what studies there are tend to be centred on one case study (i.e., learning topic) only. We have hypothesised that: (1) “It is possible to create a generalized conceptual framework for the creation of message-passing role-play activities which involve mixed-mode roles whereby some of the object-roles are ‘played’ by the system and some are played by the user – that is, they are

‘humanized’”; (2) “*enabling a student to embody an object taking part in a message-passing role-play activity with other objects in a virtual environment leads to better learning outcomes and the gaining of a more thorough understanding than using traditional approaches would do - this improvement is achieved through enhancing the learner’s engagement*”. To test these hypotheses, the study included two aspects of experimentation:

- Learning focused - the network learning experiments, Chapter 5.
- Technically focused – the FSM, Chapter 6.

The learning focused aspect presented an evaluation of the MMRP generated activities through an analysis of the participants’ learning gains, engagement, and user acceptance as compared with participant data yielded by a control group who took part in a conventional learning activity. There were three MMRP stages and these had student participants divided into three groups:

—The *HG* group participated in three runs of the role-play activities - with a fixed scenario, but a varying humanized object. Using this group, the learning affordances were validated and the humanized object generalization - the ability to change which object is humanized with respect to the same scenario – was tested and validated.

—The *SG* group participated in three runs of the role-play activities - with a fixed humanized object but varying learning scenarios. Using this group the learning affordances were validated and the scenario generalization - the ability to change which scenario is participated in (by a fixed humanized object) – was tested and validated.

—The *MG* group participated in three runs of the role-play activities - varying both the humanized object and the learning scenario. This group was used to test and validate the ability of the system to support both generalizations; this testing endorsed the flexibility of the MMRP

framework in terms of generating role-play activities. I also endorsed the learning affordance of such role-play activities.

As we expected, the MMRP groups reported significantly better results in terms of the above measures, despite the weaknesses and limitations in the testing that were discovered during the analysis stage: i.e., the limited sample size, the user acceptance measuring tool and weakness of the leaning gain measurement. More advanced experiments to overcome the limitations and the weakness of the pilot one should be carried out.

However, comparing the results from the individual MMRP groups, it was found that the *HG* analytical results were the only ones which could be identified as statistically significant. More investigation and study could usefully be pursued in order to address the features that affected these particular results.

The technically focused category of hypotheses and the third level of generalization, “*Subject generalization: The ability to change the subject/topic being taught (i.e., the ability to change the associated database)*”, were tested via the DB experimental phase. The associated database was changed from one representing a networking topic to one representing the topic of FSMs - in order to generate FSM-focused message-passing role-play activities. Subjective interviews with three experts were then conducted. They confirmed the effectiveness of these activities in terms of student learning. They also suggested more applications in which the MMRP model could be employed in order to generate learning activities. While investigating learning applications using virtual environments, Dalgarno & Lee [29] pointed out the problems associated with loading the environment with extra detail. The students may become distracted and lose their focus on the main task. In order to respond to this, we were keen to keep the RPVEs generated via the MMRP as simple as possible. Moreover, for the sake of the target generalization (that the model could be employed for several unrelated topics) the environment’s objects were designed in terms of simple

geometric shapes. However, the design chosen was very simple indeed, and this weakened the quality of the RPVE from the experts' points of view.

Ultimately, the significance of the research contributions made in this thesis are centred on the generalization levels of the MMRP framework:

4. Humanized object generalization: The ability to change which object is humanized with respect to the same scenario.
5. Learning task generalization: The ability to change which scenario is used with respect to the same subject.
6. Subject generalization: The ability to change the subject/topic being taught.

These generalizations were achieved by the data-driven approach utilized in implementing this framework. The two major components of the data-driven approach are: the CRC card structure and the object containers.

A further contribution was the empirical evidence of the learning affordances of the role-play activities generated by the MMRP framework.

7.3 Future work

Due to the time restrictions necessarily imposed on this PhD study, in terms of the scope of the study, we covered and considered only those areas which were most relevant to the testing of our hypotheses. However, this meant that there were some gaps and limitations identified from the literature which could not be covered, as well as the limitations in the pilot experiment which affect our findings that need to be addressed in future work; these are as follows:

- Advanced experiments should be carried out to overcome the limitations of the current pilot experiment which are:

- Improving the learning measurement by using equivalent pre-test and post-test instead of using a self-report knowledge.
 - Use a longer test, not entirely consisting of multiple-choice items, and use that test on all three occasions (baseline, post-instruction, post-experiment).
 - Enhance the conventional group experiment and replace the Wireshark with another tool to ensure a fairer comparison between this group and with MMRP groups, for example, an implementation using the same virtual environment and scenarios, but where the student took on the role in the virtual environment of simply being an onlooker as the transfer of various packages occurs, not taking on the role of any part of that process.
 - Extend the experiment period duration to be convinced that my MMRP is indeed superior to the control one.
- Within the system implementation, as described in Chapter 4, the instructor GUI subsystem was overlooked. The choices of learning scenario and humanized object were made at the code level instead of via the instructor GUI because of the development time limitations that determined that this (the full implementation of the GUI) was beyond the scope of the present study. The plan is to complete the implementation of the system at some point in the future, and so include this subsystem.
 - The proof-of-concept MMRP framework implementation was created as a single user system – the single user being a student enrolled in a role-play activity as a humanized object that interacts with other, automated, objects. However, the designing of a multi-user system supporting several humanized objects would result in the MMRP framework being made up to date with the current orientation of collaborative learning.
 - The two case studies employing the MMRP to generate role-play activities are within the computer science field, as are all the experts' suggested applications. However, the level

of model generalization aimed for was such that the model could be expected to be capable of covering topics from other fields, as long as they could be rendered via message-passing scenarios. Thus, it may be interesting to test the MMRP model with topics from outside the computer science field.

- The simple (visual) design of the RPVE weakened the learning experience – as evidenced by the expert interviews and some of the participants’ comments. More investigation should be carried out to find a generalized visual representation capable of representing objects relating to many differing topics and at the same time satisfying the users’ aesthetic requirements as well.
- The proof-of-concept MMRP was applied as an immersive virtual reality technology, but the user controlled this via a 2D interface. However, it might be enlightening to implement a system whereby the MMRP activities could be controlled using VR head mounted gear, as the employment of VR-AR technologies represents the state-of-art in terms of real life representations. The user’s level of immersion and engagement would be the focus of such an extended study.

Appendix

Research instruments

A. 1 Consent Form

Participants Information Sheet

Certification

I, (Enas Jambi) certify that the details of this project have been fully explained and described and my contact details have been provided to the participants for their replies, communications or inquiries.

The purpose of this study

The research is about a generalized pedagogical framework to generate message-passing role-play activity in the 3D virtual environment. In a mixed-mode simulation, the student will take a role among other automated objects to complete a specific task. They will interact with each other by passing messages between them according to the role of the object. This research evaluates the effectiveness of engaging the student in a role-play activity by making them imitate one of the environment's objects.

Do I have to take part?

Your participation is voluntary. I would like you to consent to participate in this study as I believe that you can make an important contribution to the research. If you do not wish to participate, you do not have to do anything in response to this request. I am asking you to take part in the research because I believe you can provide important information to the research evaluation that I am undertaking.

What will I do if I take part?

If you are an adult and happy to participate in the research, I will ask you to read this information sheet and sign the consent form. When we receive this you will be asked to enroll yourself in simple learning tasks (role-play activity) either remotely or locally. Also, the researcher will observe your progress while you are achieving your task to record your timing and analyse your physiological data. When you finish all the tasks, you will be asked to fill in a survey. Then, the researcher will contact you to discuss your participation in the next experiment if needed.

What are the possible benefits of taking part?

Whilst there may be no personal benefits to your participation in this study, the information you provide can contribute to the future development of e-learning when using up-to-date immersive technologies.

Will my taking part in the study be kept confidential?

All information you provide to us will be kept confidential. The participant data and survey data will be stored separately on a secure database. Only the researcher will have access to it. Providing your personal information is optional.

What will happen to the results of the research study?

All information provided by you will be stored anonymously on a computer with analysis of the information obtained undertaken by the researcher based at University of Essex. The results from this analysis will be available in one or more of the following sources; the researcher's PhD thesis, scientific papers in peer-reviewed academic journals, presentations at conferences or local seminars.

For more information, please contact Enas Jambi (eamjam@essex.ac.uk).

CONSENT FORM

Title of the Project: Toward Immersive Learning Experience using a Collaborative Role-Play Activity in a Virtual Network Environment

Researcher: Enas Jambi

Notice: If you are an adult (aged 18 and more), please sign this constant form and continue filling in the following survey. If not, please don't participate in this research experiment.

| Please check the appropriate boxes | YES | NO |
|--|--------------------------|--------------------------|
| 1. I confirm that I have read and understood the Information Sheet dated for the above study | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. I understand that my participation is voluntary and that I am free to withdraw from the project at any time without giving any reason and without penalty. | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. I agree to take part in the project. Taking part in the project will include being interviewed. | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. I understand that my words (anonymised) may be quoted in publications, reports, web pages, and other research outputs. | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. I understand that the collected survey data and users' data provided will be securely stored and accessible only by the researcher involved in the study, and that confidentiality will be maintained. | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. I understand that the analysis of the data collected in this study will be used as appropriate and for publication of findings, in which case data will remain completely anonymous. | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. I agree the researcher may contact me. | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. I agree to take part in the above study. | <input type="checkbox"/> | <input type="checkbox"/> |

Participant Name

Date

Signature

Email

Researcher Name

Date

Researcher Signature

A. 2 Background Report

| | |
|---|---|
| Student's given number: | |
| Gender: | <input type="checkbox"/> Male <input type="checkbox"/> Female <input type="checkbox"/> Prefer not to say |
| Age: | <input type="checkbox"/> 18-24 <input type="checkbox"/> 25-30 <input type="checkbox"/> Above 30 |
| Study Subject: | <input type="checkbox"/> Computer Science <input type="checkbox"/> Other: |
| Level of studies: (semester level) | <input type="checkbox"/> Third Level <input type="checkbox"/> Fourth Level <input type="checkbox"/> Fifth Level <input type="checkbox"/> Sixth Level <input type="checkbox"/> Seventh Level <input type="checkbox"/> Not an undergrad student |
| Immersive Learning Background: | Have you ever used a 3D virtual environment before (such as Second life)? <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I cannot remember If "Yes", Please write the name/s of the 3D virtual environment |
| | Have you played learning video games before that involve taking part in group work? <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I have played a learning video game but individually not as a group member If "Yes", Please describe the game and your role |
| | Have you ever been involved in an immersive education environment before? (for example, used virtual environments or augmented reality in a learning activity) <input type="checkbox"/> Yes <input type="checkbox"/> No If "Yes", Please write the course and/or the activity name |
| Network Background: | During your degree, have you ever studied network modules? <input type="checkbox"/> Yes <input type="checkbox"/> No If "Yes", Please give the names of the courses |
| | Have you ever been introduced to the concept of network layers and protocols before (Such as the TCP/IP suite) <input type="checkbox"/> Yes <input type="checkbox"/> No If "Yes", in which context? (read about it, took a course, watched a video, or what else?) |
| | Again if "Yes", what is your knowledge level about the concept of network layers and protocols? <input type="checkbox"/> I only know the terminology and the terms <input type="checkbox"/> I know a brief description of the function of each layer and its protocols <input type="checkbox"/> I can describe the journey of a network packet from the sender until it receives the receiver <input type="checkbox"/> Other: |
| | Have you ever used any software to observe the incoming/outgoing packets to/from your device? <input type="checkbox"/> Yes <input type="checkbox"/> No If "Yes", What is the name of the software? |

A. 3 Wireshark Original Lab Manual

Statement Purpose:

This lab teaches the students how to use Wireshark packet sniffing tools.

Activity Outcomes:

In this lab students will use Wireshark's (packet sniffer) basic tool for observing the messages exchanged between executing protocol entities. As the name suggests, a packet sniffer captures ("sniffs") messages being sent/received from/by your computer; it will also typically store and/or display the contents of the various protocol fields in these captured messages.

Instructor Note:

Read the instructions carefully and try to use Wireshark as described in the given instructions. Answer the questions given at the end of this lab.

English will be the official language throughout the discussion and group work.

Names

I.D

1.

.....

One's understanding of network protocols can often be greatly deepened by "seeing protocols in action" and by "playing around with protocols" – observing the sequence of messages exchanged between two protocol entities, delving down into the details of protocol operation, and causing protocols to perform certain actions and then observing these actions and their consequences. This can be done in simulated scenarios or in a "real" network environment such as the Internet. The Java applets that accompany this text take the first approach. In these Wireshark lab we'll take the latter approach. You'll be running various network applications in different scenarios using a computer on your desk, at home, or in a lab. You'll observe the network protocols in your computer "in action," interacting and exchanging messages with protocol entities executing elsewhere in the Internet. Thus, you and your computer will be an integral part of these "live" labs. You'll observe, and you'll learn, by doing.

The basic tool for observing the messages exchanged between executing protocol entities is called a **packet sniffer**. As the name suggests, a packet sniffer captures ("sniffs") messages being sent/received from/by your computer; it will also typically store and/or display the contents of the various protocol fields in these captured messages. A packet sniffer itself is passive. It observes messages being sent and received by applications and protocols running on your computer, but never sends packets itself. Similarly, received packets are never explicitly addressed to the packet sniffer. Instead, a packet sniffer receives a *copy* of packets that are sent/received from/by application and protocols executing on your machine.

Figure 1 shows the structure of a packet sniffer. At the right of Figure 1 are the protocols (in this case, Internet protocols) and applications (such as a web browser or ftp client) that normally run on your computer. The packet sniffer, shown within the dashed rectangle in Figure 1 is an addition to the usual software in your computer, and consists of two parts. The **packet capture library** receives a copy of every link-layer frame that is sent from or received by your computer. Recall from the discussion in Section 1.5 in the text, that messages exchanged by higher layer protocols such as HTTP, FTP, TCP, UDP, DNS, or IP all are eventually encapsulated in link-layer frames that are transmitted over physical media such as an Ethernet cable. In Figure 1, the assumed physical media is an Ethernet, and so all upper layer protocols are eventually encapsulated within an Ethernet frame. Capturing all link-layer frames thus gives you all messages sent/received from/by all protocols and applications executing in your computer.

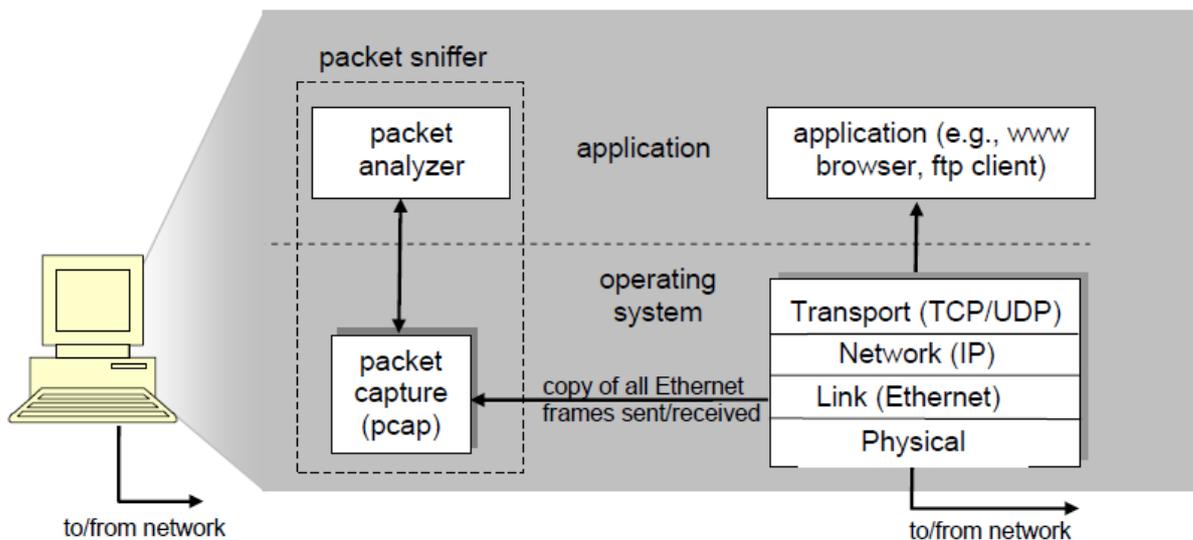


Figure 1: Packet sniffer structure

The second component of a packet sniffer is the **packet analyzer**, which displays the contents of all fields within a protocol message. In order to do so, the packet analyzer must “understand” the structure of all messages exchanged by protocols. For example, suppose we are interested in displaying the various fields in messages exchanged by the HTTP protocol in Figure 1. The packet analyzer understands the format of Ethernet frames, and so can identify the IP datagram within an Ethernet frame. It also understands the IP datagram format, so that it can extract the TCP segment within the IP datagram. Finally, it understands the TCP segment structure, so it can extract the HTTP message contained in the TCP segment. Finally, it understands the HTTP protocol and so, for example, knows that the first bytes of an HTTP message will contain the string “GET,” “POST,” or “HEAD,” as shown in Figure 2.8 in the text.

We will be using the Wireshark packet sniffer [<http://www.wireshark.org/>] for these labs, allowing us to display the contents of messages being sent/received from/by protocols at different levels of the protocol stack. (Technically speaking, Wireshark is a packet analyzer that uses a packet capture library in your computer). Wireshark is a free network protocol analyzer that runs on Windows, Linux/Unix, and Mac computers. It is an ideal packet analyzer for our labs – it is stable, has a large user base and well-documented support that includes a user-guide (http://www.wireshark.org/docs/wsug_html_chunked/), man pages (<http://www.wireshark.org/docs/man-pages/>), and a detailed FAQ (<http://www.wireshark.org/faq.html>), as well as rich functionality that includes the capability to analyze hundreds of protocols, and a well-designed user interface. It operates in computers using Ethernet, Token-Ring, FDDI, serial (PPP and SLIP), 802.11 wireless LANs, and ATM connections (if the OS on which it is running allows Wireshark to do so).

Getting Wireshark

In order to run Wireshark, you will need to have access to a computer that supports both Wireshark and the *libpcap* or *WinPCap* packet capture library. The *libpcap* software will be installed for you, if it is not installed within your operating system, when you install Wireshark. See <http://www.wireshark.org/download.html> for a list of supported operating systems and download sites

Download and install the Wireshark software:

- Go to <http://www.wireshark.org/download.html> and download and install the Wireshark binary for your computer.
- Download the Wireshark user guide.

The Wireshark FAQ has a number of helpful hints and interesting tidbits of information, particularly if you have trouble installing or running Wireshark.

Running Wireshark

When you run the Wireshark program, Wireshark's graphical user interface, shown in Figure 2, will be displayed. Initially, no data will be displayed in the various windows.

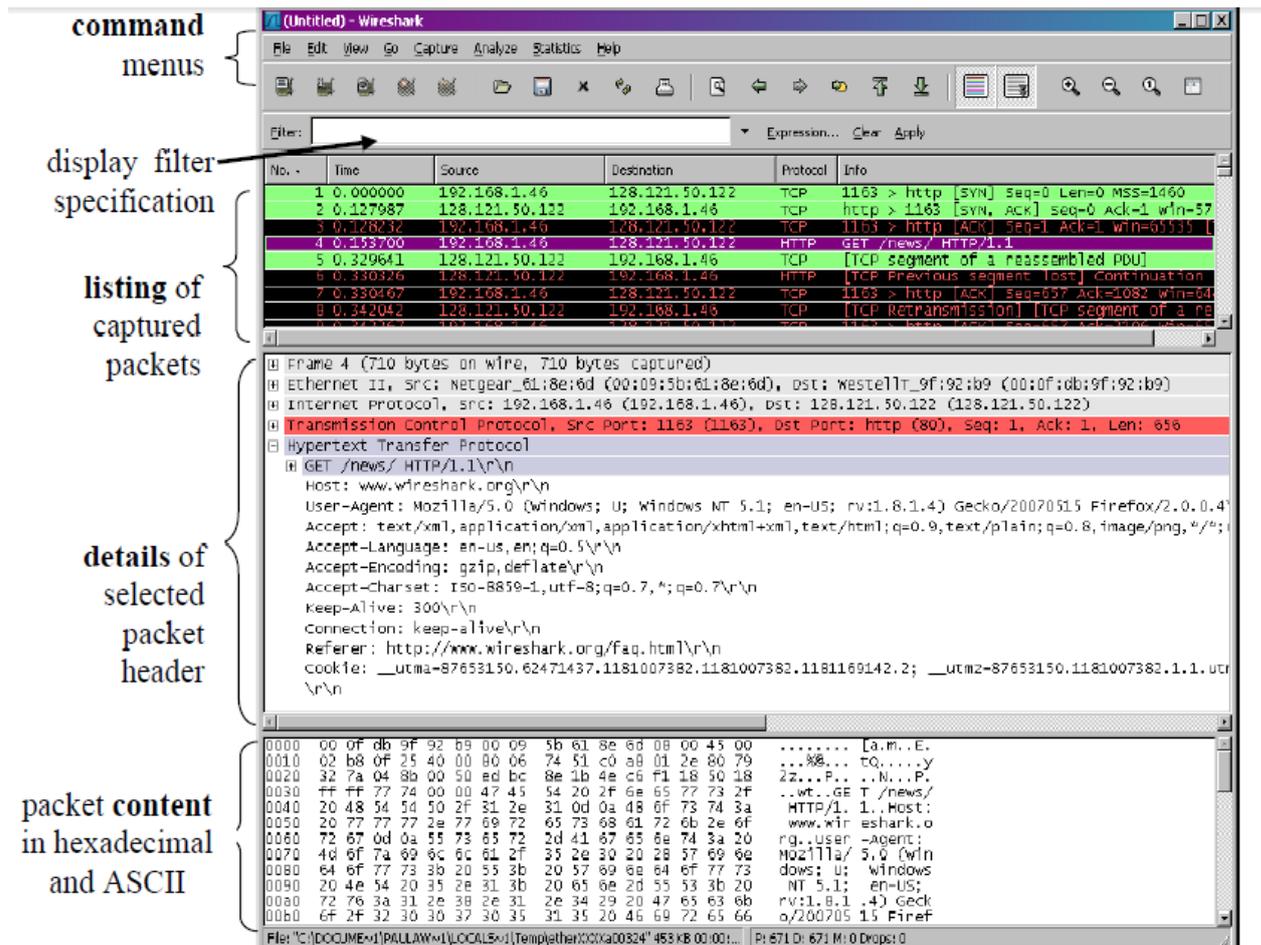


Figure 2: Wireshark Graphical User Interface

The Wireshark interface has five major components:

- The **command menus** are standard pulldown menus located at the top of the window. Of interest to us now are the File and Capture menus. The File menu allows you to save captured packet data or open a file containing previously captured packet data, and exit the Wireshark application. The Capture menu allows you to begin packet capture.
- The **packet-listing window** displays a one-line summary for each packet captured, including the packet number (assigned by Wireshark; this is *not* a packet number contained in any protocol's header), the time at which the packet was captured, the packet's source and destination addresses, the protocol type, and protocol-specific information contained in the packet. The packet listing can be sorted according to any of these categories by clicking on a column name. The protocol type field lists the highest level protocol that sent or received this packet, i.e., the protocol that is the source or ultimate sink for this packet.
- The **packet-header details window** provides details about the packet selected (highlighted) in the packet listing window. (To select a packet in the packet listing window, place the cursor over the packet's one-line summary in the packet

listing window and click with the left mouse button.). These details include information about the Ethernet frame (assuming the packet was sent/received over an Ethernet interface) and IP datagram that contains this packet. The amount of Ethernet and IP-layer detail displayed can be expanded or minimized by clicking on the plus/minus boxes to the left of the Ethernet frame or IP datagram line in the packet details window. If the packet has been carried over TCP or UDP, TCP or UDP details will also be displayed, which can similarly be expanded or minimized. Finally, details about the highest level protocol that sent or received this packet are also provided.

- The **packet-contents window** displays the entire contents of the captured frame, in both ASCII and hexadecimal format.
- Towards the top of the Wireshark graphical user interface, is the **packet display filter field**, into which a protocol name or other information can be entered in order to filter the information displayed in the packet-listing window (and hence the packet-header and packet-contents windows). In the example below, we'll use the packet-display filter field to have Wireshark hide (not display) packets except those that correspond to HTTP messages.

Taking Wireshark for a Test Run

The best way to learn about any new piece of software is to try it out! We'll assume that your computer is connected to the Internet via a wired Ethernet interface. Do the following

1. Start up your favorite web browser, which will display your selected homepage.
2. Start up the Wireshark software. You will initially see a window similar to that shown in Figure 2, except that no packet data will be displayed in the packet-listing, packet-header, or packet-contents window, since Wireshark has not yet begun capturing packets.
3. To begin packet capture, select the Capture pull down menu and select *Options*. This will cause the "Wireshark: Capture Options" window to be displayed, as shown in Figure 3.

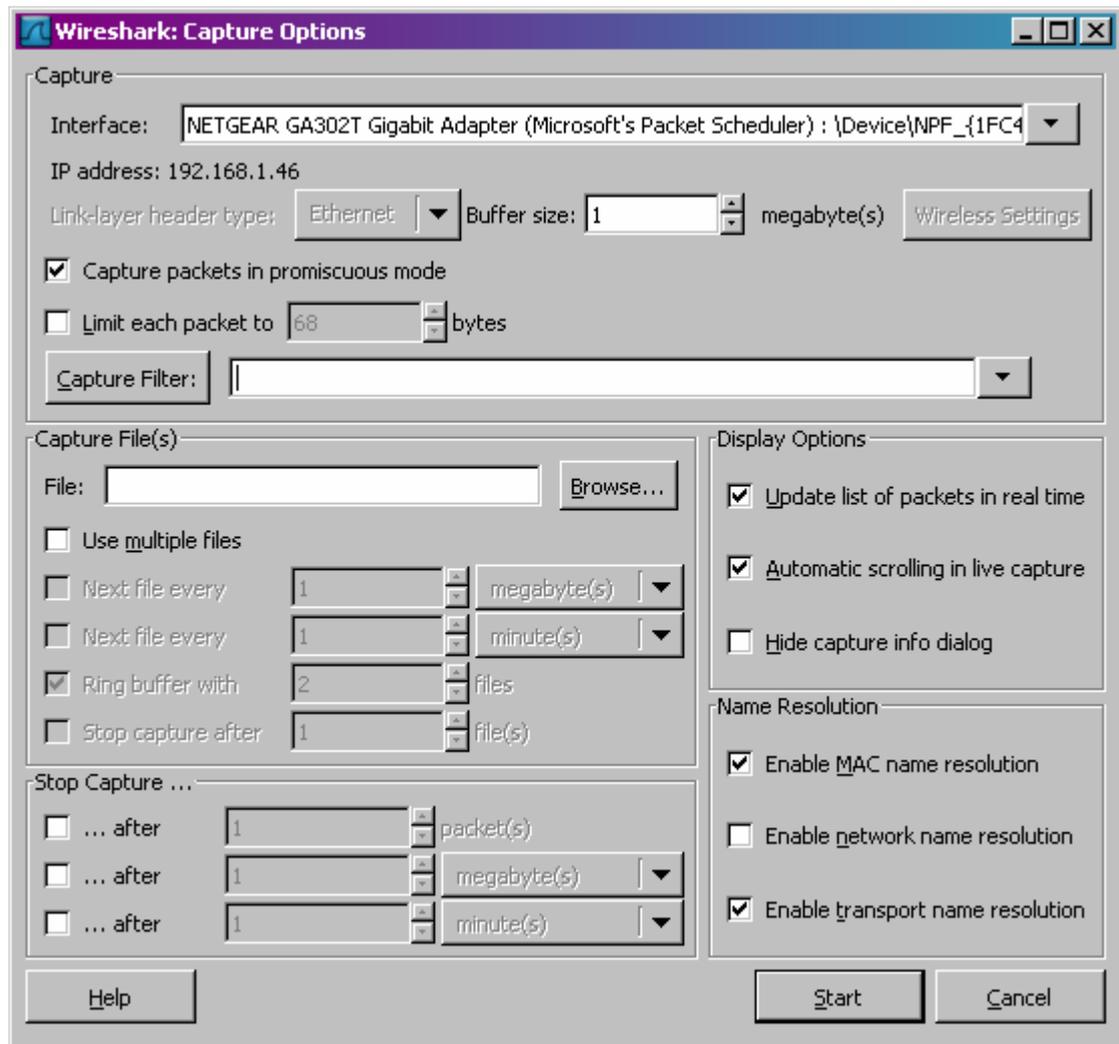


Figure 3: Wireshark Capture Options Window

4. You can use most of the default values in this window, but uncheck “Hide capture info dialog” under Display Options. The network interfaces (i.e., the physical connections) that your computer has to the network will be shown in the Interface pull down menu at the top of the Capture Options window. In case your computer has more than one active network interface (e.g., if you have both a wireless and a wired Ethernet connection), you will need to select an interface that is being used to send and receive packets (most likely the wired interface). After selecting the network interface (or using the default interface chosen by Wireshark), click Start. Packet capture will now begin - all packets being sent/received from/by your computer are now being captured by Wireshark!

5. Once you begin packet capture, a packet capture summary window will appear, as shown in Figure 4. This window summarizes the number of packets of various types that are being captured, and (importantly!) contains the *Stop* button that will allow you to stop packet capture. Don’t stop packet capture yet.

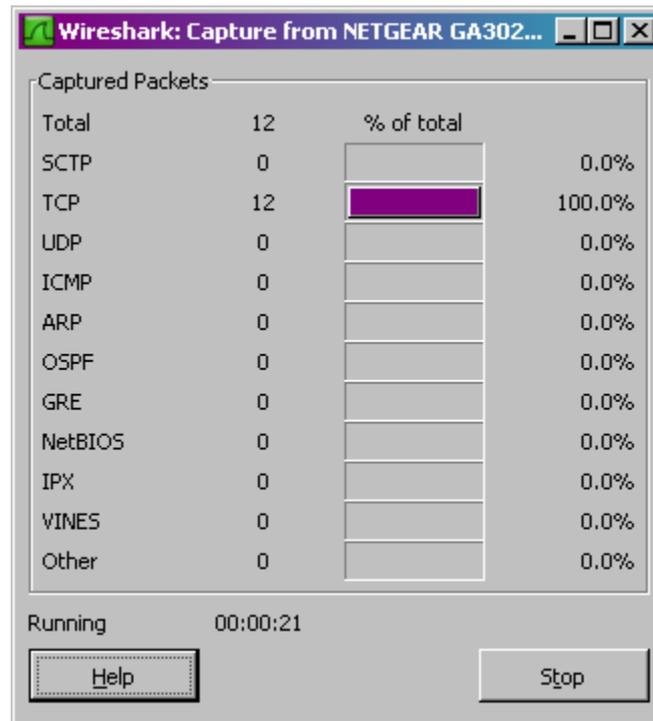


Figure 4: Wireshark Packet Capture Window

6. While Wireshark is running, enter the URL:

<http://gaia.cs.umass.edu/wireshark-labs/INTRO-wireshark-file1.html>

and have that page displayed in your browser. In order to display this page, your browser will contact the HTTP server at `gaia.cs.umass.edu` and exchange HTTP messages with the server in order to download this page, as discussed in Section 2.2 of the text. The Ethernet frames containing these HTTP messages will be captured by Wireshark.

7. After your browser has displayed the `INTRO-wireshark-file1.html` page, stop Wireshark packet capture by selecting Stop in the Wireshark capture window. This will cause the Wireshark capture window to disappear and the main Wireshark window to display all packets captured since you began packet capture. The main Wireshark window should now look similar to Figure 2. You now have live packet data that contains all protocol messages exchanged between your computer and other network entities! The HTTP message exchanges with the `gaia.cs.umass.edu` web server should appear somewhere in the listing of packets captured. But there will be many other types of packets displayed as well (see, e.g., the many different protocol types shown in the *Protocol* column in Figure 2).

Even though the only action you took was to download a web page, there were evidently many other protocols running on your computer that are unseen by the user. We'll learn much more about these protocols as we progress through the text! For now, you should just be aware that there is often much more going on than "meets the eye"!

8. Type in "http" (without the quotes, and in lower case – all protocol names are in

lower case in Wireshark) into the display filter specification window at the top of the main Wireshark window. Then select *Apply* (to the right of where you entered “http”). This will cause only HTTP messages to be displayed in the packet-listing window.

9. Select the first http message shown in the packet-listing window. This should be the HTTP GET message that was sent from your computer to the gaia.cs.umass.edu HTTP server. When you select the HTTP GET message, the Ethernet frame, IP datagram, TCP segment, and HTTP message header information will be displayed in the packet-header window³. By clicking on right-pointing and down-pointing arrow heads to the left side of the packet details window, *minimize* the amount of Frame, Ethernet, Internet Protocol, and Transmission Control Protocol information displayed. *Maximize* the amount of information displayed about the HTTP protocol. Your Wireshark display should now look roughly as shown in Figure 5. (Note, in particular, the minimized amount of protocol information for all protocols except HTTP, and the maximized amount of protocol information for HTTP in the packet-header window).

10. Exit Wireshark

Congratulations! You’ve now completed the first lab.

The screenshot displays the Wireshark interface with the following details:

Filter: http

| No. | Time | Source | Destination | Protocol | Info |
|-----|----------|----------------|----------------|----------|---|
| 4 | 0.046413 | 192.168.1.46 | 128.119.245.12 | HTTP | GET /wireshark-labs/INTRO-wireshark-file1.html HTTP/1.1 |
| 6 | 0.149755 | 128.119.245.12 | 192.168.1.46 | HTTP | HTTP/1.1 304 Not Modified |

Packet 4 Details:

- Frame 4 (974 bytes on wire, 974 bytes captured)
- Ethernet II, Src: Netgear_61:8e:6d (00:09:5b:61:8e:6d), Dst: westellT_9f:92:b9 (00:0f:db:9f:92:b9)
- Internet Protocol, Src: 192.168.1.46 (192.168.1.46), Dst: 128.119.245.12 (128.119.245.12)
- Transmission Control Protocol, Src Port: 1232 (1232), Dst Port: http (80), Seq: 1, Ack: 1, Len: 920
- Hypertext Transfer Protocol
 - GET /wireshark-labs/INTRO-wireshark-file1.html HTTP/1.1\r\n
 - Host: gaia.cs.umass.edu\r\n
 - User-Agent: Mozilla/5.0 (windows; u; windows NT 5.1; en-US; rv:1.8.1.4) Gecko/20070515 Firefox/2.0.0.
 - Accept: text/xml,application/xml,application/xhtml+xml,text/html;q=0.9,text/plain;q=0.8,image/png,*/*
 - Accept-Language: en-us,en;q=0.5\r\n
 - Accept-Encoding: gzip,deflate\r\n
 - Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7\r\n
 - keep-alive: 300\r\n
 - Connection: keep-alive\r\n
 - Cookie: MintUnique=1; __utmz=198765611.1176212581.8.2.utmccn=(referral)|utmcsr=cs.umass.edu|utmct=/c
 - If-Modified-Since: Thu, 07 Jun 2007 13:44:01 GMT\r\n
 - If-None-Match: "d6c69-50-1b716a40"\r\n
 - Cache-Control: max-age=0\r\n
 - \r\n

Raw Data:

| Offset | Hex | ASCII |
|--------|---|-------------------|
| 0030 | ff ff 3b 0d 00 00 47 45 54 20 2f 77 69 72 65 73 |GET/wires |
| 0040 | 68 61 72 6b 2d 6c 61 62 73 2f 49 4e 54 52 4f 2d | hark-labs/INTRO- |
| 0050 | 77 69 72 65 73 68 61 72 6b 2d 66 69 6c 65 31 2e | wireshark-file1. |
| 0060 | 68 74 6d 6c 20 48 54 54 50 2f 31 2e 31 0d 0a 48 | html HTTP/1.1..H |
| 0070 | 6f 73 74 3a 20 67 61 69 61 2e 63 73 2e 75 6d 61 | ost: gaia.cs.uma |
| 0080 | 73 73 2e 65 64 75 0d 0a 55 73 65 72 2d 41 67 65 | ss.edu.. User-Age |
| 0090 | 6e 74 3a 20 4d 6f 7a 69 6c 6c 61 2f 35 2e 30 20 | nt: Mozilla/5.0 |
| 00a0 | 28 57 69 6e 64 6f 77 73 3b 20 55 3b 20 57 69 6e | (windows; u; win |
| 00b0 | 64 6f 77 73 20 4e 54 20 35 2e 31 3b 20 65 6e 2d | dows NT 5.1; en- |
| 00c0 | 55 53 3b 20 72 76 3a 31 2e 38 2e 31 2e 34 29 20 | US; rv:1.8.1.4) |
| 00d0 | 47 65 63 6b 6f 2f 32 30 30 37 30 35 31 35 20 46 | Gecko/20070515 F |

Status Bar: Hypertext Transfer Protocol (http), 920 bytes | P: 7 D: 2 M: 0 Drops: 0

Figure 5: Wireshark display after step 9

What to hand in

The goal of this first lab was primarily to introduce you to Wireshark. The following questions will demonstrate that you've been able to get Wireshark up and running, and have explored some of its capabilities. Answer the following questions, based on your Wireshark experimentation:

1. List the different protocols that appear in the protocol column in the unfiltered packet-listing window in step 7 above.
2. How long did it take from when the HTTP GET message was sent until the HTTP OK reply was received? (By default, the value of the Time column in the packet-listing window is the amount of time, in seconds, since Wireshark tracing began.

To display the Time field in time-of-day format, select the Wireshark *View* pull down menu, then select *Time Display Format*, then select *Time-of-day*.)

3. What is the Internet address of the gaia.cs.umass.edu (also known as wwwnet.cs.umass.edu)? What is the Internet address of your computer?
4. Print the two HTTP messages displayed in step 9 above. To do so, select *Print* from the Wireshark *File* command menu, and select "*Selected Packet Only*" and "*Print as displayed*" and then click OK.

A. 4 Wireshark Modified Lab Manual

Statement Purpose:

This lab teaches the students how to use Wireshark packet sniffing tools.

Activity Outcomes:

In this lab students will use Wireshark's (packet sniffer) basic tool for observing the messages exchanged between executing protocol entities. As the name suggests, a packet sniffer captures ("sniffs") messages being sent/received from/by your computer; it will also typically store and/or display the contents of the various protocol fields in these captured messages.

Students will discover selected protocols that are used for "web browsing" and their messages.

Instructor Note:

Read the instructions carefully and try to use Wireshark as described in the given instructions. Answer the questions given at the end of this lab.

English will be the official language throughout the discussion and group work.

Names

I.D

2.

.....

One's understanding of network protocols can often be greatly deepened by "seeing protocols in action" and by "playing around with protocols" – observing the sequence of messages exchanged between two protocol entities, delving down into the details of protocol operation, and causing protocols to perform certain actions and then observing these actions and their consequences. This can be done in simulated scenarios or in a "real" network environment such as the Internet. The Java applets that accompany this text take the first approach. In this Wireshark lab, we'll take the latter approach.

You'll be running various network applications in different scenarios using a computer on your desk, at home, or in a lab. You'll observe the network protocols in your computer "in action," interacting and exchanging messages with protocol entities executing elsewhere in the Internet. Thus, you and your computer will be an integral part of these "live" labs. You'll observe, and you'll learn, by doing.

The basic tool for observing the messages exchanged between executing protocol entities is called a **packet sniffer**. As the name suggests, a packet sniffer captures ("sniffs") messages being sent/received from/by your computer; it will also typically store and/or display the contents of the various protocol fields in these captured messages. A packet sniffer itself is passive. It observes messages being sent and received by applications and protocols running on your computer, but never sends packets itself. Similarly, received packets are never explicitly addressed to the packet sniffer. Instead, a packet sniffer receives a *copy* of packets that are sent/received from/by applications and protocols executing on your machine.

Figure 1 shows the structure of a packet sniffer. At the right of Figure 1 are the protocols (in this case, Internet protocols) and applications (such as a web browser or ftp client) that normally run on your computer. The packet sniffer, shown within the dashed rectangle in Figure 1 is an addition to the usual software in your computer, and consists of two parts. The **packet capture library** receives a copy of every link-layer frame that is sent from or received by your computer. Messages exchanged by higher layer protocols such as HTTP, FTP, TCP, UDP, DNS, or IP all are eventually encapsulated in link-layer frames that are transmitted over physical media such as an Ethernet cable. In Figure 1, the assumed physical media is an Ethernet, and so all upper layer protocols are eventually encapsulated within an Ethernet frame. Capturing all link-layer frames thus gives you all messages sent/received from/by all protocols and applications executing in your computer.

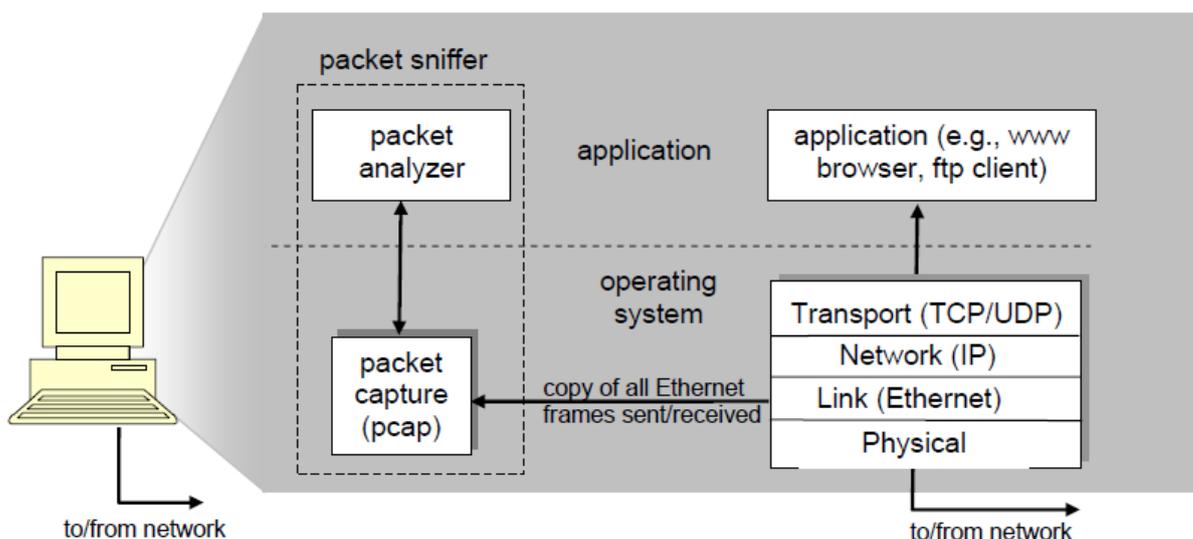


Figure 1: Packet sniffer structure

The second component of a packet sniffer is the **packet analyzer**, which displays the contents of all fields within a protocol message. In order to do so, the packet analyzer must “understand” the structure of all messages exchanged by protocols. For example, suppose we are interested in displaying the various fields in messages exchanged by the HTTP protocol in Figure 1. The packet analyzer understands the format of Ethernet frames, and so can identify the IP datagram within an Ethernet frame. It also understands the IP datagram format, so that it can extract the TCP segment within the IP datagram. Further, it understands the TCP segment structure, so it can extract the HTTP message contained in the TCP segment. Finally, it understands the HTTP protocol and so, for example, knows that the first bytes of an HTTP message will contain the string “GET,” “POST,” or “HEAD,” as shown in Figure 2.8 in the text.

We will be using the Wireshark packet sniffer [<http://www.wireshark.org/>] for these labs, allowing us to display the contents of messages being sent/received from/by protocols at different levels of the protocol stack. (Technically speaking, Wireshark is a packet analyzer that uses a packet capture library in your computer). Wireshark is a free network protocol analyzer that runs on Windows, Linux/Unix, and Mac computers. It is an ideal packet analyzer for our labs – it is stable, has a large user base and well-documented support that includes a user-guide (http://www.wireshark.org/docs/wsug_html_chunked/), [man pages](http://www.wireshark.org/docs/man-pages/) (<http://www.wireshark.org/docs/man-pages/>), and a detailed FAQ (<http://www.wireshark.org/faq.html>), as well as rich functionality that includes the capability to analyze hundreds of protocols, and a well-designed user interface. It operates in computers using Ethernet, Token-Ring, FDDI, serial (PPP and SLIP), 802.11 wireless LANs, and ATM connections (if the OS on which it is running allows Wireshark to do so).

Running Wireshark

When you run the Wireshark program, the Wireshark graphical user interface, shown in Figure 2, will be displayed. Initially, no data will be displayed in the various windows.

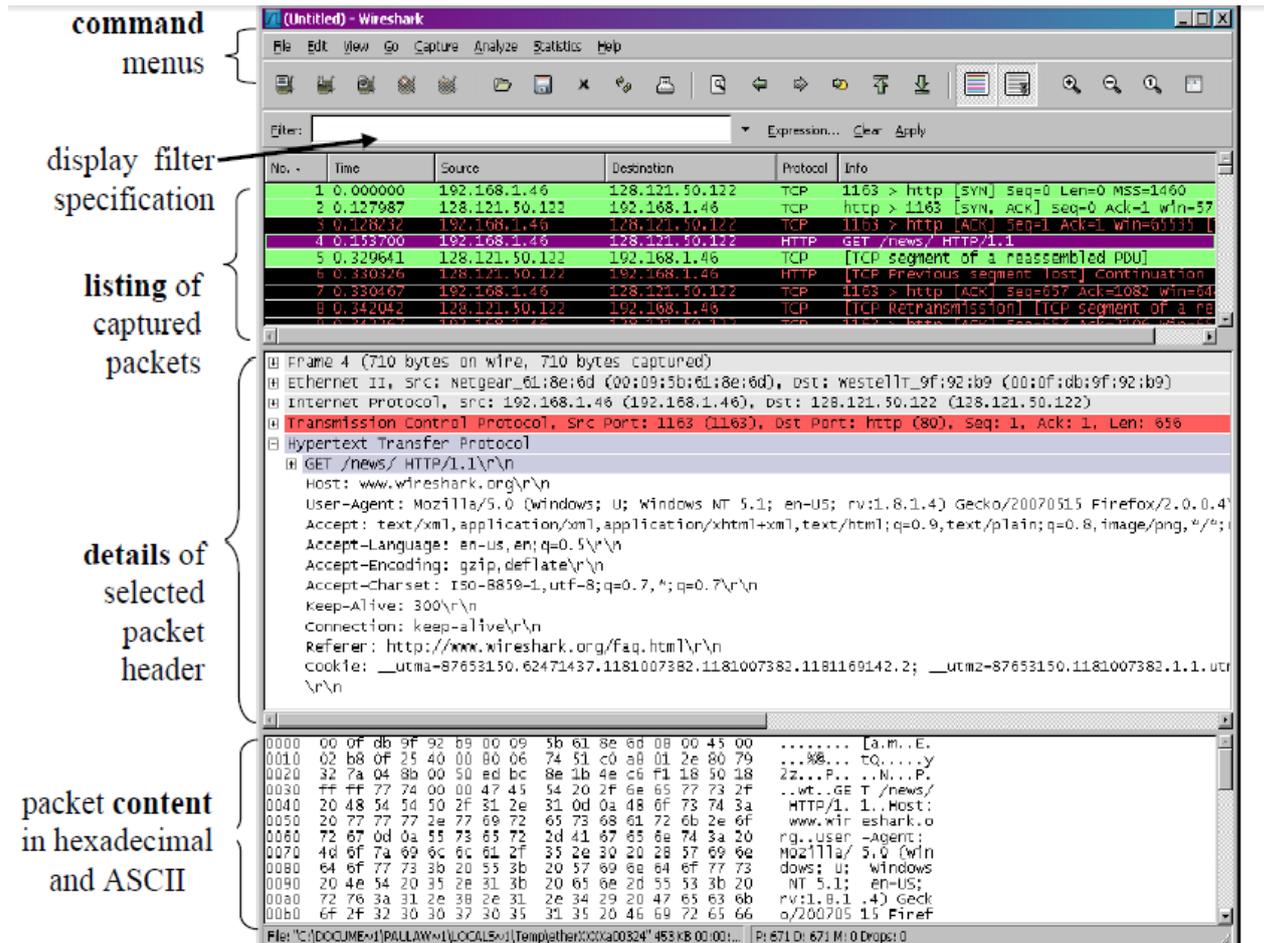


Figure 2: Wireshark Graphical User Interface

The Wireshark interface has five major components:

- The **command menus** are standard pulldown menus located at the top of the window. Of interest to us now are the File and Capture menus. The File menu allows you to save captured packet data or open a file containing previously captured packet data, and exit the Wireshark application. The Capture menu allows you to begin packet capture.
- The **packet-listing window** displays a one-line summary for each packet captured, including the packet number (assigned by Wireshark; this is *not* a packet number contained in any protocol's header), the time at which the packet was captured, the packet's source and destination addresses, the protocol type, and protocol-specific information contained in the packet. The packet listing can be sorted according to any of these categories by clicking on a column name. The protocol type field lists the highest level protocol that sent or received this packet, i.e., the protocol that is the source or ultimate sink for this packet.
- The **packet-header details window** provides details about the packet selected (highlighted) in the packet listing window. (To select a packet in the packet-listing window,

place the cursor over the packet's one-line summary in the packet-listing window and click with the left mouse button.). These details include information about the Ethernet frame (assuming the packet was sent/received over an Ethernet interface) and IP datagram that contains this packet. The amount of Ethernet and IP-layer detail displayed can be expanded or minimized by clicking on the plus/minus boxes to the left of the Ethernet frame or IP datagram line in the packet details window. If the packet has been carried over TCP or UDP, TCP or UDP details will also be displayed, which can similarly be expanded or minimized. Finally, details about the highest level protocol that sent or received this packet are also provided.

- The **packet-contents window** displays the entire contents of the captured frame, in both ASCII and hexadecimal format.
- Towards the top of the Wireshark graphical user interface, is the **packet display filter field**, into which a protocol name or other information can be entered in order to filter the information displayed in the packet-listing window (and hence the packet-header and packet-contents windows). In the example below, we'll use the packet-display filter field to have Wireshark hide (not display) packets except those that correspond to HTTP messages.

Taking Wireshark for a Test Run

The best way to learn about any new piece of software is to try it out! We'll assume that your computer is connected to the Internet via a wired Ethernet interface. Do the following:

1. Start up your favorite web browser, which will display your selected homepage.
2. Start up the Wireshark software. You will initially see a window similar to that shown in Figure 2, except that no packet data will be displayed in the packet-listing, packet-header, or packet-contents window, since Wireshark has not yet begun capturing packets.
3. To begin packet capture, select the Capture pull down menu and select *Options*.

This will cause the "Wireshark: Capture Options" window to be displayed, as shown in Figure 3.

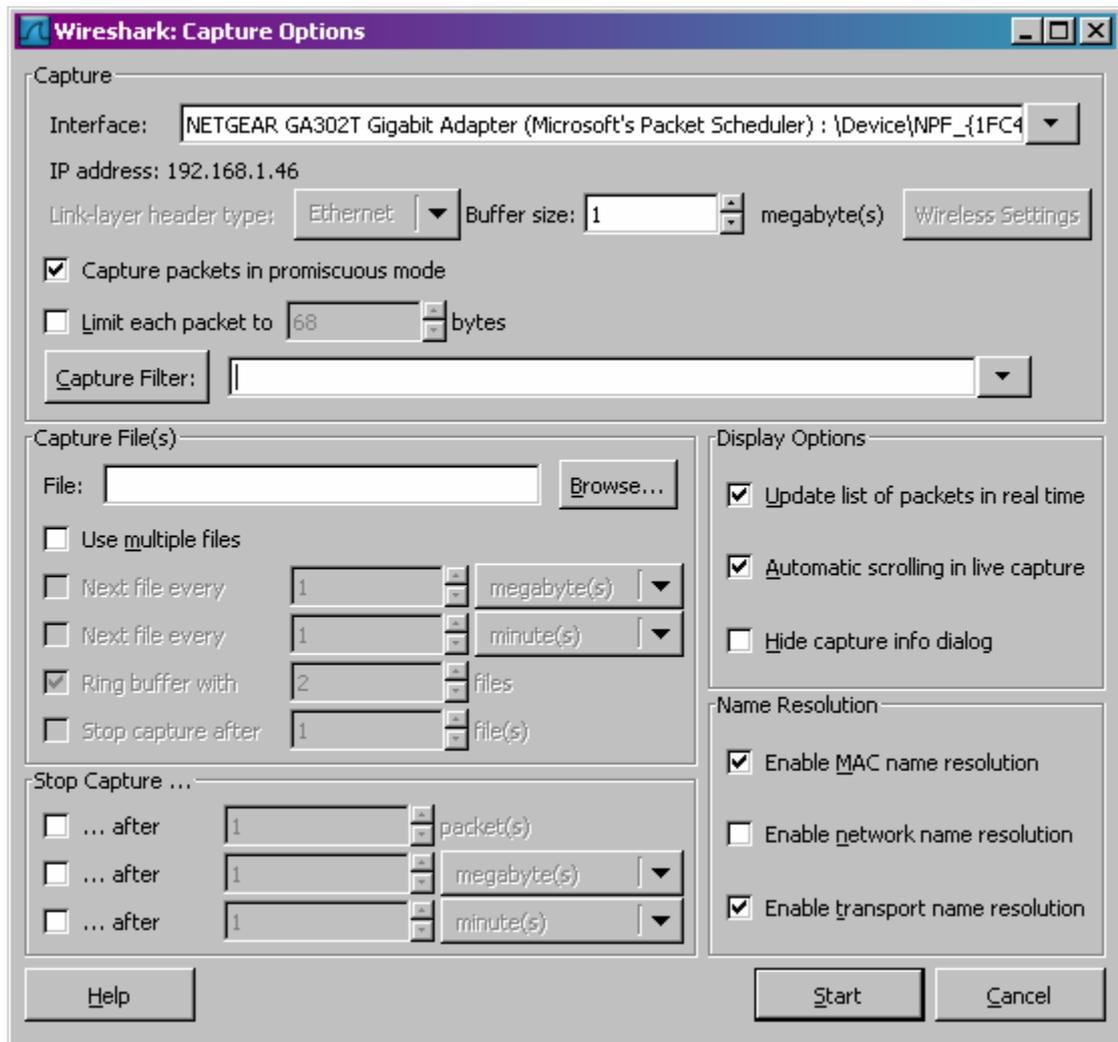


Figure 3: Wireshark Capture Options Window

4. You can use most of the default values in this window, but uncheck “Hide capture info dialog” under Display Options. The network interfaces (i.e., the physical connections) that your computer has to the network will be shown in the Interface pull down menu at the top of the Capture Options window. In case your computer has more than one active network interface (e.g., if you have both a wireless and a wired Ethernet connection), you will need to select an interface that is being used to send and receive packets (most likely the wired interface). After selecting the network interface (or using the default interface chosen by Wireshark), click Start. Packet capture will now begin - all packets being sent/received from/by your computer are now being captured by Wireshark!
5. Once you begin packet capture, a packet capture summary window will appear, as shown in Figure 4. This window summarizes the number of packets of various types that are being captured, and (importantly!) contains the *Stop* button that will allow you to stop packet capture. Don’t stop packet capture yet.

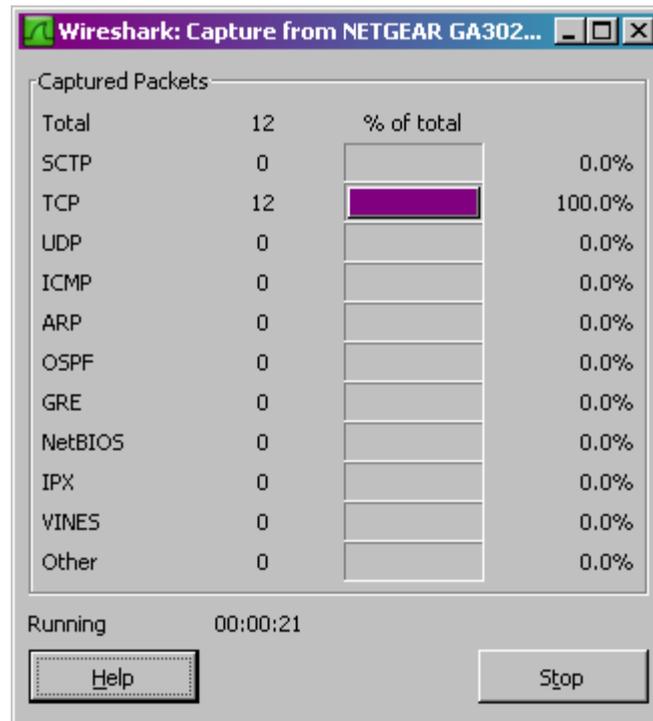


Figure 4: Wireshark Packet Capture Window

6. While Wireshark is running, enter the URL:

<http://gaia.cs.umass.edu/wireshark-labs/INTRO-wireshark-file1.html>

and have that page displayed in your browser. In order to display this page, your browser will contact the HTTP server at `gaia.cs.umass.edu` and exchange HTTP messages with the server in order to download this page, as discussed in Section 2.2 of the text. The Ethernet frames containing these HTTP messages will be captured by Wireshark.

7. After your browser has displayed the `INTRO-wireshark-file1.html` page, stop Wireshark packet capture by selecting stop in the Wireshark capture window. This will cause the Wireshark capture window to disappear and the main Wireshark window to display all packets captured since you began packet capture. The main Wireshark window should now look similar to Figure 2. You now have live packet data that contains all protocol messages exchanged between your computer and other network entities! The HTTP message exchanges with the `gaia.cs.umass.edu` web server should appear somewhere in the listing of packets captured. But there will be many other types of packets displayed as well (see, e.g., the many different protocol types shown in the *Protocol* column in Figure 2). Even though the only action you took was to download a web page, there were evidently many other protocols running on your computer that are unseen by the user. We'll learn much more about these protocols as we progress through the text! For now, you should just be aware that there is often much more going on than “meets the eye”!

8. Type in “http” (without the quotes, and in lower case – all protocol names are in lower case in Wireshark) into the display filter specification window at the top of the main Wireshark window. Then select *Apply* (to the right of where you entered “http”). This will cause only HTTP messages to be displayed in the packet-listing window.

9. Select the first http message shown in the packet-listing window. This should be the HTTP GET message that was sent from your computer to the gaia.cs.umass.edu HTTP server. By clicking on right-pointing and down-pointing arrowheads to the left side of the packet details window, *minimize* the amount of Frame, Ethernet, Internet Protocol, and Transmission Control Protocol information displayed. *Maximize* the amount of information displayed about the HTTP protocol. Your Wireshark display should now look roughly as shown in Figure 5. (Note, in particular, the minimized amount of protocol information for all protocols except HTTP, and the maximized amount of protocol information for HTTP in the packet-header window).
10. Exit Wireshark

Congratulations! You've now completed the first lab.

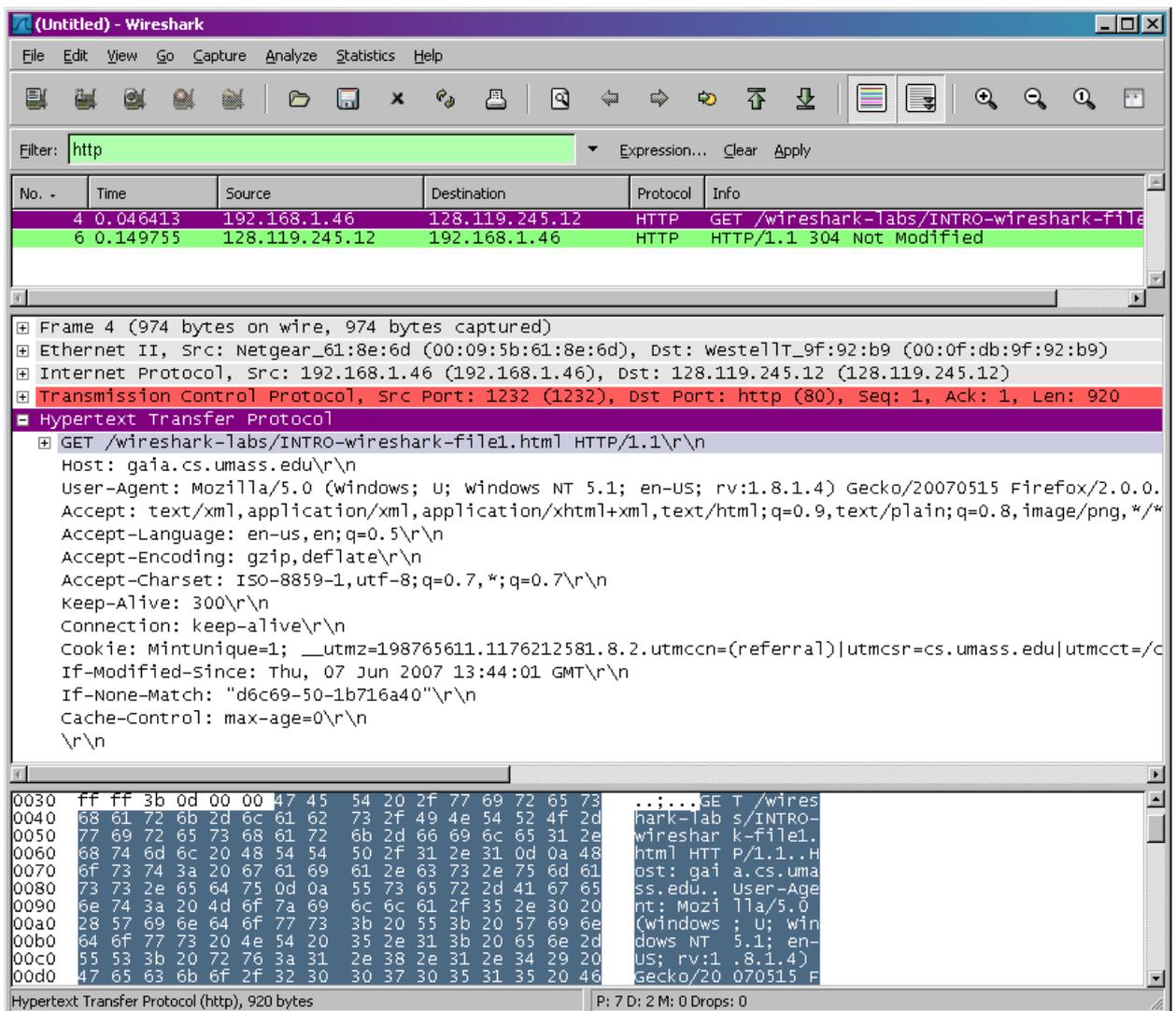


Figure 5: Wireshark display after step 9

What to hand in

The goal of this lab was primarily to introduce you to Wireshark. Answer the following questions, based on your Wireshark experimentation:

1. List the different protocols that appear in the protocol column in the unfiltered packet-listing window in step 7 above.
2. In the two HTTP messages displayed in step 9 above, can you tell the other protocols in the other layers?
3. What is the Internet address of the `gaia.cs.umass.edu` (also known as `wwwnet.cs.umass.edu`)? What is the Internet address of your computer?

A. 5 Post-test

| | | | | |
|--|--|---------------------------------------|--|---|
| Student's given number : | | | | |
| Q1. The TCP/IP model has five layers: | <input type="checkbox"/> True | | <input type="checkbox"/> False | |
| Q2. The _____ layer of the TCP/IP protocol suite provides services for end users. | <input type="checkbox"/> data-link | <input type="checkbox"/> transport | <input type="checkbox"/> application | <input type="checkbox"/> physical |
| Q3. The _____ layer of the TCP/IP protocol suit transmits a bit stream over a physical medium. | <input type="checkbox"/> data-link | <input type="checkbox"/> transport | <input type="checkbox"/> application | <input type="checkbox"/> physical |
| Q4. Which of the following is an internet application: | <input type="checkbox"/> electronic mail | <input type="checkbox"/> remote login | <input type="checkbox"/> file transfer | <input type="checkbox"/> all of the above |
| Q5. _____ is a protocol for e-mail services. | <input type="checkbox"/> FTP | <input type="checkbox"/> SMTP | <input type="checkbox"/> TELNET | <input type="checkbox"/> HTTP |
| Q6. _____ is a Transport layer protocol | <input type="checkbox"/> HTML | <input type="checkbox"/> IP | <input type="checkbox"/> UDP | <input type="checkbox"/> Ethernet |

A. 6 CG Engagement Survey

| | | | | |
|--|-----------------------------------|----------------------------------|--------------------------------|---|
| Student's given number : | | | | |
| 1. (FA) When I was doing the activity, I lost track of the world around me. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 2. (FA) I was absorbed in my task. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 3. (FA) I blocked out things around me when I was doing my task. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 4. (FA) I was so involved in my task that I lost track of time. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 5. (FA) The time I spent participating in the activity just slipped away. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 6. (FA) This activity experience was fun. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 7. (FA) I was really drawn into doing the tasks. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 8. (PU) The experience was demanding. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 9. (PU) Many times during the task I just wanted to give up. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 10. (SA) I felt discouraged many times while on the activity. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 11. (SA) I would continue doing this activity out of curiosity. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 12. (SA) This experience did not work out the way I had planned. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 13. (AE) The screen layout of the software was visually pleasing. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 14. (SA) The content of the software incited my curiosity. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 15. (SA) My experience participating in the activity was rewarding | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 16. (SA) Doing the activity on this software was worthwhile. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 17. (AE) The software interface appealed to my visual senses. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 18. (SA) I felt interested in doing my task. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 19. (SA) I would like to do another task again using this software. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 20. (PU) Using the software was mentally taxing. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 21. (PU) I felt annoyed while doing my task. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 22. (PU) I found the software confusing to use. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 23. (PU) I felt frustrated while doing my task using this software. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |

A. 7 MMRP Engagement Survey

| | | | | |
|--|--|--|--|--|
| Student's given number: | | | | |
| 1. (FA) When I was doing the activity, I lost track of the world around me. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 2. (UA) I understand the interaction between the environment's object very well | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 3. (FA) I was absorbed in my task. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 4. (FA) I blocked out things around me when I was doing my task. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 5. (FA) I was so involved in my task that I lost track of time. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 6. (FA) The time I spent participating in the activity just slipped away. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 7. (FA) This activity experience was fun. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Strongly Disagree |
| 8. (UA) I enjoy playing my role with the other objects | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Strongly Disagree |
| Please specify based on what did you choose your answer | | | | |
| | | | | |
| 9. (FA) I was really drawn into doing the tasks. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 10. (PU) The experience was demanding. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 11. (PU) Many times during the task I just wanted to give up. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 12. (SA) I felt discouraged many times while on the activity. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 13. (SA) I would continue doing this activity out of curiosity. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 14. (SA) This experience did not work out the way I had planned. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 15. (AE) The screen layout of the software was visually pleasing. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 16. (SA) The content of the software incited my curiosity. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 17. (UA) the MMRP platform was easy to use | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| Please specify based on what did you choose your answer | | | | |
| | | | | |
| 19. (UA) the access to the information was easy | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| Please specify based on what did you choose your answer | | | | |
| | | | | |
| 20. (SA) My experience participating in the activity was rewarding | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 21. (SA) Doing the activity on this software was worthwhile. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 22. (AE) The software interface appealed to my visual senses. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 23. (SA) I felt interested in doing my task. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 24. (SA) I would like to do another task again using this software. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 25. (PU) Using the software was mentally taxing. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 26. (PU) I felt annoyed while doing my task. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| 27. (PU) I found the software confusing to use. | | | | |
| <input type="checkbox"/> Strongly Disagree | <input type="checkbox"/> Disagree | <input type="checkbox"/> Neutral | <input type="checkbox"/> Agree | <input type="checkbox"/> Strongly Agree |
| Do you think the system needs to be improved? If "Yes", how? | | | | |
| | | | | |
| Additional comment: | | | | |
| | | | | |

A. 8 SPSS output

Item Statistics

| | Mean | Std. Deviation | N |
|---|------|----------------|----|
| Q1. The TCP/IP model has five layers: | .87 | .337 | 47 |
| Q2. The _____ layer of the TCP/IP protocol suite provides services for end users. | .60 | .496 | 47 |
| Q3. The _____ layer of the TCP/IP protocol suite transmits a bit stream over a physical medium. | .53 | .504 | 47 |
| Q4. Which of the following is an internet application: | .79 | .414 | 47 |
| Q5. _____ is a protocol for e-mail services. | .36 | .486 | 47 |
| Q6. _____ is a Transport layer protocol | .40 | .496 | 47 |

Item-Total Statistics

| | Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted |
|---|----------------------------|--------------------------------|----------------------------------|----------------------------------|
| Q1. The TCP/IP model has five layers: | 2.68 | 2.092 | .137 | .561 |
| Q2. The _____ layer of the TCP/IP protocol suite provides services for end users. | 2.96 | 1.694 | .310 | .496 |
| Q3. The _____ layer of the TCP/IP protocol suite transmits a bit stream over a physical medium. | 3.02 | 1.630 | .353 | .473 |
| Q4. Which of the following is an internet application: | 2.77 | 2.009 | .136 | .568 |
| Q5. _____ is a protocol for e-mail services. | 3.19 | 1.680 | .337 | .483 |
| Q6. _____ is a Transport layer protocol | 3.15 | 1.521 | .468 | .411 |

References

1. Zembylas, M., *Three perspectives on linking the cognitive and the emotional in science learning: Conceptual change, socio-constructivism and poststructuralism*. 2005.
2. Rieber, L.P., S.-C. Tzeng, and K. Tribble, *Discovery learning, representation, and explanation within a computer-based simulation: Finding the right mix*. *Learning and instruction*, 2004. **14**(3): p. 307-323.
3. Luo, W., et al., *Advantages of Computer Simulation in Enhancing Students' Learning About Landform Evolution: A Case Study Using the Grand Canyon*. *Journal of Geoscience Education*, 2016. **64**(1): p. 60-73.
4. De Jong, T. and W.R. Van Joolingen, *Scientific discovery learning with computer simulations of conceptual domains*. *Review of educational research*, 1998. **68**(2): p. 179-201.
5. Aldrich, C., *Learning by doing: A comprehensive guide to simulations, computer games, and pedagogy in e-learning and other educational experiences*. 2005: John Wiley & Sons.
6. Braund, M., *Drama and learning science: an empty space?* *British Educational Research Journal*, 2015. **41**(1): p. 102-121.
7. Gregory, S. and Y. Masters, *Real thinking with virtual hats: A role-playing activity for pre-service teachers in Second Life*. *Australasian Journal of Educational Technology*, 2012. **28**(3): p. 420-440.
8. Crimmens, P., *Drama therapy and storymaking in special education*. 2006: Jessica Kingsley Publishers.
9. Dorion, K.R., *Science through drama: A multiple case exploration of the characteristics of drama activities used in secondary science lessons*. *International Journal of Science Education*, 2009. **31**(16): p. 2247-2270.
10. Duveen, J. and J. Solomon, *The great evolution trial: Use of role-play in the classroom*. *Journal of research in science teaching*, 1994. **31**(5): p. 575-582.
11. Verhoeff, R.P., *The Use of Drama in Socio-Scientific Inquiry-Based Learning*, in *Cognitive and Affective Aspects in Science Education Research*. 2017, Springer. p. 117-126.
12. Braund, M. and Z. Ahmed, *Drama as physical role-play: actions and outcomes for life science lessons in South Africa*. *Journal of Biological Education*, 2019. **53**(4): p. 412-421.
13. McGuffee, J.W., *Drama in the computer science classroom*. *Journal of Computing Sciences in Colleges*, 2004. **19**(4): p. 292-298.
14. Gokhale, A.A., *Collaborative learning enhances critical thinking*. 1995.
15. Newell, C. and A. Bain, *Team-Based Collaboration in Higher Education Learning and Teaching: A Review of the Literature*. 2018: Springer.
16. Sooksomchitra, A., P. Koraneekij, and J. Na-Songkhla, *Education for Social Responsibility: The Use of CSCL in Undergraduate Service-Learning Modules*. *Creative Education*, 2013. **4**(9B): p. 59.
17. Perera, I., C. Allison, and A. Miller. *A use case analysis for learning in 3d muve: A model based on key e-learning activities*. in *5th International Conference on Virtual Learning*. 2010.
18. Cho, Y.H., S.Y. Yim, and S. Paik, *Physical and social presence in 3D virtual role-play for pre-service teachers*. *The Internet and Higher Education*, 2015. **25**: p. 70-77.
19. Dracup, M., *Online role play stories, engagement and learning in higher education*. 2011, Deakin University.
20. Jimenez-Diaz, G., P.A. Gonzalez-Calero, and M. Gomez-Albarran, *Role-play virtual worlds for teaching object-oriented design: the ViRPlay development experience*. *Software: Practice and Experience*, 2012. **42**(2): p. 235-253.

REFERENCES

21. Akpan, J.P., *Issues associated with inserting computer simulations into biology instruction: a review of the literature*. The Electronic Journal for Research in Science & Mathematics Education, 2001.
22. Akpan, J. and J. Strayer, *Which comes first the use of computer simulation of frog dissection or conventional dissection as academic exercise?* Journal of Computers in Mathematics and Science Teaching, 2010. **29**(2): p. 113-138.
23. Baser, M., *Effects of conceptual change and traditional confirmatory simulations on pre-service teachers' understanding of direct current circuits*. Journal of Science Education and Technology, 2006. **15**(5-6): p. 367-381.
24. Smetana, L.K. and R.L. Bell, *Computer simulations to support science instruction and learning: A critical review of the literature*. International Journal of Science Education, 2012. **34**(9): p. 1337-1370.
25. Michael Gardner, B.H., Nikhil Joshi, *Structured learning activities in virtual worlds*.
26. Joshi, N. *Learning design and structured tasks in 3D virtual world*. in *Impact of E-Technology on US (IMPETUS), 2014 International Conference on the*. 2014. IEEE.
27. McGregor, I. *The relationship between simulation and emulation*. in *Simulation Conference, 2002. Proceedings of the Winter*. 2002. IEEE.
28. Perera, I., C. Allison, and A. Miller, *Policy considerations for managing 3D multi user learning environments-achieving usability and trust for learning*. 6th ICVL, 2011. **1**(1): p. 106-112.
29. Dalgarno, B. and M.J. Lee, *What are the learning affordances of 3-D virtual environments?* British Journal of Educational Technology, 2010. **41**(1): p. 10-32.
30. Mayes, J.T. and C.J. Fowler, *Learning technology and usability: a framework for understanding courseware*. Interacting with computers, 1999. **11**(5): p. 485-497.
31. Benyon, D., P. Turner, and S. Turner, *Designing interactive systems: People, activities, contexts, technologies*. 2005: Pearson Education.
32. ALRASHIDI, M., et al., *ThePedagogical Virtual Machine: Supporting Learning Computer Hardware and Software via Augmented Reality*. London, 28-29 November 2013 King's College London, UK, 2013: p. 247.
33. Shao, K. and P. Maher, *Making advanced computer science topics more accessible through interactive technologies*. Interactive Technology and Smart Education, 2012. **9**(2): p. 89-99.
34. Sarkar, N.I. and K. Petrova, *Design and Evaluation of a Web-Based Tool for Teaching Computer Network Design to Undergraduates*. Web-Based and Blended Educational Tools and Innovations, 2012: p. 214.
35. HUA, B., *Role-play and simulation*. The English Teacher, 2017: p. 16.
36. Longford, E., M. Gardner, and V. Callaghan. *Social Organisation and Cooperative Learning: Identification and Categorisation of Groups and Sub-Groups in Non-Cooperative Games*. in *International Conference on Immersive Learning*. 2019. Springer.
37. Springer, L., M.E. Stanne, and S.S. Donovan, *Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis*. Review of educational research, 1999. **69**(1): p. 21-51.
38. Gunderson, D.E. and J.D. Moore, *Group learning pedagogy and group selection*. International Journal of Construction Education and Research, 2008. **4**(1): p. 34-45.
39. Clapper, T., *Role play and simulation*. Education Digest, 2010. **75**(8): p. 39-43.
40. Tompkins, P.K., *Role playing/simulation*. The Internet TESL Journal, 1998. **4**(8): p. 143-150.
41. Smith, N., S. Prybylo, and T. Conner-Kerr, *Using simulation and patient role play to teach electrocardiographic rhythms to physical therapy students*. Cardiopulmonary physical therapy journal, 2012. **23**(1): p. 36.
42. Andersson, N. and P.H. Andersson. *Teaching professional engineering skills: industry participation in realistic role play simulation*. in *Making Change Last: Sustaining and Globalizing Engineering Educational Reform*. 2010. École Polytechnique.

REFERENCES

43. Druckman, D. and N. Ebner, *Onstage or behind the scenes? Relative learning benefits of simulation role-play and design*. *Simulation & Gaming*, 2008. **39**(4): p. 465-497.
44. Clements, M.D., *Role-playing: a learning process to aid supply chain integration*. *Development and Learning in Organizations: an international journal*, 2007. **21**(3): p. 14-16.
45. Umopathy, S., *Teaching behavioral aspects of performance evaluation: An experiential approach*. *Accounting Review*, 1985: p. 97-108.
46. Craig, R. and J. Amernic, *Roleplaying in a conflict resolution setting: Description and some implications for accounting*. *Issues in Accounting Education*, 1994. **9**(1): p. 28.
47. Jones, J.S. *Participatory teaching methods in computer science*. in *ACM SIGCSE Bulletin*. 1987. ACM.
48. Andrianoff, S.K. and D.B. Levine. *Role playing in an object-oriented world*. in *ACM SIGCSE Bulletin*. 2002. ACM.
49. Bellin, D. and S.S. Simone, *The CRC card book*. 1997: Addison-Wesley Professional.
50. Biddle, R., J. Noble, and E. Tempero, *Use Case Cards and Roleplay for Object Oriented Development*. 2012.
51. Beck, K. and W. Cunningham. *A laboratory for teaching object oriented thinking*. in *ACM Sigplan Notices*. 1989. ACM.
52. Ambler, S.W., *The object primer: Agile model-driven development with UML 2.0*. 2004: Cambridge University Press.
53. Hvam, L., J. Riis, and B.L. Hansen, *CRC cards for product modelling*. *Computers in Industry*, 2003. **50**(1): p. 57-70.
54. Olufemi, O., *Pedagogical Approaches and Technical Subject Teaching through Internet Media*. *The Electronic Journal of e-Learning*, 2008. **6**(1): p. 53-66.
55. Onyesolu, M.O., et al., *Pedagogy: Instructivism to Socio-Constructivism through Virtual Reality*. *Pedagogy*, 2013. **4**(9).
56. Diaz, D.P. and K.F. Bontenbal, *Pedagogy-based technology training*. *Teaching and learning in a network world*, 2000. **105**: p. 50-54.
57. Hein, G., *Constructivist learning theory*. Institute for Inquiry. Available at: <http://www.exploratorium.edu/ifi/resources/constructivistlearning.html>, 1991.
58. Amineh, R.J. and H.D. Asl, *Review of constructivism and social constructivism*. *Journal of Social Sciences, Literature and Languages*, 2015. **1**(1): p. 9-16.
59. Arghode, V., E.W. Brieger, and G.N. McLean, *Adult learning theories: implications for online instruction*. *European Journal of Training and Development*, 2017.
60. El Mhouti, A., A. Nasseh, and M. Erradi, *Towards a socioconstructivist and collaborative Learning Design approach to modeling pedagogical contents used in e-learning: Implementation and experimentation*. *International Journal of Innovation and Applied Studies*, 2014. **8**(4): p. 1653.
61. Wertsch, J.V., *Vygotsky and the formation of the mind*. 1997, Cambridge.
62. Bauersfeld, H., " *Language Games*" in *the Mathematics Classroom: Their Function and Their Effects*. *The emergence of mathematical meaning: Interaction in classroom cultures*, 1995: p. 271-291.
63. McSharry, G. and S. Jones, *Role-play in science teaching and learning*. *School Science Review*, 2000. **82**: p. 73-82.
64. Brook, P., *The empty space: A book about the theatre: Deadly, holy, rough, immediate*. 1996: Simon and Schuster.
65. Groff, J.S., *The potentials of game-based environments for integrated, immersive learning data*. *European Journal of Education*, 2018. **53**(2): p. 188-201.
66. Klopfer, E., S. Osterweil, and K. Salen, *Moving learning games forward*. Cambridge, MA: The Education Arcade, 2009.
67. Milgram, P. and F. Kishino, *A taxonomy of mixed reality visual displays*. *IEICE TRANSACTIONS on Information and Systems*, 1994. **77**(12): p. 1321-1329.

REFERENCES

68. Bainbridge, W.S., *The scientific research potential of virtual worlds*. science, 2007. **317**(5837): p. 472-476.
69. Keating, T., et al., *The virtual solar system project: developing conceptual understanding of astronomical concepts through building three-dimensional computational models*. Journal of Science Education and Technology, 2002. **11**(3): p. 261-275.
70. Ketelhut, D.J., *The Impact of Student Self-efficacy on Scientific Inquiry Skills: An Exploratory Investigation in River City, a Multi-user Virtual Environment*. Journal of Science Education and Technology, 2007. **16**(1): p. 99-111.
71. Kontogeorgiou, A.M., J. Bellou, and T.A. Mikropoulos, *Being inside the Quantum Atom*. PsychNology Journal, 2008. **6**(1).
72. Alsaqqaf, A. and F. Li. *Correction to: Conceptual Framework for Virtual Field Trip Games*. in *International Conference on Immersive Learning*. 2019. Springer.
73. Lee, E.A.-L., K.W. Wong, and C.C. Fung, *How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach*. Computers & Education, 2010. **55**(4): p. 1424-1442.
74. Limniou, M., D. Roberts, and N. Papadopoulos, *Full immersive virtual environment CAVETM in chemistry education*. Computers & Education, 2008. **51**(2): p. 584-593.
75. Mikropoulos, T.A. and A. Natsis, *Educational virtual environments: A ten-year review of empirical research (1999–2009)*. Computers & Education, 2011. **56**(3): p. 769-780.
76. Hsin, C.-T., M.-C. Li, and C.-C. Tsai, *The influence of young children's use of technology on their learning: A review*. Journal of Educational Technology & Society, 2014. **17**(4): p. 85-99.
77. Prasolova-Førland, E., *Analyzing place metaphors in 3D educational collaborative virtual environments*. Computers in Human Behavior, 2008. **24**(2): p. 185-204.
78. McCaffery, J., A. Miller, and C. Allison. *Extending the Use of Virtual Worlds as an Educational Platform-Network Island: An Advanced Learning Environment for Teaching Internet Routing Algorithms*. in *CSEDU (1)*. 2011.
79. Rodríguez, F.J., N.D. Kerby, and K.E. Boyer. *Informing the design of a game-based learning environment for computer science: A pilot study on engagement and collaborative dialogue*. in *The Proceeding of the 1st Workshop on AI-supported Education for Computer Science (AIEDCS 2013)*. 2013.
80. Felemban, S., et al., *Mixed Agents Virtual Observation Lenses for Immersive Learning Environments*. J. UCS, 2018. **24**(2): p. 171-191.
81. Felemban, S., M. Gardner, and V. Callaghan, *Towards recognising learning evidence in collaborative virtual environments: a mixed agents approach*. Computers, 2017. **6**(3): p. 22.
82. Potkonjak, V., et al., *Virtual laboratories for education in science, technology, and engineering: A review*. Computers & Education, 2016. **95**: p. 309-327.
83. Peña-Rios, A., et al., *Preface to the Special Issue on Immersive Environments: Challenges, Research and New Developments*. EAI Endorsed Transactions on Future Intelligent Educational Environments, 2016. **2**(6): p. 151520-151520.
84. Gardner, M. and J. Elliott, *The Immersive Education Laboratory: understanding affordances, structuring experiences, and creating constructivist, collaborative processes, in mixed-reality smart environments*. EAI Endorsed Transactions on Future Intelligent Educational Environments, 2014. **14**(1): p. creators-Gardner= 3AMichael= 3A= 3A.
85. Salako, O., M. Gardner, and V. Callaghan. *A Responsive Templating Approach for Generating Collaborative Spaces*. in *EAI International Conference on Technology, Innovation, Entrepreneurship and Education*. 2017. Springer.
86. Gardner, M. and L. O'Driscoll, *MiRTLE (Mixed-Reality Teaching and Learning Environment): from prototype to production and implementation*. 2011.
87. Murray, T., et al. *Toward glass box educational simulations: reifying models for inspection and design*. in *2001 Workshop, External Representations in AIED: Multiple Forms and Multiple Roles*

- San Antonio, Texas.[Fichier, 2003: <http://www.psychology.nottingham.ac.uk/research/credit/AIED-ER/murray.pdf>]. 2001.
88. Beetham, H. and R. Sharpe, *Rethinking pedagogy for a digital age: Designing for 21st century learning*. 2013: routledge.
 89. Britain, S., *A review of learning design: concept, specifications and tools*. A report for the JISC E-learning Pedagogy Programme, 2004. **2006**.
 90. Dalziel, J., *Implementing learning design: A decade of lessons learned*. Electric Dreams. Proceedings ascilite, 2013: p. 210-220.
 91. Berggren, A., et al., *Practical and pedagogical issues for teacher adoption of IMS learning design standards in Moodle LMS*. Journal of Interactive Media in Education, 2005. **2005**(1).
 92. Dalziel, J. and B. Dalziel, *Adoption of learning designs in teacher training and medical education: Templates versus embedded content*. 2011.
 93. Cram, A., K. Lumkin, and J. Eade. *Using LAMS to structure and support learning activities in virtual worlds*. in *Proceedings of the 5th International LAMS Conference & Learning Design*, <http://lamsfoundation.org/lams2010sydney/papers.htm>. 2010.
 94. Dalgarno, B., et al., *Practising teaching using virtual classroom role plays*. Teacher Education, 2013. **41**: p. 1.
 95. Davis, S., *Digital Drama—Toolkits, Dilemmas, and Preferences*. Youth Theatre Journal, 2011. **25**(2): p. 103-119.
 96. King, E., et al., *Moving digital games for learning forward*. On the Horizon, 2016.
 97. Fujimoto, R., et al. *Dynamic data driven application systems: research challenges and opportunities*. in *2018 Winter Simulation Conference (WSC)*. 2018. IEEE.
 98. Anderson, C., *Creating a data-driven organization: Practical advice from the trenches*. 2015: "O'Reilly Media, Inc."
 99. Wohlstetter, P., A. Datnow, and V. Park, *Creating a system for data-driven decision-making: Applying the principal-agent framework*. School effectiveness and school improvement, 2008. **19**(3): p. 239-259.
 100. O'Keeffe, A. and M. McCarthy, *The Routledge handbook of corpus linguistics*. 2010: Routledge.
 101. Rivers, K. and K.R. Koedinger. *Automatic generation of programming feedback: A data-driven approach*. in *The First Workshop on AI-supported Education for Computer Science (AIEDCS 2013)*. 2013.
 102. Barnes, T. and J. Stamper. *Toward automatic hint generation for logic proof tutoring using historical student data*. in *International Conference on Intelligent Tutoring Systems*. 2008. Springer.
 103. Wirfs-Brock, R. and B. Wilkerson. *Object-oriented design: a responsibility-driven approach*. in *ACM sigplan notices*. 1989. ACM.
 104. Janitor, J., F. Jakab, and K. Kniewald. *Visual Learning Tools for Teaching/Learning Computer Networks: Cisco Networking Academy and Packet Tracer*. in *Networking and Services (ICNS), 2010 Sixth International Conference on*. 2010.
 105. Pizzonia, M. and M. Rimondini, *Netkit: network emulation for education*. Software: Practice and Experience, 2016. **46**(2): p. 133-165.
 106. Tashiro, J.S. and D. Dunlap. *The impact of realism on learning engagement in educational games*. in *Proceedings of the 2007 conference on Future Play*. 2007. ACM.
 107. Winn, W., *A conceptual basis for educational applications of virtual reality*. Technical Publication R-93-9, Human Interface Technology Laboratory of the Washington Technology Center, Seattle: University of Washington, 1993.
 108. Boulos, M.N.K., L. Hetherington, and S. Wheeler, *Second Life: an overview of the potential of 3-D virtual worlds in medical and health education*. Health Information & Libraries Journal, 2007. **24**(4): p. 233-245.

109. Alzahrani, A., *Towards the Development and Understanding of Collaborative Mixed-Reality Learning Spaces*. 2017, University of Essex.
110. Börstler, J. *Improving CRC-card role-play with role-play diagrams*. in *Companion to the 20th annual ACM SIGPLAN conference on Object-oriented programming, systems, languages, and applications*. 2005. ACM.
111. Gray, K.A., M. Guzdial, and S. Rugaber, *Extending CRC cards into a complete design process*. ACM SIGCSE Bulletin, 2003. **35**(3): p. 226-226.
112. Pena Rios, A., *Exploring mixed reality in distributed collaborative learning environments*. 2016.
113. Kurose, J.F. and K.W. Ross, *Computer networking: a top-down approach*. Vol. 5. 2010: Addison-Wesley Reading.
114. Combs, G. *Wireshark is 2.6.2*. 1998; Available from: <https://www.wireshark.org/download.html>.
115. *Wireshark Wiki*. 14/4/2017; the wiki site for the Wireshark network protocol analyzer]. Available from: <https://wiki.wireshark.org/>.
116. Witmer, B.G. and M.J. Singer, *Measuring presence in virtual environments: A presence questionnaire*. *Presence*, 1998. **7**(3): p. 225-240.
117. Anzai, Y. and H.A. Simon, *The theory of learning by doing*. *Psychological review*, 1979. **86**(2): p. 124.
118. Hong, J.-C., et al., *Using a "prediction–observation–explanation" inquiry model to enhance student interest and intention to continue science learning predicted by their Internet cognitive failure*. *Computers & Education*, 2014. **72**: p. 110-120.
119. Sweller, J., *The redundancy principle in multimedia learning*. *The Cambridge handbook of multimedia learning*, 2005: p. 159-167.
120. Colvin, R. and R.E. Mayer, *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning*. 2011: Pfeiffer.
121. Rosen, K.H., *Discrete mathematics and its applications*. 2011: New York: McGraw-Hill.
122. Davis, F.D., *User acceptance of information technology: system characteristics, user perceptions and behavioral impacts*. *International journal of man-machine studies*, 1993. **38**(3): p. 475-487.
123. Cohen, L., L. Manion, and K. Morrison, *Research methods in education Abingdon: Routledge Falmer*. 2007.
124. Burke, L.A. and K.E. James, *PowerPoint-based lectures in business education: An empirical investigation of student-perceived novelty and effectiveness*. *Business Communication Quarterly*, 2008. **71**(3): p. 277-296.
125. Keller, J. and K. Suzuki, *Learner motivation and e-learning design: A multinationally validated process*. *Journal of educational Media*, 2004. **29**(3): p. 229-239.
126. Fossey, E., et al., *Understanding and evaluating qualitative research*. *Australian and New Zealand journal of psychiatry*, 2002. **36**(6): p. 717-732.
127. Chenail, R.J., *Conducting qualitative data analysis: Reading line-by-line, but analyzing by meaningful qualitative units*. *The Qualitative Report*, 2012. **17**(1): p. 266-269.