Supporting the Development of Preservice Primary Teachers’ Understanding of Science Concepts Using Immersive and Modelling Environments

By
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A thesis submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy

Faculty of Arts and Social Sciences
School of Education and Social Work

THE UNIVERSITY OF SYDNEY

2019
STATEMENT OF ORIGINALITY

This is to certify that to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

Signature

Reem Mohammed

May 2019
ABSTRACT

Research has shown that primary school teachers often have a poor background in science and scientific concepts, and as a consequence may feel particularly under-prepared to teach science. This study examines the effect of an intervention that investigated the knowledge and understanding of science concepts and confidence in ability in teaching science for a group of first-year preservice primary teachers. The group was identified as having low prior background knowledge of science and self-reported low confidence in their ability to learn and teach science. The intervention consisted of engaging the participants using two technology-based resources (an immersive environment and a modelling environment) as learning and teaching tools. The environments were Omosa, a 3D game-like virtual learning environment (VLE), and Omosa NetLogo, a simulation/modelling environment. The study also explored the interrelationship between content knowledge (CK) and confidence in ability in science and scientific concepts, and sought to examine participants’ perceptions about their learning in the two environments.

A small-N study design was used in this study to determine whether or not the intervention resulted in improving preservice teachers’ science CK and confidence in their ability in science learning and teaching. A small-N study design was deemed to be a suitable research method to answer the research questions. Qualitative data were derived from several sources using multiple methods of data collection, including semi-structured interviews, participant’s concept maps, participants’ responses to the guidebooks provided and Camtasia software recordings of participants’ actions and interactions during the learning sessions. Eight preservice teachers from an Australian university, working in dyads, participated in two learning sessions. The first session involved the use of the immersive environment Omosa, and the second session involved the use of the
modelling environment Omosa NetLogo. The aim was to develop their knowledge in ecology concepts related to conceptual dimensions of ecosystems that are aligned with the new Australian science curriculum, as well as the main phases of conducting a scientific inquiry.

Participants’ science knowledge and understanding of ecology concepts were measured before and after the intervention. Changes in their confidence, perception and engagement with the learning resources during the intervention were also examined. The results indicated that all of the participants demonstrated an increase in their ecology knowledge. Examination of the participants’ interactions while using the two learning environments revealed high levels of cognitive engagement in both environments. Comparison of concept maps pre- and post-intervention revealed more sophisticated ideas and a greater number of connections between terms, indicating an improvement in participants’ understanding of ecosystem concepts after the intervention. Finally, participants’ comments on their experiences indicated that they appreciated the independence provided by the inquiry framework and acknowledged that they learnt from both technology-based resources; however, they perceived that these experiences contributed in different ways.

Overall, the findings suggest that the combination of the immersive and modelling environments facilitated and provided appropriate knowledge-building opportunities for participants by supporting their cognitive engagement. The study contributes to the knowledge of how best to prepare preservice primary teachers for the demands of the 21st-century classroom and adds to the body of knowledge on the use of immersive and modelling environments in science teacher education.
ACKNOWLEDGMENTS

First of all, I thank Allah, the almighty, for giving me the strength and patience to work through all these years and for blessing me with many great people who have been my greatest support.

The completion of this thesis would not have been possible without the support and encouragement of several special people. Hence, I would like to take this opportunity to show my gratitude to those who have assisted me in a myriad of ways.

I am extremely grateful to my supervisor, Professor Peter Reimann, for his support, guidance and motivation. It would never have been possible for me to take this work to completion without his incredible support and encouragement.

There are no proper words to express my deepest gratitude for my associate supervisor, Dr Shannon Kennedy-Clark, for her inspiring guidance, encouragement, motivation and heartfelt cooperation and supervision. It is because of her dedication, commitment, unfailing support and willingness to offer me so much of her time and intellect that my dream came true. Thank you so much Shannon.

I would like to thank my former supervisors and co-supervisors Chun Hu, Michael Jacobson, Louise Sutherland and Charlotte Taylor, as well as George Ridgway from the learning centre. I would also like to thank all participants in this research for their valuable assistance.
I would like to thank my loving family. To my dearest husband and best friend Dr Faisal Magableh for being so understanding and for putting up with me through the toughest moments of my life—I could never have accomplished this thesis without your love, understanding, prayers and continuing support. To my four beautiful sons Omar, Bassil, Zaid and Siraj, who are the pride and joy of my life, for putting up with me being a part-time mum for such a very long time; I love you and I appreciate all your patience and support during my PhD studies.

Also I express my thanks to my brothers, sisters, family-in-law, sisters-in-law and grandmothers for their support and valuable prayers. My special thanks go to my sister Reham and my gorgeous nieces Lujain and Sawsan, who have been generous with their love and encouragement despite the long distance between us.

Finally, I want to express my sincere gratitude to whom this thesis is especially dedicated—my parents. Dad, mom I do not know how to thank you enough. Your dreams for me have resulted in this achievement and without your loving upbringing and nurturing I would not have been where I am today and what I am today. I would never be able to pay back the love and affection showered upon me by you. Thank you from the bottom of my heart! I would also like to thank the rest of my family and all my friends who were by my side during all the years. Each of them helped me a lot, even if they are not aware of it.

My thesis was edited by Elite Editing, and editorial intervention was restricted to Standards D and E of the Australian Standards for Editing Practice.
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GLOSSARY OF KEY TERMS

**Concept map:** In the context of this study, a concept map is a graphics tool used by students to organise and represent their knowledge of a concept. A concept map consists of nodes and links. Observation of the construction and sophistication of a student’s concept maps can enable a researcher or teacher to monitor and assess the learner’s understanding of a phenomenon or concept after participating in an intervention or activity. Moreover, concept maps enable the identification of misconceptions.

**Confidence level:** Confidence level refers to an individual’s self-assessment about their capabilities for accomplishing a set goal. In this study, it is the participant’s self-report of their ability in science learning and teaching.

**Content knowledge (CK):** The body of knowledge and information that teachers teach and that students are expected to learn in a given subject or content area.

**Immersive environment:** In the scope of this study, an immersive environment uses elements of virtual reality and computer games to provide a unique learning experience for users. Users also have an avatar, or character, that represents them in the environment. They can interact with other characters in the ‘world’ and with objects and artefacts to gather information.

**Modelling environment:** In this study, a modelling environment refers to a computer simulation that attempts to simulate an abstract model of a particular system. Modelling environments can be used to simulate complex ecological systems, such as food webs.
Omosa: A game-like immersive environment that was collaboratively designed and developed by the University of Sydney and Macquarie University. Omosa was designed to help secondary school students to understand concepts from biology and to develop their scientific inquiry skills by enabling them to engage in scientific inquiry. In Omosa, students work together and take on a role similar to real biologists exploring the environment and viewing phenomena, and gather information to identify and understand the complex causes leading to a specific ecological crisis.

Omosa NetLogo: A simulation and modelling environment designed by the same team who designed Omosa, and linked to the Omosa environment. In Omosa NetLogo, participants can simulate ecological phenomena, run a model, control it and monitor its behaviour to enhance their understanding of an ecology topic. In this study, participants were able to test hypotheses based on the observations made in Omosa by manipulating different variables and observing the results.

Preservice teachers: Students who are enrolled in teacher preparation programs and are working towards teacher certification. In Australia, a preservice teacher is an education student that is completing an undergraduate or postgraduate university qualification.

Primary teacher: Internationally referred to as an elementary school teacher. In Australia, primary school teachers are trained to teach students from kindergarten to Year 6. They plan and deliver educational programs to assist in the intellectual, physical and social development of primary school students who are typically aged 5–12 years.
Teacher education program: In Australia, a teacher education program is the formal university program that individuals need to complete before they can gain the accreditation needed to teach in the school system.

Technological, pedagogical and content knowledge (TPACK): A theory developed to explain the set of knowledge and pedagogical practices that teachers need to effectively teach their students a subject and to use technology meaningfully.
CHAPTER 1: INTRODUCTION TO THE STUDY

1.1 Introduction

Science teaching and learning in primary (elementary) schools, more specifically the lack of science teaching in primary school, is an area of growing concern in Australia and in other countries (Aubusson, Schuck, Ng, Burke, & Pressick-Kilborn, 2015; Avery & Meyer, 2012; Fitzgerald & Smith, 2016; Woolcott & Whannell, 2017). Primary science education centres on the work of teachers (Fitzgerald & Smith, 2016); however, research has shown that primary teachers often have a limited background in science and may, as a consequence, feel under-prepared to teach science effectively (Appleton, 2002, 2003; Bayer Corporation, 2004; Bleicher, 2007, 2009; Harlen, 1997; Harlen & Holroyd, 1997; Herbert & Hobbs, 2018; Howitt, 2007; Palmer, Dixon, & Archer, 2015).

While teacher education programs aim to prepare graduates to become quality teachers equipped with the necessary content and pedagogical knowledge (PK), to meet the demands of the 21st-century classroom (Mergler & Spooner-Lane, 2012), there are concerns around some characteristics and possible insufficiencies of teacher education programs that could have adverse effects on primary teachers’ science content knowledge (CK). One concern is that primary teachers are often trained as generalist teachers during teacher education programs; thus they are expected to develop skills necessary to competently teach multiple subjects across the primary curriculum, including science, to a diverse range of learners (Fitzgerald & Smith, 2016; Nowicki, Sullivan-Watts, Shim, Young, & Pockalny, 2013; Timms, Moyle, Weldon, Mitchell, & Australian Council for Educational, 2018). Therefore, it is possible that as generalist teachers these primary teachers will not have proficiency in delivering all learning areas in primary school curricula (Hudson, 2005). This appears to affect the teaching of science more than other
subjects. Science is reported in the literature as one of the least taught subjects in primary schools (Angus et al., 2004; Angus, Olney, & Ainley, 2007; Petersen & Treagust, 2014; Treagust, Won, Petersen, & Wynne, 2015).

Another concern is the time available for preservice teacher training in science. It has been outlined that the time offered for science instruction during teacher education programs is often limited relative to the large amount of information that needs to be covered (Nowicki et al., 2013). The approaches used in teacher education programs are among these concerns. Science courses in teacher education programs may involve a large number of preservice teachers taught in a lecture format where they are exposed to traditional, didactic approaches, with only minimum experience with authentic inquiry or practical experience, which provides these students little opportunity to achieve a strong conceptual understanding of science (Abd-El-Khalick & BouJaoude, 1997; Nowicki et al., 2013). Hence, it is evident in the literature that preservice teacher education programs may not provide sufficient opportunities for preservice teachers to develop the CK necessary to teach science effectively (Abd-El-Khalick & BouJaoude, 1997).

Therefore, teacher education programs need to be designed to ensure they offer sufficient, effective and positive educational experiences in science content and teaching to provide future teachers with adequate CK and PK to become effective primary teachers. To this end, I conducted a study driven by the need to elevate scientific knowledge and skills in preservice teachers during their teacher education program. The study presents findings from a small-N design study that was conducted with a group of first year preservice primary teachers identified as having low prior background knowledge in science and low confidence in their ability to teach science. The study consisted of engaging a group of preservice teachers to learn science content (ecology concepts) using a combination of
two information and communication technology (ICT) resources—an immersive environment; and a modelling environment—and inquiry activities. The study investigated the effect of engaging preservice teachers with such environments on their science CK and confidence in their ability in science. The study also explored the interrelationship between CK and confidence in ability in science for the group of preservice primary teachers.

In this introductory chapter an overview of the study is provided. The chapter commences by providing a background of the study. It then proceeds to the aims of the study and the research questions. An explanation of the significance of the study is included. This is followed by presentation of the thesis organisation. Finally, a summary of the introduction is provided.

1.2 Background

The high-quality teaching of science in primary schools is a national priority in Australia. The aim of this priority is to support young learners who have the capacity to achieve their full potential in becoming scientifically literate adults, as well as being able to contribute to both the social and economic wellbeing of Australia (Peers, 2006). Scientifically literate individuals should be able to use existing scientific knowledge to obtain new knowledge; explain scientific issues; draw conclusions about social issues related to science; make informed decisions for resolving problems related to science; understand how science might influence our material, intellectual and cultural environments; and engage in science-related issues (OECD, 2010). Hence, science is an important part of an individual’s education. Reflecting this importance, the Australian primary school teaching curriculum positions science as one of the Key Learning Areas
in the primary education field, which means it is a compulsory curriculum component for all primary education students.

1.2.1 Issues in science education in primary schools

Studies confirm that among school-related factors, teachers are a significant factor that can contribute to a student’s success at school (RAND Education, 2012). Students taught by teachers with limited CK and low confidence in their ability in science will most likely receive poor preparation and have poor learning experiences in school. Thus, strategies must be implemented to strengthen primary teachers’ CK and confidence in science. The magnitude of this challenge is causing educators to seek solutions in a variety of ways. Stakeholders have called for strategies for improving primary teachers’ CK and confidence in science as a means to enhance students’ learning and achievement in science (Tytler, 2007).

Widespread concerns, however, regarding primary school science education have been raised in research (see, e.g., (Appleton, 1999; CBI, 2015; Fitzgerald & Smith, 2016; Hackling, Peers, & Prain, 2007; Wu & Albion, 2019). The main concerns are the inadequacy of science education in primary schools, which in turn may negatively affect students’ future educational outcomes. As evidenced by the results from the Trends in International Mathematics and Science Study (TIMSS), which has measured student achievement in mathematics and science at Year 4 and Year 8 in Australia and many other countries since 1995, there has been no change in mathematics and science scores for Australian students since the study began, while student achievement in other countries has improved. The 2015 report shows that Australian Year 4 students were outperformed by students in 21 countries in mathematics and by 17 countries in science. At Year 8 level, Australian students were outperformed in mathematics by 12 countries and by 14 in science (Thomson, 2016). The same report shows that the average time spent on Year 4
science instruction in Australia was 57 hours per year, while internationally, the average was 76 hours per year; and in Year 8, the average time spent on science instruction in Australia was 126 hours per year, whereas internationally the average time was 144 hours per year (Thomson, Wernert, O’Grady, Rodrigues, & Australian Council for Educational Research, 2017).

It is argued that two central issues negatively affect the quality of science education in primary schools. The first is the limited time devoted to teaching science in primary schools (Angus et al., 2007; Appleton, 2002; Australian Science Teachers Association, 2014). The second is that the practices that teachers use in their science classes have been shown to influence students’ scientific knowledge and skill development (Appleton, 2002; Harlen & Holroyd, 1997; Thornburg, 2009). These two issues are not new, but they appear to be increasingly problematic and are affecting the quality of science education in primary schools, and, as a consequence, students’ educational outcomes.

The limited time allocated to science education in primary schools has been shown to affect the development of scientific knowledge and skills. In Australia, primary teachers spend only 3% of their instructional time teaching science, compared with 38% teaching English, 18% teaching mathematics and 11% teaching health and physical education (Angus et al., 2007). In 2014, data from an Australian Science Teachers Association (ASTA) survey indicated that primary teachers spend 1.6 hours per week teaching science, ranging from an average of 1.1 hours per week in the pre-school years to 1.8 hours per week in Year 6 (Australian Science Teachers Association, 2014). These averages are low compared with the time recommended by The NSW Education Standards Authority (NESA) for a typical school week for kindergarten to Year 6, which is 1.5–2.5 hours per week (NSW Education Standards Authority (NESA), 2018). The
time spent teaching science in Australia is also considered low in comparison with the international average based on the 2015 TIMSS report results as shown above, as well as earlier reports. In the 2011 TIMSS report, Australian teachers reported spending around 65 hours teaching their Year 4 students science, while on average internationally teachers reported spending around 86 hours teaching science to their students (Thomson & Australian Council for Educational Research, 2012). The 2007 TIMSS report revealed that on average, Australian Year 4 students spent only ~5% of their weekly instructional time on learning science (Thomson, Trends in International Mathematics and Science Study, & Australian Council for Educational Research, 2009).

In addition to the minimal time spent teaching science, many science educational practices in primary schools are based on textbooks and didactic approaches of teaching (Harlen & Holroyd, 1997; Thornburg, 2009), and are shaped around ‘activities that work’ (Appleton, 2002). These activities are those that the teacher has taught before or has had recommended to them, and teachers often feel comfortable with them as they are low risk in terms of teaching; that is, in general, such activities have predictable outcomes that will provide students with some science knowledge, and they are safe for the teacher in terms of classroom management (Appleton, 2002, 2003). As primary school teachers have significant control over their teaching programs, other factors are most likely to be related to, and influencing, the teaching of primary school science.

1.2.2 Factors contributing to the issues in science education in primary school

Reviewing the literature related to science education in primary schools shows that several factors, classified as external and internal factors, are influencing science education in primary schools and causing these issues (C. Lee & Houseal, 2003). External
factors are more related to effects such as resources (e.g., equipment, inadequate science curriculum resources) and the priority of learning science/culture in schools (e.g., giving priority to learning literacy and numeracy) (Griffith & Scharmann, 2008; Mangiante, 2018; Rennie, Goodrum, & Hackling, 2001). Internal factors, however, are more related to the primary teachers themselves, and include their interest in science (Jarrett, 1999); attitude towards science (van Aalderen-Smeets, Walma van der Molen, & Asma, 2012); beliefs about the purposes of science education, the nature of science, and learning and teaching science (D. Anderson, 2015); and science background knowledge and confidence in science (Appleton, 2002; Harlen, 1997).

The relatively low priority placed on science teaching at the primary school level stems from curriculum demands and stronger focuses on completing instruction in other capabilities, such as literacy and numeracy (Goodrum, Rennie, & Hackling, 2001; A. R. Milner, Sondergeld, Johnson, Johnson, & Czerniak, 2012). In such circumstances, science instruction is most often completely avoided, especially when a teacher lacks confidence in their ability in science. This is supported by Rennie et al. (2001), who state that, ‘In emphasising literacy and numeracy it is easy for some teachers, especially those who lack confidence in science, to neglect the teaching of science’ (Rennie et al., 2001, p. 492). Resources for teaching and learning science—which involve, for example, curriculum resources, equipment and teaching space—are also influencing how science is taught in primary schools. Resource limitations are indicated frequently by teachers as one of the major constraints on the quality of teaching and learning (Rennie et al., 2001). Accordingly, it has been recommended that primary teachers are provided with curriculum resources and support in ongoing professional development, to build up their competence and confidence to teach science in ways that stimulate better learning
outcomes contributing to scientific literacy (Boakye & Ampiah, 2017; Rennie et al., 2001).

The internal factors, however, can influence a teacher’s decision to teach science and what strategies they will implement to achieve certain learning outcomes. Having a negative attitude towards science can result in teachers avoiding teaching science or teaching it minimally, as primary teachers’ attitudes towards science has been identified as predictive of their intention to teach science in their classroom (Appleton & Kindt, 1999; van Aalderen-Smeets et al., 2012). It should be clarified here that the intention to teach science is distinct from a curriculum requirement that they must teach science. Primary teachers’ intention to teach science is derived from statements they report regarding their attitudes towards teaching science, such as dropping or postponing science lessons when running out of time in the week, rather than language and mathematics lessons, which is a matter of course for the curriculum, and system priorities implicitly value language and mathematics lessons more than science lessons (a short time is allocated to science lessons in the system) (Appleton & Kindt, 1999).

Teachers’ beliefs are also among the factors that both influence their behaviour and work as a guide for their actions in the classroom (Levitt, 2002). Teachers’ beliefs about the purpose of science education, the nature of science and learning and teaching science were found to strongly influence their practice and knowledge (D. Anderson, 2015). In addition, teachers’ beliefs about the purposes and goals of teaching science are important elements in their ‘orientations toward teaching science’ (Magnusson, Krajcik, & Borko, 1999). Hence, it has been shown that a teacher’s beliefs and perceptions of science can influence how they teach science and how often they teach science.
Primary teachers’ interest in science can influence their knowledge and practice in science as well. The influence of primary teachers’ interest in science on their knowledge and practice in science can be mediated by their confidence: correlations have been identified between interest and confidence in science (Jarrett, 1999) and primary teachers’ confidence in ability in teaching science, among the factors affecting science teaching in primary school (Appleton, 2002; Harlen, 1997). Primary teachers’ lack of confidence in their ability in science (Bleicher, 2007, 2009; Hoban, Macdonald, & Ferry, 2009; Howitt, 2007; Palmer et al., 2015) tends to affect their instructional approach, leading many to avoid teaching science, teaching as little of the subject as possible or relying on books rather than engaging in practical activities (Appleton, 1995; Harlen, 1997).

Limitations to primary teachers’ science CK can also cause primary teachers to avoid science instruction or to allocate less time for teaching science in the primary curriculum (Appleton & Kindt, 2002; Hoban et al., 2009; Naidoo, 2013). Insufficient CK tends to have an effect on teachers’ instructional approach as well (Kallery & Psillos, 2001). Scientific thinking approaches are often absent in teaching when teachers lack science CK (Pine et al., 2006). More details about primary teachers’ CK and confidence in science are presented in the next chapter, as these two factors are the focus of this study.

As it has been shown that both teaching science to primary school students and using appropriate teaching techniques are associated with preservice primary teachers’ science CK and confidence in their ability in science, teacher education programs can play a central role in addressing these challenges. In fact, educational practitioners have experimented with various teaching styles and methods during teacher education programs to enhance preservice primary teachers’ science CK and confidence in science. Sanger (2007), for example, found that an inquiry-based instructional approach in science
content courses helped preservice primary teachers learn science CK at a level as good as, or better, than the traditional lecture-based approach. Avery and Meyer (2012) also report that in their study gains were made in the majority of preservice primary teachers’ conceptual understanding of science; understanding of the science process and scientific research; and confidence in their ability in science as a result of inquiry-based science content course. Collaborative learning workshops and problem-based assignments were also found to be effective in developing preservice teachers’ conceptual and PK, as well as enhancing their sense of science teaching self-efficacy (Watters & Ginns, 2000). The use of ICT resources such as animations is also among the instructional strategies suggested in a number of studies to engage preservice teachers in understanding science CK and has been found to be effective in this regard (Hoban, 2007; Hoban et al., 2009; Masters, Carolan, & Draaisma, 2013). Literature centred on the development of preservice teachers’ technological, pedagogical and content knowledge (TPACK) has also shown that learning gains can be achieved by presenting preservice teachers with opportunities to learn content and pedagogy through technological interventions (L. Gill & Dalgarno, 2017).

Additionally, in regard to science methods courses, a range of approaches have been suggested to improve teachers’ confidence in their ability in understanding and teaching science. These include the use of hands-on activities; group work (Bleicher & Lindgren, 2005; Butts, Koballa, & Elliott, 1997; Palmer, 2006a); inquiry approaches (Jarrett, 1999; Sanger, 2008); and learning science content explicitly (Jarrett, 1999; Palmer, 2006a). Other studies have shown that undertaking professional practice where preservice teachers have the opportunity to teach science during or immediately after the learning science methods had the potential to enhance teachers’ confidence in their ability in science (Cantrell, Young, & Moore, 2003; Palmer, 2006a). Overall, there are a number
of factors that influence a preservice teacher’s ability and confidence in science and teaching science. This study aims to identify a set of strategies to address these issues.

1.3 Aims and Research Questions

Given that teacher education programs have been targeted as a means of improving preservice teachers’ science CK and confidence in teaching science, it is the intention of this research to suggest an understanding of ways in which teacher education courses can prepare preservice teachers for the classroom. The aim of this study is to examine the effect of an intervention on knowledge and understanding of science concepts and confidence in ability in science learning and teaching for a group of preservice primary teachers who have a low prior background in science and low confidence in their abilities in science, by utilising a combination of two ICT resources. The research also explores the interrelationship between CK and confidence in ability in science for a group of preservice primary teachers.

To achieve the aims of the research, an intervention was designed based on the findings presented in the reviewed literature. The intervention consisted of engaging the group of preservice teachers in the learning of science content using two ICT resources: an immersive environment and a modelling environment. Research suggests that immersive and modelling environments can have a positive effect on students’ understanding and learning, especially in science (Blikstein, Abrahamson, & Wilensky, 2005; Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005a, 2005b; Dede, Nelson, Ketelhut, Clarke, & Bowman, 2004; Gobert et al., 2004; Grotzer et al., 2015; Jacobson & Kozma, 2000; Ketelhut, 2007; Metcalf, Kamarainen, Tutwiler, Grotzer, & Dede, 2011; Wilensky & Reisman, 2006). Findings include enhancing students’ understanding of particular ecosystem concepts, such as complex causal relationships in ecosystems (Metcalf et al.,
and in transferring complex ecosystems concepts (Grotzer et al., 2015); enhancing students’ motivation (Dede, Ketelhut, & Nelson, 2004; Nelson & Ketelhut, 2007); and improving engagement with learning activities (Dede et al., 2005a, 2005b; Dede, Nelson, et al., 2004; Ketelhut, 2007). Computer modelling is also being used increasingly in education and training. In science education, for example, computer modelling approaches have been used in several educational research projects (Gobert et al., 2004; Jacobson & Kozma, 2000; Wilensky & Reisman, 2006). This has been shown to be a beneficial tool for learning about various scientific phenomena in fields such as physics, chemistry, biology, economics, sociology, engineering and psychology (Blikstein et al., 2005). The immersive environment used in this study was Omosa and the modelling environment was Omosa NetLogo. It should be noted here that the study’s aim was not to evaluate the tools, but to investigate how they can support the development of preservice teachers’ CK and confidence in teaching science. In this respect, the focus was on CK rather than TPACK.

The following research questions guided this research:

1. What is the effect of an intervention using an immersive environment (Omosa) and a modelling environment (Omosa NetLogo) on the development of first year preservice primary teachers’ knowledge and understanding in science?

2. What is the effect of an intervention using immersive and modelling environments on the development of first year preservice primary teachers’ confidence in science?

3. How do the experiences and perception of participating preservice primary teachers about their learning in immersive and modelling environments influence their knowledge and understanding and confidence in teaching ecology in a primary school?
1.4 Significance of the Study

This study is significant because it contributes to the knowledge of how best to prepare preservice teachers for the demands of the 21st-century classroom. The study is significant as it centres on developing preservice teacher skills and knowledge of how to teach science effectively in the primary classroom. The aim of this research is to assess the effect of an intervention—which involves engaging a group of first year preservice teachers to learn some ecology concepts using a combination of an immersive and modelling environment—on the development of their knowledge and understanding of science content and confidence in ability in science. In this approach, this research addresses the issues of primary teachers’ lack of science CK and lack of confidence in teaching science, which has been identified in the literature.

The study is also significant as it adds to the body of knowledge on the use of ICT resources in science teacher education. Few studies have investigated the effect of the combination of an immersive and a modelling environment on school students’ understanding in science (Jacobson, Taylor, & Richards, 2016). In addition, to my knowledge, no studies have investigated the combined effect of an immersive environment and a modelling environment on preservice primary teachers’ understanding and confidence in science.

This combination of the immersion and modelling environments is of interest to the researcher as they provide two different but complementary learning experiences for learners. In Omosa learners gain more understanding by exploring and testing different hypotheses related to factors that may contribute to the problems. Then, when using the Omosa NetLogo modelling environment they are able use their observations from the
An immersive environment to manipulate variables and observe the results. The game-like environment is immersive and requires the user to take on an avatar and to interact with the space, while the modelling environment is a simpler interface where users manipulate variables to ascertain the effect of changes. Both environments may present users with unique experiences that they may not encounter in a normal preservice teacher education program.

In addition, the study adds to the body of knowledge on primary science pedagogy. The results from this research will provide information on how to design and scaffold learning activities to enhance preservice teachers’ science CK and confidence in their abilities in science during their education program by utilising ICT resources. Based on the results of the study, a set of strategies are developed to help educators develop materials and approaches to teaching science using immersive and modelling environments. The goal of the strategies is to improve preservice teachers’ science CK and confidence in their ability in science. Positive change might occur because improvement in primary teachers’ science CK could potentially lead to improvements in students’ learning outcomes in science.

Despite many previous efforts devoted to help improve primary teachers’ science CK and confidence in their ability in science, there remain serious concerns relating to this problem in science education in primary schools. Therefore, novel interventions need to be introduced. In this regard, there is a dire need to examine new teaching and learning tools to be utilised in teacher education programs to improve preservice primary teachers’ science CK and confidence in their ability in science teaching, which may address the problem of ineffective teaching of primary school science. The literature suggests that primary teachers’ science CK and confidence in their ability in science affects science
education in primary schools. Teachers who are more knowledgeable about the subject are more likely to engage in effective classroom practices (Wenglinsky, 2000). This study explores an innovative dual approach to learning ecology concepts through immersion and modelling.

Teacher education programs should make use of newly available and easy-to-access technologies such as immersive and modelling environments to address the need to better prepare primary teachers to teach science. Including learning experiences that utilise these technologies in primary teachers’ education programs has been shown to make a difference in helping preservice teachers understand science concepts and improving their confidence in teaching science. Many studies have been undertaken that explore the development of preservice teachers’ TPACK (L. Gill & Dalgarno, 2017; Pope, Hare, & Howard, 2005; Schwarz, Meyer, & Sharma, 2007). Thus, these experiences should be part of quality primary teacher education programs. It is hoped that this research will encourage teacher educators to adopt new tools as effective teaching strategies that will benefit their students.

1.5 Thesis Organisation

This thesis is organised into seven chapters. Chapter 1 is the introduction chapter, which commences with an introduction to the study followed by the background of the problem. It then proceeds to outline the aims of the study and the research questions. An explanation of the significance of a study is included. This is followed by a presentation of the thesis organisation. Finally, a summary of the introduction is provided.

Chapter 2 presents a review of the literature and relevant research associated with the problem addressed in this study and makes reference to suggested approaches to address
the problem. The literature review also addresses primary teachers’ science CK and confidence in ability in science including the sources and strategies used to enhance CK and confidence of primary teachers in science. It also covers the body of research on the use of ICT resources in science education, particularly immersive and modelling environments.

Chapter 3 describes the methodology applied in this study, including the development and implementation of the learning experiences, the selection of participants and setting, and procedures used for data collection and analysis.

Chapter 4 contains a detailed analysis of the data and presentation and discussion of the results for one group of participants. This detailed analysis is used to demonstrate how the data are analysed for each of the dyads.

Chapter 5 contains an analysis of the data and presentation of the results for all groups, highlighting the themes across all of the dyads.

Chapter 6 offers a summary and discussion of the research findings for all dyads based on the research questions.

Chapter 7 provides a summary and conclusion for the study, implications and recommendation for practice, which is followed by the limitations of the study, areas for future research and final words.
1.6 Summary

It is evident from the literature that there are many issues that influence the quality of science education in primary schools. This is apparent from the limited time devoted to teaching science in primary schools and using didactic approaches to teaching science. It has been confirmed that among the major factors causing these issues in primary schools are primary teachers’ science CK and confidence in their ability in science and teaching science. This study aims to investigate new ways to improve preservice teacher education by exposing preservice teachers to innovative teaching and learning tools to improve their science CK and confidence in their ability in science learning and teaching. It is hoped that this may address the deficiencies in the teaching of science in primary schools in Australia.

In the next chapter, a detailed background to the study is provided in terms of the relevant literature on primary teachers’ science CK and confidence in ability in science. The chapter also discusses the possible approaches and strategies suggested in the literature to enhance science CK and confidence in science during teacher education programs, and their limitations. It also covers the body of research on the use of ICT resources in science education, particularly the use of immersive and modelling environments and how these resources can influence preservice primary teachers’ science CK and confidence in their ability in science learning and teaching.
CHAPTER 2: LITERATURE REVIEW

2.1 Introduction
This study examined the effects of using a combination of an immersive and modelling environment on the development of knowledge and understanding of science concepts for a group of preservice primary teachers (students enrolled in a teacher education program preparing for professional teaching positions), who have a low prior background and low confidence in their abilities in science. This study considered the development of preservice primary teachers’ CK during teacher education programs as a basis for the development of their pedagogical content knowledge (PCK). Along with changes in CK, the study sought to understand changes in preservice teachers’ confidence in their ability in science and the interrelationship between CK and confidence in ability in teaching primary science. The study assumed that an improvement in science CK would lead to development in confidence in ability in science.

In this chapter, the relevant literature on primary teachers’ science CK and confidence in ability in science learning and teaching science is discussed. The chapter also considers the possible approaches and strategies suggested in the literature to enhance the lack of science CK and lack of confidence in science during teacher education programs, and their limitations. This includes the use of ICT resources and how these resources can affect preservice primary teachers’ science CK and confidence in their ability in science.

2.2 Content Knowledge
The position of teachers’ science CK and what needs to be included in this knowledge are incorporated in the vision of science education described in recent curricula and standards, such as the Australian Science Standards and the United States (US) Next
Generation Science Standards (NGSS). Both standards are designed and developed with emphasis on the knowledge, understanding and skills students need to develop in science to become scientifically literate citizens (National Curriculum Board, 2009; Next Generation Science Standards (NGSS), 2013b). Thus, the Australian Science Standards and the US NGSS focus on the quality of knowledge and learning, rather on the quantity. In this sense, teachers are not required to teach more content but instead teach the content more effectively. The Australian Curriculum: Science, for instance, acknowledges the importance of three strands: science understanding, science inquiry skills and science as a human endeavour. The content of these three strands should be taught in an integrated way to provide students with understanding, skills and knowledge through which they may develop a scientific view of the world. Students are challenged to explore the concepts, processes and nature of science through procedures of inquiry (Australian Curriculum Assessment and Reporting Authority (ACARA), 2015; Mullis, Martin, Goh, & Cotter, 2016). Parallel to that, the NGSS have three dimensions: disciplinary core ideas (content), scientific and engineering practices and cross-cutting concepts. This method of teaching science gives teachers the flexibility to design classroom learning practices that motivate students’ interests in science and prepare them for college, careers and citizenship (Next Generation Science Standards (NGSS), 2013a, 2013b).

To deliver the quality of science education called for in these standards, a teacher’s own understanding of the subject matter is vital (Harlen & Holroyd, 1997). Teachers are responsible for making decisions about the instructional approach that will provide the best learning outcomes for their students. To be effective and successful science teachers they are expected to understand science content and learning and teaching approaches; and to be able to combine this knowledge for teaching science (Garbett, 2011). Continuous teacher development is necessary in this regard: teachers need a deep
understanding of the disciplinary core ideas and practices that they are anticipated to teach as defined in the curriculum. They also require knowledge of how students learn these ideas and practices and a range of instructional approaches and practices that support student learning (National Science Teachers Association (NSTA), 2016; Victoria Department of Education and Training, 2005).

Other aspects that provide a meaningful context for teachers’ subject matter are the nature of science and scientific inquiry. It is believed that achieving an in-depth understanding of subject matter is not possible for students unless they understand the nature of science and scientific inquiry (Lederman, 2006). A teacher’s understanding and belief about the importance and nature of science is therefore an important aspect of teaching. To help students learn about and understand subject matter, teachers need to be able to embed aspects of the nature of science and scientific inquiry in their teaching. This means they are required to have adequate understanding of the nature of science and scientific inquiry, and how to teach these aspects to students as well (Lederman, 2006). In this regard, Appleton (2006) argues that:

> there is substantial evidence to suggest that unless teachers’ perceptions of the nature of science, as well as science PCK, are addressed alongside the science content, more science per se does not necessarily lead to increased confidence, more science teaching, or better science teaching. (p. 43)

Research has shown that primary teachers (both preservice and in-service) and students do not possess adequate understanding of the nature of science (Leden, Hansson, Redfors, & Ideland, 2013; Lederman, 2007). It has been suggested that explicit emphasis on, and the inclusion of nature of science in teacher education programs and in teacher
professional development, could help teachers develop approaches to the teaching of the nature of science in their classrooms (Leden et al., 2013).

In the following section, CK and pedagogy are discussed in relation to preservice teacher scientific CK and teaching and teacher education programs. One of the issues faced by the researcher was whether to first present CK or the design of teacher education programs, as both concepts underpin the approach and the design of the study. Here, I place CK and Shulman’s (1987) work first so that the reader can contextualise the design of teacher education programs in research on PCK.

2.2.1 Content Knowledge as a Critical Aspect of a Teacher’s Knowledge

A large body of literature has examined how teacher quality and knowledge can affect a student’s learning experience. Research suggests that teachers are the most significant factor among school-related factors that can contribute to a student’s success at school (J. Cakiroglu & Boone, 2002; RAND Education, 2012); in fact, it has been suggested that teacher quality has the greatest influence on a student’s achievement (Goldrick, 2002; Stronge, 2010). Quality teaching is built upon teachers having an understanding of professional knowledge, so teachers need to have an understanding of what contributes to successful teaching. Shulman (1987) proposes seven categories of knowledge essential for teachers: general PK’ knowledge of learners and their characteristics’ knowledge of educational contexts’ knowledge of educational ends’ CK’ curriculum knowledge’ and PCK. By proposing these categories, Shulman (1987) intends to highlight the important role of CK and to position this knowledge base in the wider range of professional knowledge for teaching, as he notes the absence of a focus on CK in the research studies on teaching and teacher knowledge at the time of his study.
By introducing PCK within the categories of knowledge crucial for teachers, Shulman (1987) intends to direct attention to and emphasise the role of CK in teaching quality, in addition to general PK. At this point, it is worth discussing PCK first, as it underpins the theoretical framework that guides this study and provides insights into why teachers may struggle with teaching science. The study centres on the development of a teacher’s CK; however, CK needs to be understood within the context of PCK.

2.2.1.1 Pedagogical Content Knowledge (PCK)
PCK has gained much attention since it was introduced and defined by Shulman as ‘the category most likely to distinguish the understanding of the content specialist from the pedagogue’ (1987, p. 8). PCK relates to a teacher’s understanding of the CK as well as their ability to transfer that knowledge to their students (PK). In this respect, as stated by Shulman (1987), teachers should understand the content they are expected to teach as well as how to formulate, organise and represent that content for teaching in a way that makes it accessible and better understood by learners in a given context, which incorporates the aspects of content, pedagogy and learner, and the importance of the connection among these aspects (Shulman, 1987).

Since Shulman (1986) introduced the concept of PCK, many researchers have studied and reconceptualised this distinct blend of knowledge in several ways (Cochran, DeRuiter, & King, 1993; Fernández-Balboa & Stiehl, 1995; Grossman, 1990; Magnusson et al., 1999; Van Driel, Verloop, & de Vos, 1998). While a number of these studies have focused and adapted the two main components of Shulman’s original components of PCK—that is, CK and PK (Lowery, 2002; Niess, 2005)—others have taken a more general view to understand the special role of teachers’ knowledge in their teaching practice by adding other components. For example, the component ‘knowledge of purposes for teaching’
was added to Shulman’s original PCK components by Grossman (1990) when she noticed in her study that teachers can have different teaching purposes and this affects their selections of instructional approaches (Grossman, 1990).

Building on from this, Magnusson et al. (1999) modified Grossman’s (1990) model of instructional approaches. They modified what Grossman (1990) calls ‘knowledge of purposes for teaching’ to ‘orientations toward teaching science’ and they refer to this as ‘teachers’ knowledge and beliefs about the purposes and goals for teaching science at a particular grade level’ (Magnusson et al., 1999, p. 97). Magnusson et al. (1999) discuss how a teacher’s orientation acts as a ‘conceptual map’, in that this map guides the teacher’s instructional decisions about issues related to student assignments, the use of curricular materials and the evaluation of student learning, and consequently influence the development of the teacher’s PCK. Magnusson and colleagues (1999) then propose nine orientations to refer to different approaches to teaching, as extracted from the literature: (1) process, (2) academic rigor, (3) didactic, (4) conceptual change, (5) activity-driven, (6) discovery, (7) project-based science, (8) inquiry and (9) guided inquiry (Magnusson et al., 1999). As teachers can have multiple purposes and goals in their teaching, they may have different orientations, which can affect their PCK (Friedrichsen & Dana, 2005). This implies that teachers’ orientations towards teaching are based on their knowledge and beliefs of goals and purposes of teaching. This is relevant to the current study as it highlights the role of teachers’ knowledge and beliefs in influencing and shaping their instructional practices, as discussed in Section 2.2.3.

Other research has suggested the explicit inclusion, in the discussion of PCK, of a constructivist view of teaching and learning processes. In their expanded version of PCK, Cochran et al. (1993) place increased emphasis on the dynamic nature of knowledge
development. Accordingly, they rename PCK as pedagogical content knowing (PCKg) to be consistent with the constructivist perspective and the dynamic nature of the concept. They also emphasise the importance of teachers knowing about the learning of their students and the environmental context in which learning and teaching occur. Accordingly, there are four components of PCK, from their perspective: pedagogy, subject matter content, student characteristics and the environmental context of learning (Cochran et al., 1993).

These examples are not intended to be exhaustive, but rather to highlight that there is no universally established conceptualisation of PCK or what comprises PCK. The concept of PCK was introduced and defined by Shulman (1986) and refined and reconceptualised in following decades. It is the kind of knowledge that is important and unique for teachers as it guides their actions in the classroom. While different aspects have been identified in the pedagogical component of teachers’ knowledge, it seems that most researchers are arguing about the interaction between Shulman’s two fundamental elements of PCK, that is, CK and PK (Cochran et al., 1993; Grossman, 1990; Magnusson et al., 1999; Van Driel et al., 1998). However, a teacher’s understanding of the content of a subject—their CK—remains an important component that leads to high-quality PCK. Tytler (2007) for example, contends that as part of primary teachers’ initial training, they need a combination of science CK and PCK to teach science confidently in primary school, which concurs with what Shulman (1987) clarified earlier—that teaching a subject matter should begin with a teacher’s knowledge of that content (what is to be learnt), followed by knowledge of how to teach that subject.

Hence, it is both clarified and advocated in the literature that CK alone is not sufficient for effective teaching (McConnell, Parker, & Eberhardt, 2013). It is argued that other
qualities can determine teacher effectiveness, such as the ability to transform knowledge into forms that can be easily understood by students (Coe & Sutton, 2014; Oh & Kim, 2013). However, the importance of teachers’ understanding of the content of a subject (CK) remains an important component and prerequisite for the development of their PCK, which is an indicator of the quality instruction (Appleton, 2003; Gess-Newsome & Lederman, 1999; Santau, Maerten-Rivera, Bovis, & Orend, 2014; Van Driel, Jong, & Verloop, 2002; Van Driel et al., 1998) that is an important factor in predicting student educational outcomes (Gess-Newsome, Carlson, Gardner, & Taylor, 2010; Rowe, 2004). A second important insight from the literature is that teachers’ orientations play a critical role in their PCK development (Friedrichsen & Dana, 2005).

Although the TPACK framework (Mishra & Koehler, 2006) is not the focus of this study, it is worth considering the literature in this field as it influences how researchers and educators understand the nexus between technology, pedagogy and CK in the 21st-century classroom. Teachers are being increasingly asked to integrate technology into their classroom, nevertheless most are unprepared to do that as they often have inadequate (or inappropriate) experience and training with using technologies for learning and teaching (Koehler, Mishra, & Cain, 2013). To incorporate this domain of knowledge into the teacher knowledge base, a framework for the integration of technology has been built on Shulman’s concept of PCK. The framework adds technology knowledge as a main component of teachers’ knowledge in addition to the original two components (CK and PK) of Shulman’s construct of PCK. The revised framework consists of three components: content, pedagogy and technology. Accordingly it is called technology, pedagogy and content knowledge (TPACK) (Koehler et al., 2013). The additional knowledge types overlapping those in Shulman’s model are Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological
Pedagogical Content Knowledge (TPCK) (L. Gill & Dalgarno, 2017). The complexity of knowledge types does make it difficult to measure development of a preservice teacher’s TPACK (Archambault & Barnett, 2010). L. Gill and Dalgarno (2017), in their longitudinal study of Australian preservice teachers and the development of their TPACK, found that five factors influenced the successful uptake of ICT in the classroom. Their study was conducted over a period of 4 years and the five factors were a culmination of tracking TPACK development over the course of a degree. Of the five factors, two were linked to professional experience and three were relevant to this study. First, the researchers found that an initial ICT skills and pedagogy subject was essential for developing confidence. They also found that university assignments, particularly those that required the creation of artefacts that could be used in professional experience, developed positive attitudes towards ICT; the final finding was that university lecturers’ modelling of ICT use proved to be a positive influence on the development of TPACK.

Knowledge of technology is also stated among the domains of knowledge that are becoming increasingly essential for effective teaching (Koehler et al., 2013). As with the study by L. Gill and Dalgarno (2017), the TPACK framework holds considerable sway in the development of teacher training programs and understanding of the curriculum.. TPACK has gained traction in Australia as a valid framework as a direct consequence of the Teaching Teachers for the Future (TTF) project. The TTF project was underpinned by the TPACK framework as articulated by Mishra and Koehler (2006), which conceptualises the intersection of technological knowledge (TK), CK and PK, while allowing for contextual differences dependent on the learning environment. One of the main findings of the national project was that while educators were confident in teaching students to use technology to gather information and to communicate, they were not confident in teaching students to use technology to facilitate integration of curriculum.
areas to construct multidisciplinary knowledge; understand and participate in a changing knowledge economy; synthesise their knowledge; acquire awareness of global implications of ICT-based technologies; or develop functional competencies in specified curriculum areas (Finger et al., 2013).

The TPACK model has also influenced the design of national school curricula. For example, the new digital technologies curriculum is mandatory for all Australian children from kindergarten to Year 10. According to (ACARA, 2012) the Australian Curriculum: Technologies will:

shape the future of Technologies learning in schools, ensuring that all students benefit from learning about and working with the traditional, contemporary and emerging technologies that shape the world in which we live. (p. 3)

The aim of the new digital technologies curriculum is to:

Develop the knowledge, understanding and skills to ensure that, individually and collaboratively, students: design, create, manage and evaluate sustainable and innovative digital solutions to meet and redefine current and future needs (ACARA, 2018).

As a consequence, teachers face new demand to develop digital competence in students, where their teaching practice is one of the most critical factors affecting the breadth and depth of integrating advanced learning technologies in classrooms once the technology is available (Reimann & Ebooks, 2016).

It is acknowledged here that the TPACK model has considerable value as a framework within which preservice teachers’ TK can be measured. However, this study is centred on measuring science CK rather than TK. Therefore, this study focuses on primary teachers’ CK because deep understanding of science CK is a critical characteristic of effective
science teachers (Großschedl, Harms, Kleickmann, & Glowinski, 2015; McConnell et al., 2013; Nowicki et al., 2013; Oh & Kim, 2013). The major features in the definitions of this CK is what teachers need to know and to understand about the subject they are to teach. Shulman (1986) argues that:

Teachers must not only be capable of defining for students the accepted truths in a domain. They must also be able to explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions, both within the discipline and without, both in theory and in practice. (p. 9)

This involves knowledge and understanding of the purposes of teaching, where, as pointed out earlier, differences in teaching purposes exist among teachers, which in turn leads to different approaches to teaching a subject (Grossman, 1990).

As shown above, primary teachers’ science CK and understanding in science is considered by many as an important component and prerequisite of the development of their PCK and TPACK, which determine their effectiveness as primary science teachers. Empirical evidence suggests that primary school teachers lack adequate science CK.

2.2.2 Lack of Primary Teachers’ Science Content Knowledge
Primary teachers’ science CK is an ongoing concern in science education and has been well documented in Australia and internationally. However, according to Diamond, Maerten-Rivera, Rohrer, and Lee (2014) this construct is under-studied. Numerous studies have acknowledged that many primary teachers lack adequate science CK to teach science efficiently (Akerson, 2005; Appleton, 2002, 2003, 2008; Appleton & Kindt, 2002; Davis, Petish, & Smithey, 2006; Harlen, 1997; Hoban et al., 2009; Nowicki et al., 2013; Oh & Kim, 2013; Trygstad, Smith, Banilower, & Nelson, 2013), resulting in science CK
being viewed as a challenge for primary teachers. For example, in an extensive review of
the literature related to challenges facing preservice and early-career science teachers,
Davis et al. (2006) identifies several challenges facing science teachers and organises
them along five themes as challenges related to understanding (1) content and disciplines
of science; (2) learners; (3) instruction; (4) learning environments; and (5)
professionalism. The most salient challenge was the respondents’ lack of understanding
of science. This reflects an earlier study by Rennie et al. (2001) about the status and
quality of teaching and learning of science in Australian schools, which revealed that
primary teachers’ most cited factor was their lack of background knowledge affecting
their teaching of science.

A more recent survey conducted in Australia asked 102 primary school teachers from
eight schools to rate themselves against critical areas of science and mathematics
teaching. The results showed that less than 48% rated their knowledge of science content
as good or very good, whereas 90% rated their knowledge of mathematics content as good
or very good (Victorian Auditor-General, 2012). A US national survey conducted in 2013
into the current status of elementary science education in the country found that only
around one-third of teachers felt that they were very well prepared to teach both life
science and earth science and only 16% felt that they were very well prepared to teach
physical sciences (Trygstad et al., 2013).

Other studies have examined and assessed primary teachers’ science CK in different ways
and reported it as inadequate. For example Nowicki et al. (2013) utilised a mixed methods
approach using both survey and observational data to examine the classroom teaching
practice of preservice teachers during their science methods course and during their
student teaching year, and also examined a science lesson taught by each student’s
cooperating teacher. Results revealed that 11 participants including both preservice and in-service teachers failed to deliver accurate science content to the class (these teachers presented lessons with less than 70% science content accuracy). They provided inaccurate explanations of the science concepts they taught and struggled to correct student misconceptions.

Garbett (2003) also provided evidence that, in general, the preservice teachers’ subject knowledge in science was poor. Garbett (2003) investigated conceptual knowledge of science for 57 first year preservice teachers enrolled in a bachelor of education degree in New Zealand. The study used questionnaires and a science knowledge test to determine whether preservice teachers’ actual and perceived competence in science CK covered the four strands in the curriculum document: biology, chemistry, physics and astronomy. Preservice teachers were also asked to predict the number of correct answers they had made in each of the four strands. The results highlighted that many preservice teachers had poor understanding of science. It also emerged that the preservice teachers were unaware of how little they knew in science: there was a weak correlation between their perceived competence and the actual competence as measured by the test in the study.

The above examples of studies on teachers’ science CK show that both indirect methods such as surveys, questionnaires and observational data, and direct measures such as test scores are used when teachers’ CK is studied and assessed (Davis et al., 2006; Garbett, 2003; Nowicki et al., 2013; Rennie et al., 2001; Trygstad et al., 2013; Victorian Auditor-General, 2012). However, indirect methods are used more frequently than direct measures (Diamond et al., 2014). Indirect methods mainly are based on primary teachers themselves reporting how they perceive their science CK, or being observed while teaching science.
2.2.3 Science Content Knowledge and Teachers’ Effectiveness

A significant number of studies has established a link between teachers’ science CK and their effectiveness (Abell, 2007; Diamond et al., 2014; Fitzgerald, 2013; McConnell et al., 2013; Nowicki et al., 2013; Oh & Kim, 2013). Teachers’ science CK was claimed in the literature to influence different aspects related to science education in primary schools; among these are teachers’ professional practice and their students’ achievement (Horizon Research, 2010; McCormack, 2015).

Several studies have examined the link between teachers’ science CK and their teaching practice, revealing science CK to have a direct or indirect influence on classroom practice (Horizon Research, 2010). Abell (2007), in her review of the literature, attempted to identify the relationship between science CK and science teaching. She summarised findings that teachers who have limited science CK rely heavily on textbooks and seatwork; avoid whole-class discussions; spend more time lecturing; use fewer hands-on activities; rely more on text-based lessons; interact less; ask fewer causal questions; avoid spontaneous questions from students; and fail to help their students to grasp important scientific concepts. In contrast, teachers with more science CK ask higher-level questions and are more able to detect student misconceptions (Abell, 2007). Windschitl (2009) adds that ‘Teachers with stronger content knowledge are more likely to teach in ways that help students construct knowledge, pose appropriate questions, suggest alternative explanations, and propose additional inquiries’ (p. 6).

Other studies have identified a significant positive relationship between teachers’ CK and their ability to apply specific instructional methods such as creating an inquiry-based science lesson. Primary teachers with stronger science CK are more able to construct an
inquiry-based science lesson (Luera, Moyer, & Everett, 2005). Similar conclusions were reached by Horizon Research Inc. in their *Knowledge Management and Dissemination* project, which was based on a number of studies identified in a large-scale literature review (Horizon Research, 2010). Comparable results had been reported by Appleton (2002) who showed that beginning elementary teachers with minimal science CK usually compensate by either not teaching science at all or relying on ‘activities that work’. These activities are those that the teacher has taught before or has had recommended to them. They feel comfortable with them as they are low risk in terms of teaching. In general, such activities have predictable outcomes that will provide students with some science knowledge and are safe for the teacher in terms of classroom management (Appleton, 2002, 2003).

The effect of teachers’ science CK on their classroom practices can sometimes be indirect, usually as a result of its effect on their confidence in their ability in science. The literature shows that a lack of scientific knowledge likely results in poor confidence of primary teachers, which in turn affects these teachers’ ability to provide effective science instruction to enhance student learning (Oh & Kim, 2013). However, research indicates that confidence is not only reliant on CK; teachers with low confidence use various strategies for coping, but when some of these coping strategies are regularly used they severely limit students’ learning (Harlen & Holroyd, 1997).

Science CK has also been suggested by some researchers to influence student science outcomes (Diamond et al., 2014; Dogan & Abd-El-Khalick, 2008; Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Horizon Research, 2010; Lederman, 1999); however, few studies were found in this review that focused on describing the relationship between teachers’ science CK and student achievement in science at the primary level.
(Diamond et al., 2014; Heller et al.). These studies have shown that primary school students of teachers with higher levels of science CK have higher achievement in science. Diamond et al. (2014), for example, used a science knowledge test, a self-reported science knowledge questionnaire and classroom observations to measure teachers’ science CK. These three measures, along with the college science courses taken, were then used to examine the effect of teachers’ science CK on student achievement outcomes on a high-stakes science test. The teacher science knowledge test consisted of multiple choice and short response items. The study found that the teacher science knowledge test score was a statistically significant predictor of mean classroom science achievement as these scores predicted 6% of the variance observed in teachers’ mean student science test scores. Accordingly, the study revealed that teacher science CK as measured by post-test had a significant effect on student science achievement outcomes. However, the other measures used for teachers’ science CK—a self-reported science knowledge questionnaire, classroom observations and college science courses taken—did not predict student science achievement outcomes (Diamond et al., 2014).

The critical role of primary teachers’ CK in their effectiveness, in addition to the evidence for a lack of primary teachers’ science CK reported in many studies, prompts examination of the sources of teachers’ science CK.

2.2.4 Sources of Teachers’ Science Content Knowledge

There are many sources that inform primary teachers’ science CK. Stein (2006) researched eight case studies of primary school teachers identified as successful at teaching science. Using a set of interviews and classroom observations, the study aimed to further knowledge about how primary teachers acquire their science CK. The analysis of the case studies revealed that there is not just one source from which primary teachers
acquire the science knowledge needed to be an effective science teacher. However, science content courses and specific types of methods courses during teacher education program were identified as the main sources of science learning opportunities. Experiencing teaching science during their student teaching opportunities in the course of a teacher education program; participating in in-service science programs offered by their school districts; and working with colleagues in developing and/or implementing science units were also mentioned among the main sources of science learning opportunities by primary teachers who had these opportunities (Stein, 2006).

How preservice teachers build and integrate scientific knowledge is also discussed in the literature. Preservice teachers come to the teacher education program with their own previous science knowledge gained from their earlier science learning experiences over time (Södervik, Mikkilä-Erdmann, & Vilppu, 2014). For example, Usak, Ozden, and Eilks (2011) examined how students construct new scientific knowledge on what they already know, and how they integrate this new knowledge with their previous ideas and experiences. Research has shown that students’ conceptions usually reflect their teachers’ understanding, whether it is right or wrong (Södervik et al., 2014). Consequently, primary teachers who do not have a good understanding of science or have misconceptions about science often transfer these qualities to their students (Abd-El-Khalick & BouJaoude, 1997) who might be the future teachers. This can result in gaps in their science CK because in general, misconceptions can be deeply rooted in student thinking and in their new experiences interpreted through these incorrect understandings, thus interfering with their ability to acquire accurate knowledge (Butler, Mooney Simmie, & O'Grady, 2015; Lucariello & Naff, 2014). In view of that, if misconceptions held by preservice teachers about science concepts are ignored or dismissed out of hand, this will result in a new generation of teachers with limited CK in science. Hawkins (1990) described the
consequences of poor science preparation in school on current teaching of science as ‘a loop in history by which some children grow to be teachers, taught science little and poorly, they teach little and poorly’ (p. 97). This is apparent as research into science CK of primary teachers reveals that many primary teachers of science do not have an adequate understanding of the science content they are required to teach (McConnell et al., 2013) or have misconceptions about science concepts (Ahopelto, Mikkilä-Erdmann, Anto, & Penttinen, 2011; Bulunuz & Jarrett, 2010; Kikas, 2004; King, 2000; Parker & Heywood, 2000; Sarioglan & Küçüközer, 2014).

Unless steps are taken to address this cycle of misconceptions, it will persist. Hence, it is necessary for teacher education programs to equip preservice teachers with the appropriate scientific knowledge and skills to be able to teach effectively and confidently. This means that they must be provided with opportunities to gain these skills, because if improvements are not made during their education program, once these preservice teachers commence teaching careers, their lack of science knowledge and misconceptions may be transferred to their own students. In the following section, teacher education programs are discussed.

2.2.5 Teacher Education Programs

Teacher education programs are designed and aim to ‘expose students to new perspectives as well as train them in knowledge and skills. Knowledge includes disciplinary content, or subject knowledge, and PCK, or knowledge of how to teach’ (Wilke, 2004, p. 3). While research has revealed that science courses in primary teacher education programs can provide opportunities to build and develop teachers’ science CK (Stein, 2006), there are still concerns around some issues in teacher education programs that could have adverse effects on primary teachers’ science CK. One concern is that primary teachers are usually
considered generalist teachers (Ardzejewska, McMaugh, & Coutts, 2010) and most are trained as generalist teachers during teacher education programs. As generalist teachers they are expected to develop skills necessary to competently teach multiple subjects in the primary curriculum—including science—to a diverse range of learners (Fitzgerald & Smith, 2016; Nowicki et al., 2013). Generalist primary teachers are assumed to have the ability to deliver instruction in all key subject areas and are expected to competently teach a diverse range of subject matter in the primary curriculum (Angus et al., 2007; Ardzejewska et al., 2010; Fitzgerald, 2013) including all areas of science. For example, in Australia, generalist primary teachers are responsible for teaching all eight learning areas: English, mathematics, science, health and physical education, humanities and social sciences, the arts, technologies and languages. Therefore, it is possible that as generalist teachers these primary teachers will not have proficiency in delivering all learning areas in primary school curriculum (Hudson, 2005).

Being a generalist teacher appears to more strongly influence the teaching of science than it does other subjects, as science is reported in various studies as one of the least taught subjects in primary schools (Angus et al., 2004; Angus et al., 2007; Petersen & Treagust, 2014; Treagust et al., 2015). For example, according to Angus et al. (2007), primary teachers in Australia spend only 3% of their instructional time teaching science, compared with 38% teaching English, 18% teaching mathematics, and 11% teaching health and physical education. Also, in 2014, data from the ASTA survey indicated that teachers spend 1.6 hours per week teaching science on average—ranging from 1.1 hours per week in pre-school years to 1.8 hours per week at Year 6 (Australian Science Teachers Association, 2014)—which is lower than the time recommended by The NSW Education Standards Authority (NESA) for a typical school week for kindergarten to Year 6, which is 1.5–2.5 hours per week (NESA, 2018).
Another concern is the time available for preservice teacher training in science. It has been outlined that the time offered for science instruction during teacher education programs is often very limited compared with the large amount of information that needs to be covered (Nowicki et al., 2013). The approaches used in teacher education programs are also among these concerns. Science courses in teacher education programs usually involve a large number of preservice teachers being taught in a lecture format where they are exposed to traditional, didactic approaches, with only minimum experience of authentic inquiry. This gives these students little chance to achieve a conceptual understanding of science (Abd-El-Khalick & BouJaoude, 1997; Nowicki et al., 2013).

While teacher education programs are designed and intended to provide future teachers with the necessary content and PK, the literature review revealed that teacher education programs usually focus much more on methods courses than on CK courses. These programs are likely to centre on helping preservice teachers learn how to teach, rather than on what to teach, which is normally achieved by exposing them to general pedagogies of teaching and techniques for classroom management (Abd-El-Khalick & BouJaoude, 1997; Nowicki et al., 2013).

These circumstances in teacher education programs suggest that such programs are not helping teachers develop the CK necessary to teach science effectively (Abd-El-Khalick & BouJaoude, 1997). Therefore, enhancing the quality of teacher education programs to offer different and positive learning experiences that should provide future teachers with adequate CK in addition to PK—and thus enable them to become effective primary teachers—is necessary to avoid repeating the cycle of poor preparation and learning experiences. Considering this, the present study centres on developing preservice
teachers’ science CK with respect to a specific topic in science (i.e., biology—ecosystems) during their teachers’ education program as a critical element of the implementation of effective science instruction in their classrooms in the future.

2.2.6 Enhancing Primary Teachers Science Content Knowledge During Teacher Education Programs

Efforts have been made to apply different instructional strategies to help solve the problem of lack of primary teachers’ science CK. The examination of the literature showed that a number of studies have trialled interventions during teacher education programs and professional development training, aiming to improve primary teachers’ science CK. However, it has been noted in the literature that there is a lack in research dealing with teacher education programs, especially those focusing on the development of preservice teachers’ science CK (Jong, Veal, & Van Driel, 2002; Widhiyanti, Treagust, Mocerino, & Vishnumolakala, 2017). Such studies have suggested and explored the effects of different instructional strategies and science experiments on preservice primary teachers’ science CK. For the purpose of this research, where the target population is preservice primary teachers, only interventions applied during teacher education programs were explored.

A number of studies have investigated the effect of inquiry-based science courses and activities on primary teachers’ science CK. Sanger (2007), for example, investigated the influence of an experimental inquiry-based science content course on preservice teachers’ chemistry CK. The chemistry CK of 16 preservice primary teachers enrolled in the experimental content course (chemistry and physics content course intended for primary teaching) was compared with chemistry CK of 24 secondary science teaching majors in a traditional content course (general chemistry courses) taught by the same instructor.
The author included the latter group for comparison because preservice primary teachers were allowed to use this course as a substitute for other courses. The experimental course was an inquiry-based course with experiments specifically designed so that they could be adapted to the primary science classroom. It involved equipment and chemicals that could be purchased at supermarkets, toy stores or hardware stores and was structured with minimal lecturing; most class time was spent in the laboratory setting. Prior to taking this course, the students had completed two to four science content courses using similar inquiry methods. The general chemistry course was structured in the traditional format, with 3 hours of lectures and one 3-hour laboratory session per week. Both groups of students were asked to answer the same chemistry content questions after receiving very different instructional lessons on the topic, to enable comparison of their chemistry CK. The statistical results from comparison of the two groups’ responses showed that the inquiry-based instructional approach helped preservice primary teachers learn chemistry CK at a level as good as, or better, than students taught using the traditional approach. Sanger suggests that preservice primary teachers would benefit more from inquiry-based science courses than lecture-based courses.

In a mixed methods study including both quantitative and qualitative measures, Avery and Meyer (2012) also investigated the effects of an inquiry-based science course on preservice teachers’ understanding of science. The study investigated the effects of the inquiry-based content course on 77 preservice primary and early childhood teachers in the context of a required science course in environmental biology. Interviews, test scores and course grades were used to obtain evidence of achievement in the areas of student gain in conceptual understandings of science content and to determine their understanding of the process and nature of science. The study found that gains were made in the majority of students’ conceptual understanding of science, the science process and scientific
research. Students explicitly described how they had a better understanding of science as a result of engaging in hands-on inquiry activities. The study also investigated the effects of the inquiry-based science course on preservice teachers’ self-efficacy for science and science teaching (as discussed in Section 2.3.5).

The influence of inquiry-based activities on preservice teachers’ understanding of science in science methods courses has also been considered in research. Hypolite (2003), for example, explored the effects of a 6-week inquiry-based unit on preservice primary teachers’ understanding of plant science principles. Participants were 40 preservice elementary teachers enrolled in two elementary science methods classes. One class participated in inquiry-based activities related to a unit on principles of plant biology and served as the treatment group, while the other class studied those same concepts with the same instructor via traditional/didactic instructional methods, and served as the comparison group. A focus group was formed from the treatment group to participate in co-concept mapping sessions. Each group was administered a pre-instructional test at the beginning of the study. A comparison of pre- and post-instructional tests, artefacts from activities and concept maps generated by the focus group was used to assess participants’ understanding. The results indicated that the inquiry-based instructional strategy enhanced preservice primary teachers understanding of plant science CK, as well as PK. The control group’s performance revealed a mean gain of 0.9 points, whereas, the treatment group showed a mean gain of 2.6 points; the effect size was determined to be 0.53, which is significant as it is greater than the 0.50 size score considered by most researchers to indicate an important finding of difference.

The effects of other instructional methods have been also examined in research. Bulunuz and Jarrett (2010) examined the effects of instructional methods including readings,
hands-on learning and concept mapping in improving preservice teachers’ conceptual understanding of earth and space science concepts. Participants were 52 preservice teachers in two classes of a science methods course. The data source was an open-ended survey about earth and space science concepts. The survey was administered three times: once as a pre-test and twice as post-tests (once after textbook reading assignments v. hands-on learning intervention; once after a concept mapping intervention). Data analysis demonstrated that readings, hands-on learning and concept mapping are all effective in building preservice teachers’ understanding; the advantage of hands-on learning over readings approached significance. Concept mapping had an additive effect on understanding. The authors suggested that another advantage of hands-on learning and concept mapping as modelling activities for teachers was that those teachers can use them in their classroom after certification, which may be more effective in helping young children develop scientifically conceptual understanding than reading from textbooks. Working collaboratively was also proposed in the study to have positive effects on helping preservice teachers scaffold their knowledge by explaining to one another, asking various questions and discussing different versions of the concept maps they draw.

Effectiveness of hands-on activities and group work applied in content courses for helping preservice teachers learn science has also been demonstrated in research. Gibson (2001) analysed the effectiveness of a variety of constructivist instructional methods including hands-on activities, cooperative group work, real-life applications, field trips and weekly reflective journals on science learning of 14 preservice teachers enrolled in an introductory physical science course. Data were collected by conducting a focus group with the preservice teachers and an interview with the instructor, and by collecting preservice teachers’ weekly reflective journals at the conclusion of the course. The data
analysis suggested that the use of constructivist instructional practices had a positive effect on preservice teachers’ science knowledge.

Groves and Pugh (2002) explored the effects of a short-term intervention on preservice primary teachers’ understanding of a current environmental issue (ozone depletion), using a mix of constructivist approaches. Fifty-eight preservice primary teachers enrolled in the semester prior to student teaching were given a pre-test survey; the intervention was then introduced immediately where factual content was presented and explained to provide basic knowledge, and small group discussions were held to facilitate concept development. Also, students had to explain their understanding of the various aspects of ozone depletion and were challenged with contrasting evidence whenever they made an incorrect assertion. After 8 weeks a post-test survey was administered to the preservice teachers. Survey results showed that understanding of this issue can be significantly improved through a short-term intervention, using a mix of constructivist approaches.

In a similar study, Watters and Ginns (2000) described the implementation and evaluation of an instructional program designed to provide experiences for preservice teachers to have success in terms of learning content, pedagogy and professional practice implemented in a core science methods course. The main instructional strategies adopted for this course involved collaborative learning workshops, a problem-based assignment and reflective writing. Quantitative and qualitative data obtained through surveys, observations and focus session reviews revealed that a learning environment based on social constructivist perspectives was effective for developing preservice teachers’ CK and PK, as well as enhancing their sense of science teaching self-efficacy.
Another instructional strategy suggested in a number of studies to engage preservice teachers in understanding science CK is the use of ICT resources (Hoban, 2007; Hoban et al., 2009; Masters et al., 2013). For example, Hoban et al. (2009) presented a study involving a new way for preservice elementary teachers to use technology resources and engage in learning science content. The study aimed to investigate if preservice primary teachers improved their science knowledge when they used a three-phase framework to create, review and publish a slow-motion animation to a web site. In their study, Hoban and colleagues intended to make the participating preservice teachers themselves design and create the animations. This was because many computer animations have been produced in countries such as the US and Australia to promote science education and are freely available on a web site or CD, but their value for enhancing student learning has been shown to be limited; if learners design and create these animations themselves then they have more value. Twenty-nine preservice primary teachers in two science method classes participated in the study. Each preservice teacher was allocated a different topic from kindergarten to Year 6 science curriculum about which to create their own ‘slowmation’. To monitor each preservice teacher’s science learning, qualitative data were collected through three semi-structured interviews; two sketching and reviewing concept maps completed during the interviews; and the animations themselves as knowledge artefacts. The findings showed that asking preservice elementary teachers to create, review and publish slowmations of science concepts increased the science CK of almost all participating preservice teachers. Similar results were revealed in other study by (Masters et al., 2013) where preservice teachers worked in pairs for 6 weeks to create a digital animated presentation in which they were to use particle model ideas to explain an observable change from a chemistry perspective. The teaching team was satisfied with the task and felt that it engaged the students effectively with the learning content. According to the researchers, ‘Creating a representation of understanding may best
facilitate learning as the increased time required for construction allows testing and consolidation of understanding by the students’. (Masters et al., 2013, p. 97).

Few studies have investigated the effect on preservice primary teachers’ science CK of using technology resources, in particular new and emerging technology resources such as immersive and modelling resources, although these environments have been found to have a positive effect on science learning in schools and in other fields in universities, such as engineering. With regard to teacher education programs, the main purpose of studies that propose the use of these technology environments in science courses for preservice teachers is to improve preservice teachers’ understanding and use of these educational technologies (Rawlins & Kehrwald, 2014) (examples are included in the next section). Thus, the current study used immersive and modelling learning environments to teach preservice teachers science CK to improve their understanding of some ecology concepts. The study assumed that preservice teachers’ science CK would improve as a result of using these environments. It is also argues that the improvement in preservice teachers’ science CK may improve their confidence in their ability in science, as teachers’ confidence has been claimed in much research to be connected to their understanding of CK (as discussed in Section 2.3.4), which then may address the issue of ineffective science teaching in primary schools. The study also expected that this may be useful for preservice teachers as they might integrate these approaches into their own teaching in the future to enhance their students’ learning in science.

In addition, primary teachers need to be confident in science to be able to teach it effectively to their students (Avery & Meyer, 2012). Teachers’ confidence has been claimed in many studies to be connected to their understanding of CK.
2.3 Preservice Teacher and Teacher Confidence

As previously discussed, primary school teachers’ confidence in their own ability to teach science is among the main factors contributing to the problems of science teaching and learning in primary schools. Confidence refers to how a person feels about themselves and their abilities in general (Bandura, 1997). The review of the literature shows that the term confidence is frequently used interchangeably with the term self-efficacy (J.-A. Lee, 2009; H. R. Milner & Hoy, 2003; Palmer, 2006a; Palmer et al., 2015; Walker, 2008; Watters & Ginns, 2000), which is defined by Bandura (1997) as ones’ beliefs in or judgment of their ability to perform and succeed at a particular task. However, Bandura (1997) differentiates between the two terms by clarifying that confidence is the colloquial expression that refers to strength of belief but does not necessarily identify what the certainty is about, while self-efficacy is a more technical concept referring to strength of belief and specifies the type of attainment. However, some researchers still use the two terms interchangeably and some justify this use.

Palmer et al. (2015), for example, use the terms self-efficacy and confidence interchangeably: the term confidence was used with the participants in their study, instead of self-efficacy. The researchers justified this on the basis that its meaning would be more obvious to the participants in the study; that is, participants may not know what self-efficacy is, but it was assumed they would know what confidence is. The type of attainment was specified where the focus was on participants’ confidence to teach primary science (Palmer et al., 2015). The current research also used the term ‘confidence’ rather than self-efficacy for the reason given by Palmer et al. (2015), in that in order to make the general term ‘confidence’ more specific, the type of attainment was specified in this study by using ‘confidence in ability in science’. This term comprises both learning and teaching science, while collecting data and reporting the results.
However in the literature review, studies in both confidence and self-efficacy were reviewed.

2.3.1 Primary Teachers’ Confidence in Their Ability to Teach Science

The significance of primary teachers’ confidence in their knowledge of science, and its effect on science education, has been much discussed. In particular, the lack of confidence in science has been stated as an ongoing concern in a number of reports and studies in Australia and internationally (Australian Science Technology and Engineering Council, 1997; Kenny et al., 2014; McCormack, 2015; Murphy, Neil, & Beggs, 2007). In general, research indicates that primary teachers—both preservice (Australian Science Technology and Engineering Council, 1997; Bleicher, 2007, 2009; Hoban et al., 2009; Howitt, 2007; Palmer et al., 2015) and in-service (Appleton, 2002, 2003; Aubusson et al., 2015; Australian Science Technology and Engineering Council, 1997; Harlen, 1997; Harlen & Holroyd, 1997; C. Lee & Houseal, 2003; Rennie et al., 2001)—lack confidence either in their ability in science teaching, or in both science teaching and learning. It should be noted here that ‘science’ is often referred to in the context of a school subject—for example, ‘I like history’ or ‘I like science’—so it is difficult to differentiate between knowledge of science, experiences in school and how to teach science. For example, the Australian Science Technology and Engineering Council (1997) conducted a study that relied largely on interview and survey techniques to gain a view of the classroom in regard to how science and technology are being taught and learnt in Australian primary schools. A large number of both experienced and inexperienced teachers who had recently completed their preservice education reported low confidence in their ability to teach primary science. The limited confidence of many teachers in their ability to teach science was identified as the most significant factor among those identified in the study as being serious obstacles to primary science education. The study suggested that the low
confidence in primary teachers’ ability to teach primary science is a result of insufficient attention being given by faculties of education to the science content of many preservice primary programs. Eighteen years after the Australian Science Technology and Engineering Council study, the lack of Australian primary teachers’ confidence in their ability in science was still acknowledged (Aubusson et al., 2015).

This issue is not felt by Australia alone. It has reported also in the United Kingdom (UK) and New Zealand (Lewthwaite, 2000; Murphy et al., 2007). Murphy et al. (2007) compared the findings from a large-scale UK-wide survey of primary teachers’ confidence in teaching science with the results of a report published 10 years previously by Wynne Harlen (1995) in Scotland. Murphy indicated that there remained serious concerns relating to primary teachers’ confidence and ability to teach science effectively. Using telephone interviews and focus groups the study found that lack of confidence and ability to teach science were identified as the major issue of concern in primary science by half of the teachers surveyed in the UK for the study.

2.3.2 Science Confidence and Teachers’ Effectiveness

Teachers’ confidence in their ability in science plays an important role in their effectiveness. It can influence different aspects related to science education in primary schools. For example, research has shown that primary teachers’ attitudes and beliefs have a significant role in shaping their instructional approaches (Jones & Carter, 2007; Thibaut, Knipprath, Dehaene, & Depaepe, 2018). Teachers’ confidence has been linked to the utilisation of appropriate instructional methods. Teachers with low self-efficacy who employ didactic approaches (Appleton & Kindt, 1999)—relying on textbooks or prescriptive work sheets that give students step-by-step directions—to cope with their low confidence in their ability to teach science (Harlen, 1997) are likely to spend less
time developing and teaching science concepts than are teachers with high self-efficacy, who are more confident about teaching primary science efficiently (Czerniak & Haney, 1998; Harlen, 1997; Naidoo, 2013).

2.3.3 Sources of Teachers’ Confidence in Ability in Science

Various factors that influence primary teachers’ confidence in their ability in science have been examined in research (Howitt, 2007; Jarrett, 1999; Menon & Sadler, 2018; Palmer, 2006a, 2006b, 2011; Ramey-Gassert, Shroyer, & Staver, 1996; Rice & Roychoudhury, 2003; Schoon & Boone, 1998; Taştan Kırık, 2013). Primary teachers’ attitudes towards science, interest in science, prior experiences with science (Jarrett, 1999; Ramey-Gassert et al., 1996) and misconceptions about science (Schoon & Boone, 1998) are among the factors that can influence primary teachers’ confidence in their ability in science. Primary teachers’ CK in science was found to also influence their confidence in their ability in science (Howitt, 2007; Menon & Sadler, 2016) (the relationship between confidence and CK is described in detail in the next section).

Primary teachers’ prior experience with science during their own school years appears to be a core factor in their confidence in ability to teach and learn science. Such experiences are found to be the best predictor of primary teachers’ interest and confidence in science as adults (Jarrett, 1999). Teachers’ lack of confidence in science has been linked to their negative attitude towards science, which in many cases began with negative prior experiences that they had during their own school years; these negative attitudes continue during and after their preservice education program (van Aalderen-Smeets et al., 2012) To determine what background experiences predict initial preservice teachers’ interest and confidence in science, Jarrett (1999) examined the effect of background variables including primary school, high school and college science experiences. The study found
that primary school experiences in science are the best predictors of preservice teachers’ interest and confidence in science as adults. The study also reported a highly significant correlation between interest and confidence in science. Similar results regarding the influence of science-related prior experiences, including in- and out-of-school science experiences, on primary teachers’ interest and confidence in ability in science were reported by Ramey-Gassert et al. (1996), who found that participants who expressed continuing interest in science teaching attributed it to enjoying in- and out-of-school science activities as children; where originally it was found the participants’ interest in science and interest in science teaching were related to their self-efficacy in science.

Holding misconceptions can also affect primary teachers’ confidence in their ability in science. Schoon and Boone (1998) in their study suggested that holding certain misconceptions in science might be one of the causes of low confidence in ability in science, because these misconceptions make it difficult to understand other science concepts, which may result in a lowered confidence in their own abilities. Similar results regarding the relationship between misconceptions in science and confidence in ability in teaching science were reported by Koc (2006); Koc and Yager (2016) who found that the majority of preservice primary teachers in their study held a number of misconceptions about core concepts that would be covered in most primary science curricula. The study also examined the potential relationship between the numbers of misconceptions held by preservice teachers and their self-efficacy beliefs about science teaching. Participants with the lowest number of misconceptions regarding science had a relatively high confidence in their ability to teach science effectively, which led the researchers to conclude that the holding of misconceptions related to science is associated with low science teaching efficacy. In addition, a study regarding the source of these
misconceptions Koc (2006) showed that prior science experiences, science teachers and science textbooks were the main cited sources of preservice teachers’ misconceptions.

In addition to prior experiences, interest, attitudes and misconceptions, primary teachers’ science CK has also been linked to their confidence in ability in science and is considered an important factor influencing their confidence in their ability in science (Howitt, 2007; Menon & Sadler, 2016). Menon and Sadler (2016) utilised a mixed methods study design to investigate changes in preservice teachers’ science self-efficacy beliefs and science CK in a specialised science content course, and the relationship between the two variables as they co-evolve (i.e., if/how changes in preservice teachers’ self-efficacy beliefs may relate to changes in their science conceptual understandings). Pre- and post-course administrations of the Science Teaching Efficacy Belief Instrument-B (STEBI-B) and a physical science concept test along with semi-structured interviews, classroom observations and artefacts served as data sources for the study. The results showed significant gains in preservice teachers’ science self-efficacy beliefs and science conceptual understandings. The study revealed a moderate positive relationship between gains in their science conceptual understanding and gains in their confidence in ability. Preservice teachers credited science content understanding as contributing to their gains in confidence for science teaching. Nevertheless, scholars have different explanations regarding how primary teachers’ science CK may interrelate with their confidence in their ability in science.

2.3.4 Relationship between Primary Teachers’ Science Content Knowledge and Confidence in Ability in Science

Several studies have outlined the connection between primary teachers’ science CK and their confidence in ability in science (Appleton, 1992, 1995; Bleicher & Lindgren, 2005;
Harlen & Holroyd, 1997; Hoban et al., 2009; Howitt, 2007; Macdonald & Hoban, 2009; Menon & Sadler, 2016; Velthuis, Fisser, & Pieters, 2014). Most such studies have explored the interaction between science CK and confidence in ability in science implicitly within the context of science content courses (Baldwin, 2014; Bergman & Morphew, 2015) or science methods courses that combine science CK and PK (Appleton, 1995; Palmer, 2006b). However, some studies have explicitly investigated the relationship between primary teachers’ science CK and confidence in ability in science (Harlen, 1997; Menon & Sadler, 2016; Wimsatt, 2012).

Overall findings are similar and the role of science CK in confidence in ability in science is acknowledged in various ways. For example, when relationships among confidence, understanding and background in science were explored by Harlen (1997) using questionnaires, interviews and teachers notes, it was found that primary teachers with a background in science in their own education had better understanding of science and expressed higher confidence in their ability in science teaching. Wimsatt (2012) concludes that to increase primary teachers’ confidence in their ability in science, they need to be given opportunities to improve their science CK. This conclusion came when in-service primary teachers’ science CK and self-efficacy were examined to explore the relationship between these two constructs, revealing a significant relationship between primary teachers’ confidence in their ability in science and their science CK (Wimsatt, 2012).

However, it seems that there is a two-way relationship between science CK and confidence in ability in science. Research acknowledges the role of primary teachers’ confidence in ability in science in developing their science CK. Nilsson and van Driel (2011), for example, provide insight into how confidence can affect further development
of science CK. During interview, participants highlighted their confidence in their ability in science as an important aspect of developing their CK.

2.3.5 Enhancing Primary Teachers’ Confidence in Science

A considerable amount of research has focused on enhancing preservice teachers’ confidence in their ability in science (Avery & Meyer, 2012; Cantrell et al., 2003; Ford, Fifield, Madsen, & Qian, 2013; Knaggs & Sondergeld, 2015; Palmer, 2006a; Palmer et al., 2015; Ramey-Gassert & Shroyer, 1992; Savasci-Acikalin, 2014). A number of studies have examined the effect of science teaching methods courses on preservice teachers’ confidence in their ability in science and have found that these courses can be highly effective in this regard (Bleicher, 2007; Cantrell et al., 2003; Gunning & Mensah, 2011; Palmer, 2006a, 2006b; Utley, Moseley, & Bryant, 2005). Such courses are designed to provide preservice teachers with the pedagogical skills to teach science. Particular features of these courses have been recognised as having the potential to enhance teachers’ confidence in their ability in science. These include the intensive use of hands-on activities and group work (Bleicher & Lindgren, 2005; Butts et al., 1997; Palmer, 2006a), inquiry approaches (Jarrett, 1999; Sanger, 2008) and learning science content (Jarrett, 1999; Palmer, 2006a). Professional practice in teaching science during or immediately after science methods is also acknowledged as being among the factors that have the potential to enhance teachers’ confidence in their ability in science (Cantrell et al., 2003; Palmer, 2006a).

Palmer (2006a), for example, investigated the effect of a science methods course on primary teachers’ science teaching self-efficacy and the durability of these changes, using a survey and interviews. In addition to covering teaching techniques and strategies, some science content was embedded in this methods course. Throughout the course, hands-on
activities and group work were intensively utilised. The study involved a pre-test, immediate post-test and delayed post-test design. The results indicated that positive changes in preservice teachers’ science teaching self-efficacy occurred as a result of the course, and these high levels of self-efficacy were still present after the delay period (by measuring their science teaching self-efficacy at the beginning and end of a science methods course, and then after 9 months). The study also revealed that having an opportunity to teach science in primary school was an important factor in consolidating efficacy levels after the methods course.

Jarrett (1999) investigated the effect of an inquiry-based science methods course on interest and confidence of preservice teachers in teaching science. The course was designed to provide participants with science content and inquiry methods in such a way that made these preservice teachers feel confident, skilled and motivated to integrate inquiry science into their future classrooms. Using pre–post-surveys the study found that the inquiry-based science methods course increased both interest and confidence of preservice teachers.

Sanger (2008) compared views on how science is taught and learnt among primary teaching majors who had taken several inquiry-based science courses and secondary science teaching majors who had taken several traditional lecture-based courses. Based on written reflections from students in the two groups, the results showed that the use of inquiry-based methods can greatly affect teachers’ interest and confidence in teaching science as well as their views regarding how science is undertaken, and how it is taught and learnt.
Science content courses can also be a source for increasing primary teachers’ confidence in their ability in science; however, the effectiveness of these courses in improving confidence is uncertain (Palmer et al., 2015). Content courses are designed to give preservice teachers the CK to teach science. Studies have investigated the influence of science content courses, or interventions applied to these courses, on preservice teachers’ confidence in their ability in science (Baldwin, 2014; Bergman & Morphew, 2015; Menon & Sadler, 2016; Palmer et al., 2015). The results acknowledge the role of science content courses specifically designed for preservice primary teachers in increasing their confidence in their ability to learn and/or teach science (Baldwin, 2014; Bergman & Morphew, 2015; Knaggs & Sondergeld, 2015; McLoughlin & Dana, 1999; Palmer et al., 2015). As with methods courses, some factors relating to science content courses are recognised as having potential to enhance teachers’ confidence in their ability in science. These include the use of hands-on activities, group work, studying artefacts (Palmer et al., 2015), micro teaching (Knaggs & Sondergeld, 2015) and inquiry approaches (Avery & Meyer, 2012; Bergman & Morphew, 2015; Narayan & Lamp, 2010).

Palmer et al. (2015) investigated whether a tailored science content course would enhance primary teachers’ self-efficacy. The science content course consisted of content and techniques developed to be relevant to the students in primary teacher education, where a traditional format of lectures supported by interactive tutorials was utilised. The tutorials were highly interactive, as students participated in hands-on activities, group work and discussion, as well as studying artefacts. The STEBI-B was used and administered three times: as a pre-test during the first week of the science course, as an immediate post-test in the last week of the course, and as a delayed post-test, which was carried out 10 months after the end of the course. The study provided evidence that a tailored science content course using a traditional format of lectures supported by
interactive tutorials can increase science teaching self-efficacy and the increase was stable for at least a 10-month period (Palmer et al., 2015).

Knaggs and Sondergeld (2015) used Bandura’s concept of self-efficacy as a conceptual framework and examined a sample of preservice primary teachers engaged in a semester-long science content course, with purposefully embedded verbal persuasion, vicarious and simulated mastery experiences. The science content course was a specifically designed integrated course in which preservice teachers were introduced to science content as learners and provided with opportunities to share their new knowledge as a teacher by teaching science content to their peers or teaching it at a local science museum. The course included hands-on science experiences and interactive science field trip experiences components, which have been shown to increase preservice teachers’ science self-efficacy. Preservice teachers were simultaneously engaged in learning and teaching science content in either a real life or simulated experience. The STEBI-B and open-ended questions added to the survey to collect data. The study reported significant increases in preservice teachers’ science self-efficacy after participating in the science content course.

Likewise, Bergman and Morphew (2015) acknowledged the role of a science content course specifically designed for preservice primary teachers in increasing preservice teachers’ self-efficacy. They investigated the effect of a new science content course created and designed to educate preservice primary teachers about essential physical science concepts through a hands-on application setting. They also advocated modelling for these teachers the instructional strategies and activities necessary for promoting inquiry-based science learning in the classroom, on their confidence in ability in science. The study featured a pre and post-test design using the STEBI-B. By comparing preservice teachers’ self-efficacy in teaching science before and after the course, the study
found that after experiences and learning in this science content course, participants showed a significant increase in their self-efficacy in teaching science. Narayan and Lamp (2010) also found that involving preservice primary teachers in a constructivist, inquiry-based science class (inquiry-based pedagogical strategies) was a major factor in increasing their self-efficacy. Baldwin (2014) reported similar results when investigating the effect of an introductory geology laboratory course designed for preservice primary teachers, on their science teaching self-efficacy; the results indicated a significant increase in science teaching self-efficacy.

The combination of science content and science methods courses is acknowledged as being successful in enhancing primary teachers’ confidence in their ability in science. Ford et al. (2013), for example, explored the effect of a semester-long course that integrated three science content courses and a science methods course in the development of preservice teachers’ conceptions about inquiry, science teaching efficacy and reflections on learning through inquiry. The course was designed to provide inquiry-oriented and problem-based learning (PBL) experiences, opportunities to examine socially relevant issues through cross-disciplinary perspectives; it aligned with content found in primary curricula and standards. Data were collected using open-ended survey, the STEBI-B and focus group interviews. The study reported that by the end of the semester, preservice primary teachers moved from naïve to intermediate understandings of inquiry and had significantly increased self-efficacy for science for science teaching. Preservice teachers showed appreciation of the goals of the course and the PBL as a model of instruction appropriate for primary teaching.

In summary, it is clear from the literature review that different teaching and learning strategies have been suggested and implemented in a range of studies of both content and
methods courses, to enhance preservice teachers’ science CK and confidence in ability in science. Many of these strategies were implemented on small numbers of preservice teachers and tended to focus on improving their confidence in their ability in science, rather than on enhancing their science CK. In addition, most strategies were implemented during methods courses. Nonetheless, the literature shows that many primary teachers of science do not have an adequate understanding of the science content they are required to teach (McConnell et al., 2013), or have misconceptions about science concepts (Ahopelto et al., 2011; Bulunuz & Jarrett, 2010; Kikas, 2004; King, 2000; Parker & Heywood, 2000; Sarioglan & Küçüközer, 2014). It is necessary to offer new teaching and learning experiences for preservice primary teachers during teacher education programs that can improve their CK and confidence in ability in science. My perspective on these new experiences, based on the reviewed literature, is that they should be able to support the integration and implementation of constructivist approaches in teaching and learning, as these approaches have been shown to enhance science understanding and confidence, as discussed above.

Another argument that should be considered here—while thinking about new teaching and learning experiences to improve preservice primary teachers’ CK and confidence in science—is essentially that many students lack science knowledge because many ideas in science are abstract and complex, and experiences of these ideas may not always be available or may be difficult or even impossible to offer because of safety, time, cost or distance issues (Metcalf, Clarke, & Dede, 2009; Tarng, Ou, Tsai, Lin, & Hsu, 2009). However, students need to be able to visualise these ideas and concepts if they are going to genuinely understand them (Allison, 2017). This motivated the exploration of alternative, innovative instructional environments and approaches to enable experiences of these ideas in reliable contexts that can help present students with some aspects of real
life and make abstract scientific ideas tangible to them, thus improving their engagement (Huizenga, Admiraal, Akkerman, & Dam, 2009; Kamarainen, Metcalf, Grotzer, & Dede, 2015) and therefore their learning outcomes. Learner engagement is the keystone of effective teaching (Beasley, Gist, & Imbeau, 2014). It is included as one of the elements of a quality learning environment (New South Wales Department of Education, 2009) and is widely acknowledged as critical to the learning process (Reading, 2008). For example:

Students who actively engage with what they are studying tend to understand more, learn more, remember more, enjoy it more and be more able to appreciate the relevance of what they have learnt, than students who passively receive what we teach them. (Park, 2003, p. 183).

Thus, it is vital that new teaching and learning experiences offered for preservice teachers are able to encourage and enable them to engage in the learning process.

In the following section, the immersive and modelling environments used in the study are discussed in relation to the learning opportunities presented to the preservice teachers that participated in the intervention. The potential benefits of technology in the classroom are also discussed.

2.4 Information and Communication Technologies

ICT is a comprehensive term that includes any communication device or application including radio, television, mobile phone, computer and network hardware and software, satellite systems and so on, as well as the various associated services and applications such as distance learning and videoconferencing (Pagani, 2005). The development of ICT innovation has encouraged educators to employ these innovations with different educational subjects and settings, including teacher education programs, to provide future
teachers with opportunities to enhance their CK and confidence in these subjects. Examples of these innovations are blogs, wikis, social networking sites, virtual learning environments (VLEs), laptops, netbooks, interactive whiteboards, web apps, digital cameras, scanners, projectors, augmented reality, simulations, mobile/handheld computing, programming applications, electronic books (Groff, 2013) and so on. To narrow the scope, in this research I explored two examples of these technologies: an immersive and a modelling environment. The study implemented an immersive environment (Omosa, a 3D game-like VLE) and a modelling environment (Omosa NetLogo, a simulation/modelling environment) as teaching and learning tools and constructivist approaches for teaching to enhance preservice teachers’ science CK.

The immersive and modelling environments were chosen for this study as these types of environments are identified in the literature as having a notably positive effect on students’ understanding and learning, especially in science (as the next two sections present).

### 2.4.1 Potential Value of ICT in Preservice Teacher Science Education

There have been many studies on the use of ICT in preservice teacher education. These studies have explored a range of areas, such as TPACK, English language, self-efficacy, Web 2.0, digital literacy and communication (L. Gill & Dalgarno, 2017; Hammond et al., 2009; Oz, 2015; Parr, Bellis, & Bulfin, 2013). These studies all show that preservice teachers who have more exposure to and have acquired a higher level of technological skills during their teacher training are more willing to use technology in their classrooms. The key features of the new teaching and learning experiences suggested in this study for offering to preservice primary teachers during teacher education programs to improve their CK and confidence in science, as discussed above, are that they support the
integration and implementation of constructivist approaches to present and visualise abstract and complex ideas and concepts in reliable contexts; and enable and support learners to engage in the learning process. This makes the integration of ICT particularly suitable. The content aimed to be taught in the current study consists of ecology concepts and phenomena that are difficult to visualise in real life, which made the use of particular ICT resources (immersive and modelling environments) appropriate (Kamarainen et al., 2015).

My argument here is that ICT resources can effectively support the integration and implementation of constructivist approaches to create a reliable context (learning environment) in which to experience complex and abstract ideas and to enhance engagement in learning. The focus in this study is on the technology itself as well as on the purposeful design of learning activities (based on constructivist approaches) that engage preservice teachers in learning, using these technologies to solve authentic problems. This idea is supported by the literature: Nanjappa and Grant (2003), for example, examined the literature on technology integration and constructivist principles and found technology and constructivism to be complementary to each other. They suggest that ‘a complementary relationship between technology and learning within a constructivist framework seems sound and advantageous to teachers and learners’ (Nanjappa & Grant, 2003, p. 46). Kandi (2013) suggests that the inclusion of technology resources itself can be regarded as a constructivist approach because of such features as the ability to encourage students to create their knowledge at their own convenience; support for collaborative learning; creation of a student-centred classroom; and establishment of authentic tasks in a realistic environment, which encourages learners to be responsible for their actions. ICT resources such as immersive learning environments have the potential to advance students’ understanding and learning by creating effective
and efficient learning environments to present topics that were difficult to visualise before in a way that is easily achieved by learners (M. Barnett, Yamagata-Lynch, Keating, Barab, & Hay, 2005; Kamarainen et al., 2015; Kennedy-Clark, Jacobson, & Reimann, 2009).

Modelling and simulation environments also have the potential to advance students’ understanding and learning in situations and systems in which it is difficult or even impossible to make direct observations of a system behaviour: for example, because of safety issues for humans or the cost of exploration or data collection; or because of the time required to observe systems categorised as very slow processes. The alternative is to study, analyse and evaluate models of such situations and systems (Bandini, Manzoni, & Vizzari, 2009; Kamarainen et al., 2015). Moreover, research has pointed to the potential of ICT resources to increase engagement of learners and improve learning outcomes. The use of ICT in schools has been encouraged with a critical goal to increase the efficiency of teaching and improve students’ learning, where increasing student motivation and engagement has been reported as one of the major benefits of the use of ICT for learning (Higgins, 2003).

The previous statements support my argument here that a combination of ICT resources and constructivist approaches during teacher education programs is an effective way to enhance the effectiveness of preservice teachers’ science learning. This is also suggested in the literature on ICT in education (Higgins, 2003; Kandi, 2013; Nanjappa & Grant, 2003). Following the previous discussion, this study focuses on the development of preservice primary teachers’ science CK utilising a combination of two ICT resources (an immersive and a modelling environment) and constructivist activities and approaches for teaching.
2.4.2 Immersive Learning Environments

Immersive environments are designed to simulate real-world experiences (realistic visual displaying) through the use of computer graphics programs to generate 3D environments. The objects in these environment are designed to represent aspects of the physical world; however, they may be enhanced in some way for emphasis (Zhang & Kaufman, 2013). It should be noted that there are myriad terms to describe an immersive environment. For example, in the literature they may be referred to as 3D environments, VLEs or multi-user virtual environments (MUVEs). In this study, the term immersive environments was used for the sake of clarity. Immersive environments provide opportunities to interact with objects such as planets while collaborating with peers. MUVEs are immersive environments that enable multiple users to access the environment simultaneously over a server or the internet, and collaborate with other users simultaneously to participate in experiences integrating modelling and mentoring about problems similar to those in a real-world context (Duncan, Miller, & Jiang, 2012; Kamarainen et al., 2015). Immersive environments can be adapted to different disciplines; science education is one of the disciplines that uses immersive environments to support learning and teaching (Reisoğlu, Topu, Yılmaz, Karakuş Yılmaz, & Göktas, 2017; Zhang & Kaufman, 2013). Several immersive environments and MUVEs have been designed and used for this purpose. EcoMUVE (Metcalf et al., 2011), River City (Dede, Nelson, et al., 2004), Quest Atlantis (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005) and Omosa (Jacobson, 2012) are examples of some of these environments that empower learners to engage with concepts within computer environments that aim to mimic important features of reality (Grotzer et al., 2016).

In biology, for example, researchers have pointed to immersive environments as valuable technologies for education in supporting students’ learning (Metcalf et al., 2011; Patridge,
2003; Tranter, 2004). In ecology specifically, a variety of immersive environments have been developed to support learning in ecosystems and are seen as an effective teaching aids for helping students accomplish a deeper understanding of ecosystem concepts (Kamarainen et al., 2015; Metcalf et al., 2009; Richards et al., 2012). Encouraging positive learning outcomes from implementing immersive environments in a variety of projects and areas have been shown. Findings include enhancing students’ understanding of particular ecosystem concepts such as complex causal relationships in ecosystems (Metcalf et al., 2011); transferring complex ecosystems concepts (Grotzer et al., 2015); and enhancing students’ motivation (Dede, Ketelhut, et al., 2004; Nelson & Ketelhut, 2007) and engagement (Dede et al., 2005a, 2005b; Dede, Nelson, et al., 2004; Kamarainen et al., 2015; Ketelhut, 2007).

EcoMUVE (Metcalf et al., 2009) is an example of a virtual world designed as a collaborative, inquiry-based, simulated ecosystem environment to teach middle school students about ecosystems and help them develop a deeper understanding of ecosystems and causal patterns. EcoMUVE focuses on the application of an immersive environment in ecosystems education. Students can access EcoMUVE via computers and recreate authentic ecological settings within which they explore and collect information. Students work individually at their computers and collaborate in teams within the virtual environment. They can travel to different points in time, zoom in to the microscopic level and observe effects across time and distance to achieve ecosystem understandings that are otherwise difficult to achieve. The immersive interface allows students to learn science by exploring and solving problems in realistic environments (Harvard Graduate School of Education, 2015; Metcalf et al., 2011).
The effectiveness of EcoMUVE in facilitating students’ learning of ecosystem concepts that is difficult to achieve in the real world was evaluated in a pilot study by Metcalf et al. (2011). The findings revealed a gain in student understanding of particular ecosystem concepts, particularly learning goals related to the interaction between biotic and abiotic factors; processes of photosynthesis and respiration; and the role of decomposition in gas exchange (Metcalf et al., 2011). In another study, Grotzer and colleagues (2015) examined the learning of fifth and sixth graders about causality over time and across spatial distances. They used the affordances of EcoMUVE designed to support learning of ecosystem concepts and complex causal dynamics; and mobile broadband device (MBD) components designed to assess and support learning and transfer in a real pond ecosystem. Immersive environments and MBD interfaces are complementary as each provides affordances that the other does not. Grotzer et al. conducted two studies, each of which compared two conditions. In the first study, the conditions were contrasted by combining the MBD experience with the EcoMUVE program and using the MBD components following EcoMUVE. In the second study, the MBD experience was provided first, followed by the learning components in EcoMUVE; or EcoMUVE was first, followed by the MBD components. Findings suggest promise for the roles of immersive environments and MBDs in helping students to learn and transfer complex ecosystem concepts. All groups made learning gains and shifts towards more expert views of ecosystems, including recognition of change over time and learning about particular obscure variables that are essential parts of the causal mechanisms at play in ecosystem dynamics (Grotzer et al., 2015).

Another example of an immersive environment is River City (Dede, Nelson, et al., 2004), which was designed for middle school science students to learn scientific inquiry and 21st-century skills. River City has the look and feel of a videogame but contains content
developed from National Science Education Standards, National Educational Technology Standards and 21st Century Skills (Harvard University, 2007). As visitors to River City, students travel back in time, bringing their 21st-century skills and technology to address 19th-century problems. Based on authentic historical, sociological and geographical conditions, River City is a town besieged by health problems. Students work together in small research teams to help the town understand why residents are becoming ill. Students use technology to keep track of clues that hint at causes of illnesses; form and test hypotheses, develop controlled experiments to test their hypotheses; and make recommendations based on the data they collect—all in an online environment (Harvard University, 2007). Research using River City has explored the effects of different elements on students’ learning and engagement, such as design-based research strategies (Clarke, Dede, Ketelhut, & Nelson, 2006; Nelson, Ketelhut, Clarke, Bowman, & Dede, 2005), guidance (Nelson, 2007) and self-efficacy (Ketelhut, 2007). River City MUVEs have repeatedly been associated with increased learner learning, motivation and engagement (Dede et al., 2005a, 2005b; Dede, Ketelhut, et al., 2004; Ketelhut, 2007). Many studies have been conducted in the River City environment (mostly with Year 5–12 students) to determine its capability to increase students’ motivation and achievement in science. Results from these studies reveal its effectiveness for motivating students, especially lower-achieving students (Dede, Ketelhut, et al., 2004; Nelson & Ketelhut, 2007).

Quest Atlantis (Barab et al., 2005) is a learning and teaching project that can be integrated into many settings including classrooms, after-school programs, public libraries and museums. Quest Atlantis uses a 3D immersive environment to engage children aged 9–12 in educational tasks. Quest Atlantis combines strategies used in commercial gaming environments with lessons from educational research on learning and motivation. It
allows users to travel through virtual spaces to perform educational activities (known as quests), communicate with other users and mentors and build virtual characters. A quest is an engaging curriculum task designed to be entertaining and educational at the same time. Statistically significant learning in the areas of science and social studies, and a sense of academic efficacy has been demonstrated by students using Quest Atlantis (Barab, Dodge, Jackson, & Arici, 2003 as cited in (Barab et al., 2005)).

Quest Atlantis was also designed and found to be effective for teaching and learning mathematics. An educational game about mathematical functions was developed in parallel with Quest Atlantis. The developed Quest Atlantis-like environment was used with children 14–16 years old. To evaluate the effectiveness of the environment, participants were observed during use and interviewed by the researchers at the end. Based on the results of semi-structured interviews with all participants after the implementation, and researchers’ observations and reflections during and after the implementation, the Quest Atlantis-like environment was effective for teaching and learning about mathematical functions (Tuzun, Arkun, Yagiz, Kurt, & Yermeydan-Ygur, 2008).

Omosa (Jacobson et al., 2011) is a game-like immersive environment collaboratively designed and developed by the University of Sydney and Macquarie University. Omosa aims to help secondary school students to understand concepts in biology and to develop their scientific inquiry skills by enabling them to engage in scientific inquiry that reflects the complexity of ecosystems and interrelations. Omosa supports collaboration between companion learners in the real world. In Omosa, students work together and take on roles similar to those of real biologists exploring the environment and viewing phenomena, and gather information to identify and understand complex causes of specific ecological crises.
(Richards et al., 2012). Research on Omosa reveals its positive effects on school students’ science learning (Jacobson, 2012; Jacobson et al., 2016).

The literature review revealed that several immersive environments have been designed and used in kindergarten to Year 12 education and their effects on students’ understanding of science investigated (Grotzer et al., 2015; Metcalf et al., 2011). However, limited studies have examined the use of these environments in primary teacher education programs to teach preservice teachers science concepts and investigate their effects on preservice teachers’ science CK and their confidence in science. In fact, most studies of preservice teachers have given more attention to the potential for utilising immersive environments in their teaching in the future; that is, they experienced these environments and then their perceptions about and attitudes towards the use of these environments in their future teaching were explored (Kennedy-Clark, 2011; Nussli, Oh, & McCandless, 2014; Sardone & Devlin-Scherer, 2008).

Kennedy-Clark (2011), for example, investigated preservice teachers’ current knowledge and attitudes regarding the use of immersive environments in science education after they accessed and explored an immersive environment called Virtual Singapura. An open-ended questionnaire was designed to elicit knowledge about and attitudes towards use of immersive environments in the classroom. The results indicated that the majority of preservice teachers were positive about the use of immersive environments in the classroom and that they saw the main value of the technology as enhancing visualisation and the ability to engage and motivate students. Likewise, Nussli et al. (2014) provided preservice teachers with opportunities to experience an immersive environment and to reflect on its usability for education. Using pre- and post-surveys and reflective journals they inquired about preservice teachers’ perceptions of the usability of immersive
environments for education. The results suggest that the experience had a positive effect on the preservice teachers’ attitudes towards integration of immersive environments in teaching. Participating preservice teachers identified some affordances for virtual worlds including their potential for learning and instruction; their collaborative platform, which boosts learning and motivation; the support of experimental learning; and an innovative, engaging environment to teach students. The findings also recommended a fully immersive experience for preservice teachers to recognise the capability of immersive environments.

2.4.3 Modelling Environments

Modelling environments, as with immersive environments, are defined in a variety of ways in the literature. Ören (2011), for example, reports over 100 of these definitions. According to Bandini et al. (2009), ‘The term computer simulation is related to the usage of a computational model to improve the understanding of a system's behaviour and/or to evaluate strategies for its operation, in explanatory or predictive schemes’ (p. 1). Computer modelling is the process by which a computer is used to develop a mathematical model of a complex system or process. Such a model can be used to understand and clarify historical data in better ways, to predict future behaviour or to make decisions based on the likelihood of anticipated outcomes (The Models of Infectious Disease Agent Study (MIDAS), n.d.).

Computer simulations and modelling differ from virtual reality. Brey (2008) states that the aim of computer simulations usually is not to undertake realistic visual modelling of the systems they simulate, unlike in virtual reality. Instead the graphical representations usually include only the features that are relevant for the purposes of the simulation. Another difference is that computer simulations do not need to be interactive; typically,
the user will determine a number of parameters at the beginning of a simulation and then run the simulation without any further involvement in the process (Brey, 2008). Computer modelling is increasingly used in education and training. In science education, for example, computer modelling approaches have been used in several educational research projects (Gobert et al., 2004; Jacobson & Kozma, 2000; Wilensky & Reisman, 2006) to help school students understand complex systems in different fields in the sciences, such as physics and biology. They have shown to be successful at helping students develop a deep understanding of evolving phenomena (Dickes, Sengupta, Farris, & Basu, 2016; Sengupta, Kinnebrew, Basu, Biswas, & Clark, 2013). However, there has been very few studies on the use of modelling environments in primary teacher education programs to teach preservice teachers science concepts and their effect on preservice teachers’ science CK and confidence in science. As with immersive environments, studies using modelling environments with preservice teachers during their education program are more focused on preparing them to use computer modelling in their classrooms in the future (Schwarz et al., 2007).

Agent-based modelling is a computer modelling approach that has been used to simulate different types of complex systems utilising various platforms available to facilitate the development of models of these systems (Bajracharya & Duboz, 2013; Bandini et al., 2009). Different agent-based platforms exist and the current study used an agent-based modelling environment developed using one of these platforms: NetLogo. NetLogo is a programming language and modelling environment used commonly in both educational and research contexts (Wilensky, 1999) to simulate complex natural and social phenomena (Tisue & Wilensky, 2004). It has been shown to be a beneficial tool for learning about scientific phenomena in many fields including physics, chemistry, biology, economics, sociology, engineering and psychology (Blikstein et al., 2005). Railsback,
Lytinen, and Jackson (2006) reviewed five agent-based models and concluded that NetLogo was the highest-level platform affording a simple powerful programming language, extensive documentation and integrated graphical interfaces. In regard to appearance and usability, NetLogo is a user-friendly platform (Railsback et al., 2006).

NetLogo includes many examples and samples that teachers can use to support students in visualising complex phenomena. Because of this, it is argued that teachers can always find an example to suit their particular learning and teaching purposes (Niazi & Hussain, 2009). NetLogo has several features that make it a powerful platform for learning and teaching contexts. In terms of usability, it has been used in several studies in education because it is simple to download and use even for non-programmers, who can then progress quickly; is free; and has a large library of pre-existing models, which gives users the opportunity to explore the variety of models that can be created using this modelling environment and select an appropriate type for their context (Gammack, 2015). Thus, both students and educators can use it without the need for strong programming skills (Kanjilal, Rajgire, & Jain, 2013). In addition, NetLogo can be programmed to simulate natural and social phenomena and is especially suitable for modelling complex systems that change over time (Allen & Davis, 2010; Wilensky, 1999).

Tissue and Wilensky (2004) identify growing acceptance of NetLogo in research and education as a valid modelling platform. It has been used for modelling and simulating diverse complex systems, including biological and social systems, because of its ability to provide visual simulation. In NetLogo, the user can set up simulations via an interface that requires minimal coding, after which the outcomes can be observed (Niazi & Hussain, 2009). No technical knowledge is required from users to explore the models. This makes NetLogo an exciting technique for teaching. It is easy for both teachers and
students to design and run simulations as it can be learnt and used by novices (Blikstein et al., 2005). NetLogo allows users to control parameters before and during a model run through a ‘slider’ provided on the interface page that can be adjusted to the desired model variable (Railsback et al., 2006). It is also a useful research tool and is appropriate for diverse learners (Tisue & Wilensky, 2004).

NetLogo is increasingly used in ecological and environmental modelling and has become a recognised tool in this area (Thiele, 2010). Different research has demonstrated learning improvements in science and science-related areas using computer modelling systems in both schools and higher education (Blikstein & Wilensky, 2008, 2010; Jacobson et al., 2016; Scarlatos, Courtney, & Tomkiewicz, 2014; Sengupta & Wilensky, 2009; Thompson & Reimann, 2006; Wilensky & Reisman, 2006). NetLogo was selected for this study as it runs across a number of platforms and is user friendly, thus making it accessible for preservice teachers. The focus of the study was on science knowledge, not on developing ICT skills as such.

In addition to the potential learning affordances of immersive and modelling environments, the authenticity and design of a ‘meaningful and pedagogically sound activity’ are essential factors to successfully exploit immersive environments in teaching and learning (Mamo et al., 2011) and facilitate the transfer of knowledge and skills gained in these environments to the real world (Kennedy-Clark, 2011). Thus, in addition to the technology learning resources, attention should also be given to the design of activities and tasks supported and facilitated by the technology used. As this study examined the development of preservice teachers’ CK in science, the selected immersive (Omosa) and modelling (Omosa NetLogo) environments, along with the activities designed for the
study, were planned with the aim of enhancing participants’ CK in science. This included the utilisation of an inquiry-based instructional approach and collaborative learning.

**2.5 Summary**

Lack of CK in science is a common challenge for primary teachers. Therefore, improving science education in primary schools is a universal concern. Much research has been conducted to enhance the quality of teaching in primary schools where the aim was to improve the quality of primary teachers; in particular, by enhancing their science CK and confidence in their ability in science learning and teaching during their learning as preservice teachers.

It is crucial to help teachers to build and improve their science CK and confidence in their ability in science if they are to add science to the learning areas that they are required to teach and to teach effectively. Improving teacher education programs is one rational way to achieve this. Teacher education programs need to provide more learning opportunities and experiences to boost CK and confidence in ability in science for primary teachers. Thus, understanding how to support the development of preservice teachers’ science CK and confidence in science is an important issue in planning primary teacher education programs.

Many interventions aiming at providing primary teachers with learning opportunities and experiences to boost their CK and confidence in their ability in science have been implemented. These are similar in the features of teaching strategies applied in content and methods courses during teacher education programs that have been recognised as having the potential to enhance primary teachers’ science CK and confidence in ability in science. Research demonstrates that the use of instructional methods that emphasise
inquiry-based methods, PBL, hands-on experience and group work (collaborative) learning, in addition to learning science content and practising teaching, can reform and improve primary teachers’ science CK and confidence in ability in science, and may lead them to implement effective practices in teaching science in their classrooms. All of these approaches to learning are grounded in and supported by constructivist learning theory. This theory advocates that knowledge must be constructed by the learner building on existing experiences and knowledge, and cannot be transmitted (Moore, 2003). According to constructivist theory, learning occurs as learners attempt to make sense of a situation based on what is already known (i.e., prior knowledge) and fit it with their own experience. The effectiveness and success of constructivist approaches in enhancing learners’ CK and confidence has been shown in research discussed in this chapter. Kelly (2000) suggests that a constructivist-based primary science methods course can enhance PK and science knowledge, and increase science teaching self-efficacy. Narayan and Lamp (2010) found that involving preservice primary teachers in a constructivist, inquiry-based science class (inquiry-based pedagogical strategies) is a major factor increasing their self-efficacy.

As the development of knowledge and confidence are complex, this study draw upon many theories that relate to various aspects of preservice teachers learning, understanding and confidence in science, such as constructivism, self-efficacy, active learning, immersivity, situated learning and visualization. In this sense, the study is multifaceted and draws upon several theories to enable the researcher to understand the research questions.

Although considerable effort has been devoted to helping improve primary teachers’ science CK and confidence in their ability in science, there remain serious concerns
relating to this problem in science education in primary schools. Therefore, novel interventions are required. There is a call in the literature to conduct research that addresses the issue of primary teachers’ lack of science CK and lack of confidence in teaching science (Appleton, 2002, 2003; Bayer Corporation, 2004; Bleicher, 2007, 2009; Harlen, 1997; Harlen & Holroyd, 1997; Howitt, 2007; Palmer et al., 2015). Similarly, as few studies have investigated the effect of a combination of immersive and modelling environments on school students’ understanding in science (Jacobson et al., 2016), there is a need to understand how such a combination of platforms can contribute to both knowledge and confidence in science for preservice teachers, as no studies have investigated the combination of immersive and computer modelling environments on preservice primary teachers’ understanding and confidence in science, as undertaken in the current study.

The next chapter describes the methodology used in this study to address the research questions. The chapter presents information concerning the method used in this research, along with a justification for the use of this method. The chapter describes the various stages of the research, including the process used to select participants and allocate groups, the methods used to collect data and the approach used to analyse the data. The chapter also outlines how the learning experience was designed, developed and implemented.
CHAPTER 3: METHODOLOGY

3.1 Introduction

To achieve the aims of the research, an intervention was designed and applied on a group of eight preservice primary teachers. The participants in the study were a group of preservice teachers that had low prior background in science and low confidence in their abilities in science. The intervention consisted of engaging the participants in learning with two technology-based resources: Omosa, a game-like VLE and NetLogo, a simulation/modelling environment. These technologies were used as teaching and learning tools, and the study was framed by a constructivist approach to knowledge building. Participants’ science knowledge and understanding of ecology concepts was measured before and after the intervention. Changes in the participants’ confidence and their perception and engagement with the learning resources during the intervention were also examined. The study was conducted in compliance with the University of Sydney’s ethics policies and procedures (see Appendix A).

This chapter describes the methodologies used in this study to address the following research questions:

1. What is the effect of an intervention using an immersive environment (Omosa) and a modelling environment (Omosa NetLogo) on the development of first year preservice primary teachers’ knowledge and understanding in science?

2. What is the effect of an intervention using immersive and modelling environments on the development of first year preservice primary teachers’ confidence in science?

3. How do the experiences and perceptions of participating preservice primary teachers about their learning in immersive and modelling environments
influence their knowledge and understanding and confidence in teaching ecology in a primary school?

To address these questions, this chapter is organised into (1) research methodology, (2) design and development of the learning experiences, (3) pilot studies, (4) participants and setting, (5) data collection instruments (6) implementation of the learning experience, and (7) data processing and analysis.

3.2 Research Methodology

This study aims to contribute to teacher education programs by targeting a group of first year preservice teachers who have low CK and low confidence in their ability in science, to apply and explore the effects of an intervention designed to help them gain more knowledge and confidence in science. The goal was to determine the effectiveness of teaching this group of preservice teachers some ecology concepts by engaging them in learning with two technology-based resources: Omosa, an immersive environment and Omosa NetLogo, a modelling environment. A qualitative small-N study research design was utilised for this study. A small-N research design is also known as a single-subject (McDougall & Smith, 2006) or a single-case design (Lobo, Moeyaert, Baraldi Cunha, & Babik, 2017), where N can be an individual or a group of individuals (Engel & Schutt, 2016). Determining what happened in this small number of individual cases was of particular value here. Therefore, the small-N design was chosen over larger sample size designs as the focus of the study was this particular group of preservice teachers and not the whole cohort of first year preservice teachers, and large-sample designs usually reveal group average effects that may not represent individual participants or groups (Lammers & Badia, 2005). Variation in individual responses will always exist (Dugard, File, &
Todman, 2012) and small-N designs attempt to examine elected cases in depth, rather than making claims based on large numbers (Gouvea, 2017).

The small-N design was chosen over the case study design, although there are some similarities between the two in terms of the small number of participants/subjects and the focus on individuals. However, the small-N design was more appropriate in this study, because it implemented an intervention and assessed it in terms of enhancing participants’ CK and confidence in science, whereas case studies focus purely on following and describing subjects without any intervention (Rassafiani & Sahaf, 2010). The small-N design allowed for evaluation of the effect of the study intervention by comparing pre- and post-measurements and changes throughout the intervention in participants’ understanding and confidence; and exploring their perceptions about the intervention. Thus, the small-N design should not be confused with the case study design.

The small-N design offers an alternative to large group designs (Alnahdi, 2015; Lobo et al., 2017). The approach in small-N design research involves sequential observations of studied individuals or groups before, during and after an intervention (Graham, Karmarkar, & Ottenbacher, 2012). Each participant/group serves as their own control, which means there is no need for a control group (O. Cakiroglu, 2012). Researchers and educators use this type of design as a tool to examine and document the effectiveness of an intervention for participant/s (Alnahdi, 2015; Rassafiani & Sahaf, 2010) when there is a limited number of participants (Rassafiani & Sahaf, 2010). The small-N design is increasingly used in health and rehabilitation research (S. D. Barnett et al., 2012; Graham et al., 2012); however, as indicated by Gouvea (2017), the value of small-N design in the social sciences is contested by many scholars. Gouvea (2017) refers to recent papers (e.g. (Jaber & Hammer, 2016; Quan & Elby, 2016) that illustrate how small-N studies can make contributions to education research and practice. Quan and Elby (2016) explored
the connection between self-efficacy and nature of science views in the context of research experiences for first year physics major students (nine students). The study provided proof of the connections, or coupling, between shifts in these two constructs and sought to understand in more detail how these shifts come about. Therefore, in a small-N study the authors chose three participants (two who experienced coupled shifts in self-efficacy and in views about nature of science; and, as a contrasting case, one participant who showed no evidence of shifting along either dimension) to illustrate the coupling between shifts in self-efficacy and views on the nature of science. By examining data from interviews and classroom discussions, the study identified some potential underlying mechanisms for the shifts.

A qualitative small-N research design was seen as a suitable and valid approach for this study because of its characteristic purpose to gain rich understanding of a particular situation; in this case, the effect of technology-based resources on participants’ knowledge and understanding, confidence, engagement and perception. A small number of participants volunteered to participate in the study, which is consistent with small-N design research (Myers & Hansen, 2011; Rassafiani & Sahaf, 2010). The effects of the study intervention were observed on a relatively small number of experimental participants (P. L. Smith & Little, 2018): eight participants who shared the characteristic of having low prior background and low confidence in their abilities in science. Although having a small number of participants available for a study may be considered a limitation for a study, a positive view can be taken of the small-N design, particularly when the characteristics of this design are well-suited to the aim and intention of the conducted research.
It is often assumed that findings from studies employing a small-N design might not generalise to the population at large. Because of the small number of subjects investigated in small-N design studies, generalising their results to other subjects is considered a limitation of this design (Alnahdi, 2015). However, some researchers suggest that this issue can be resolved by including more than one participant and repeatedly testing experimental effects across multiple participants and studies (Alnahdi, 2015; Lobo et al., 2017; Simonsen & Little, 2011). In the current study, for the purpose of improved generalisability, the effects of the intervention were investigated with eight participants.

The qualitative small-N study design offered a mechanism for an in-depth study of the relatively small number of available participants. This design frame provided opportunities to gain an understanding of how technology-based resources and pedagogies embedded in these resources influence preservice primary teachers’ understanding and confidence in science. Qualitative and quantitative data were derived from several sources using multiple methods of data collection to get better chance to answer the research questions for the study (Creswell, 2003; Johnson & Onwuegbuzie, 2004; Kazempour, 2014), including four semi-structured interviews, participants’ concept maps, participants’ responses recorded in the guidebooks provided and Camtasia software recording of participants’ actions and interactions during learning sessions.

The data collected via these methods expanded the variety of information and provided more details of factors influencing participants’ understanding and confidence, as well as offering a base for triangulation. Each of the data sources provided a specific type of information and had specific strengths and weaknesses. By using a combination of sources, possible weaknesses in one source can be compensated by strengths in another source (Moen, 1998). The outcomes of this study will provide insights into how to
improve the science knowledge, understanding and confidence of preservice primary teachers. As such, the study offers unique insights into how ICT resources can be used in preservice teacher education to improve science CK and science teaching confidence.

3.3 The Design and Development of the Learning Experiences

The intervention designed for this study involved participants’ engagement with learning in two technology-based resources over two learning sessions. The first session involved the use of Omosa, the immersive environment and the second session involved the use of Omosa NetLogo, the modelling environment. These two resources aimed to teach participants some ecology concepts related to conceptual dimensions of ecosystems and food webs that line up with the new Australian science curriculum, as well as the main phases of conducting scientific inquiry (e.g., hypothesis generation, dependent and independent variables, data collection, analysis and interpretation, reporting) (Jacobson, Taylor, Hu, et al., 2011). The teaching was based on constructivist teaching practices that emphasise active and collaborative learning and provide opportunities for learners to discover and construct new knowledge based on their prior knowledge and understanding from previous experiences (Zhao, 2003). In Omosa and Omosa NetLogo, participants followed the scientific method where they were able to test hypotheses using Omosa NetLogo models based on observations made in the Omosa game-like virtual environment by manipulating different variables and observing the results. Figures 3.1 and 3.2 are screenshots from Omosa and Omosa NetLogo, respectively.
Figure 3.1: Screenshots from the Omosa environment

Figure 3.2. Screenshots from the Omosa NetLogo environment
3.3.1 Omosa Resource and Omosa Guidebook

Omosa is a 3D game-like VLE designed and developed collaboratively by the University of Sydney and Macquarie University. Omosa was designed and developed to help secondary school students to obtain scientific knowledge and science inquiry skills. In Omosa, students work together on scientific fieldwork similar to real biologists, and can explore an ecosystem and collect and analyse data to help address an ecological crisis scenario presented in a model (Richards et al., 2012).

A guidebook was developed for this study to help participants organise their learning and to make meaning from the learning experiences (Appendix B). As explained later in this chapter, different activities and tasks were developed following the ‘5Es’ (engage, explore, explain, elaborate and evaluate) learning cycle model (Bybee, 1997) and arranged in a way intended to promote the building of participants’ knowledge and understanding. The engage, explore and explain phases were applied to help participants learn and understand the contents presented and complete the assigned tasks while working collaboratively. The following paragraphs provide an overview of the structure of the guidebook with selected examples.

Engage. As an essential element for learning, engagement was the first feature to apply to the designed activities. To engage participants in the learning process, the Omosa guidebook began with text taken from Jacobson, Taylor, and Newstead (2011). The text was in a form of a letter from a ‘chief scientist’ used to establish the context to introduce and explain the issue on planet Omosa:

Welcome to planet Omosa. My name is Dr. Sarah Newton and I am the Chief Scientist at the IEIA (Interplanetary Environmental Investigation Agency) in charge of environmental affairs affecting terrestrial type worlds. Recently, planet Omosa has been showing signs of ecosystem change. The indigenous
people who live there have reported that the populations of certain species of animals, including those that are an important food source in their society, are declining.

The Omosans have agreed to allow scientists to come and study the situation. We think you can help our investigators and the people of Omosa in understanding their ecological crisis. During your trip, you will learn a lot about planet Omosa. The inhabitants know that you are coming and they are looking forward to talking with you.

Additional text was included to inform the participants about what they needed to do: your main job is to conduct investigations into possible reasons for the animal population decline using your scientific knowledge and inquiry skills.

The purpose of introducing the issue and the task in this way was to highlight the value of the given task and create interest for the participants, so that they perceived the learning experience as being meaningful and would thus engage more with the learning materials. In this way, their learning and achievement may be enhanced. Another feature that aimed to help increase student engagement in the learning process was the inclusion of collaborative learning. Participants were asked to read the text together and to work on all the tasks collaboratively, as students’ engagement may be improved when they work successfully with others (Wentzel, 2009).

Explore. To provide participants with experience of the ecosystem and its components to improve their understanding, two exploration activities were designed for the Omosa guidebook. The first activity was a free/open exploration activity where participants were
asked to use observations to investigate the Omosa ecosystem and the relationships between the ecosystem components; then to make some brief notes about features they observed as they explored. The second activity was a focused/directed observation where participants were presented with two images in the guidebook of certain areas of Omosa with patches of burnt areas of bush alternating with clumps of dry grass, and asked to think about why this pattern was occurring and what it might mean for the survival of the animals. This activity aimed to direct participants’ investigation to consider factors that might influence the animals’ survival—such as fire and weather—so that they gain more understanding of the issue and related concepts by understanding the different factors that may contribute to the problems on Omosa.

**Explain.** At the end of Omosa guidebook, participants were asked a synthesis question requiring them to identify the ideas they would put into a report to the chief scientist about what had caused the decline in the populations of animals on Omosa. This activity aimed to prompt participants to pull together all of the ideas they gathered from Omosa and connect them to clarify their ideas. By interpreting the evidence they collected in Omosa and constructing explanations of possible factors, participants could make more sense of the materials being studied, which in turn may improve their understanding. This synthesis question was used as an assessment of participants’ knowledge and understanding to track progress in their learning, as shown later in this chapter.

The previous examples are of some of the activities included in the Omosa guidebook in relation to the phases of the 5Es model. The guidebook included additional exploring and explaining activities to support participants’ learning (see Appendix B).
3.3.2 Omosa NetLogo Resource and Omosa NetLogo Guidebook

Omosa NetLogo is a modelling environment designed by the team who designed Omosa and linked to the Omosa environment. In Omosa NetLogo participants can simulate ecological phenomena, run a model, control it and monitor its behaviour to enhance their understanding of the ecology topic. In this study, participants were able to test hypotheses based on the observations made in Omosa by manipulating different variables and observing the results.

As with the Omosa resource, to assist participants while learning from Omosa NetLogo, a second guidebook was designed and developed based on the 5Es model to guide participants’ exploration and organise their learning to help them to make meaning of the learning experiences in Omosa NetLogo (Appendix B). The activities in the Omosa NetLogo guidebook combined with the Omosa NetLogo resource aimed to facilitate the constructivist learning process to promote opportunities that encourage and support the building of participants’ knowledge and understanding.

Engage. The guidebook began with the following introduction text introducing computational experiments using the NetLogo model and explaining how scientists can use this model:

Many areas of modern science use computer models to run experiments—sometimes called computational experiments or simulations. These computer experiments are usually based on data scientists have collected from observations. Scientists can use such a model to carry out virtual experiments by changing an independent variable and taking measurements of the dependent variable in the computational experiment. Each time the scientist runs a virtual experiment, the mathematic model in the computer program can calculate changes in the relative numbers of animals and plants. This
means that scientists can use a mathematic model to test their ideas about the factors impacting an ecosystem.

Additional text was included to inform participants that they would be using the NetLogo modelling environment to run computational experiments about Omosa, and was followed by information regarding procedures to follow to run the model:

*You will use a powerful computer modelling program called NetLogo to run computational experiments about Omosa. Below you will find a screenshot of the NetLogo model for Omosa world.*

Both of the texts (the introduction text and the additional text) were taken from Jacobson, Taylor, and Newstead (2011) and aimed to engage participants with the learning process. Explaining to the participants that scientists use this model to do virtual experiments, and how they do so, might motivate them and promote their engagement with learning.

**Explore.** To provide participants with an experience of the phenomenon and concepts in the NetLogo model to improve their understanding, two kinds of exploration activities were designed. The first activity was a free/open exploration activity where participants were asked to run the simulation twice with the default settings following the procedures explained in the guidebook; stop the run at different stages; draw a population graph for three stages of each run; describe the most common pattern they observed and explain why this pattern was occurring. The second activity was a focused directed exploration where participants were told that after reviewing reports from research teams on Omosa, the chief scientist had decided that there were several experiments that could be done to discover more about the possible causes of the decline of the population of animals. One possibility was that the decline in the population had a natural cause related to the ongoing
drought. Another possibility was that one of the Omosans’ activities, such as firestick farming or over hunting, was causing the decline. They were then asked to test these possibilities using the NetLogo model with different settings.

The aim of this activity was to develop participants’ skills in working scientifically to develop their understanding. Participants’ investigations were directed to investigate specific causes for the problem on planet Omosa to help them to think scientifically about how these factors might affect the animals’ survival. To achieve this, the activity began by presenting participants with information taken from Jacobson, Taylor, and Newstead (2011) (see Figure 3.3) to help them design and organise their experiments to test their ideas as is done by scientists, so that they gain more understanding by exploring and testing different hypotheses related to factors that may contribute to problems on Omosa.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research question.</td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td>Does the level of drought impact the population of the animals?</td>
<td></td>
</tr>
<tr>
<td>2. Your hypothesis.</td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
<tr>
<td>if there is an increase in the level of drought, then______________________________</td>
<td>if there is______________________________</td>
</tr>
<tr>
<td>____________________________________________________________________________</td>
<td>then______________________________</td>
</tr>
<tr>
<td>because______________________________________________________________________</td>
<td>because______________________________</td>
</tr>
<tr>
<td>____________________________________________________________________________</td>
<td></td>
</tr>
<tr>
<td>3. Independent variable.</td>
<td>The independent variable is an “if”—it is what causes the change.</td>
</tr>
<tr>
<td>drought severity level</td>
<td></td>
</tr>
<tr>
<td>4. Dependent variable.</td>
<td>The dependent variable is the “then”—it is the thing that you measure.</td>
</tr>
<tr>
<td>_________________________________</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.3: Omosa NetLogo activity to support the explore phase
**Explain.** As in the Omosa guidebook, at the end of the Omosa NetLogo guidebook, participants were asked a synthesis question to uncover what has been learnt from the use of both resources. The activity involved participants identifying ideas they would include in the report to the chief scientist about what had caused the decline in the populations of animals on Omosa. This required them to pull together all the parts/ideas they learnt from both Omosa and Omosa NetLogo and connect them, to clarify their ideas. This kind of activity helps participants to make more sense of the materials being studied; prompts deeper and more critical thinking; and allows participants to demonstrate their knowledge and understanding and show their ability to integrate knowledge. This synthesis question was also used as an assessment of participants’ knowledge and understanding to track progress in their learning, as shown later in this chapter.

The previous examples are of some activities included in the Omosa NetLogo guidebook about the phases of the 5Es model. The guidebook includes additional exploring and explaining activities to support participants’ learning (see Appendix B).

The immersive environment Omosa and the modelling environment Omosa NetLogo were selected for this study as they are reported in the literature generally to have a notably positive effect on students’ (secondary and high school) learning, especially in science. For example, research on the use of immersive environments to support science learning and teaching has revealed encouraging positive learning outcomes in a variety of projects and areas, including enhancing students’ understanding of particular ecosystem concepts such as complex causal relationships in ecosystems (Metcalf et al., 2011); transferring complex ecosystems concepts (Grotzer et al., 2015); and enhancing students’ motivation (Dede, Ketelhut, et al., 2004; Nelson & Ketelhut, 2007) and engagement (Dede et al., 2005a, 2005b; Dede, Ketelhut, et al., 2004; Ketelhut, 2007) (see
Chapter 2 for more examples). NetLogo is one of the more common programming languages and modelling environments used in educational and research contexts (Wilensky, 1999) and has been used in many educational levels and disciplines.

The immersive environment Omosa and the modelling environment Omosa NetLogo were originally developed for secondary school students to help improve their scientific inquiry skills and understanding of ecology concepts. Significant learning gains by school students about key things related to understanding of science have been made (Jacobson, 2012). Therefore, the immersive and modelling environments are expected to be effective in improving preservice teachers’ science understanding, as such teachers generally have just finished high school and their experiences with science are thus mostly gained in high school.

3.4 Pilot Studies

Two pilot studies were conducted with volunteer Doctor of Philosophy (PhD) students prior to the actual implementation of the study. The pilot studies aimed to examine the sequence of sessions and activities in each session to identify any research issues. The pilot studies mainly aimed to trial the research instruments (including Camtasia recording software) and adequacy of the proposed time for each session. Based on the results from the pilot studies and suggestions from the volunteer participants, very few modifications and adjustments were made. Modification was mainly in the time allocated for learning from technology-based resources. It was evident that the time assigned to the learning from technology resources was shorter than was required; therefore, the time was extended from ~30 to ~45 minutes. The interview questions were deemed to be understandable and participants found them easy to answer. The guidebook activities were also clear and understandable. Therefore, the interview questions and guidebook
activities were appropriate for their purpose. The Camtasia recordings were also checked and found to be capable of capturing the video and audio of the participants while working on both technology resources.

### 3.5 Participants and Setting

A demographic survey (Appendix C) was designed by the researcher and used to identify and recruit appropriate participants. The criteria for involvement were students with low confidence in their ability in science and limited formal study of science. The survey included questions about gender, current level of confidence in ability in biology on a scale from 1 (lowest) to 10 (highest) and science courses studied in Years 11 and 12 at school, and at university. Based on the literature reviewed while planning for the initial survey, additional questions about age, highest level of education and average weekly time playing video/computer games were also included in the survey, as these factors may have influenced participants’ engagement.

The survey was administrated to all preservice teachers in the first year of their enrolment in the bachelor of education primary degree at an Australian university undertaking a core science subject that all students must complete. Preservice teachers were informed that participating in the study was voluntary and they were encouraged to volunteer if they had low confidence in science and had not studied science subjects after Year 10 at school. Initially, 148 respondents (preservice teachers) took part in the demographic survey; 29 of these respondents (approximately 20%) expressed their willingness to participate in the research. However, several had high confidence and/or had studied science after Year 10. Twelve preservice teachers met the study criteria for involvement.

A recruitment email with a participant consent form and participant information sheet (Appendix A) attached was sent to the selected participants to arrange for the study
sessions. However, as too few replies were received from these selected participants, two additional potential participants were selected from among the volunteers who departed only slightly from the criteria for involvement (one had studied science in Years 11 and 12 but had low confidence in ability in science; the other had high confidence in ability in science but had not studied science beyond Year 10). As the study intervention required pairs, one more participant was needed to make the number of participants even. This participant did not meet the selection criteria for the study because she was a former university science student who had changed her major to education, and she had high confidence in her science knowledge and ability. At the end of the recruitment process, a final number of eight participants was achieved. These participants were paired into dyads on the basis of their available times.

### Table 3.1: Participants’ demographic data

<table>
<thead>
<tr>
<th>Participant pseudonym</th>
<th>Age category (years)</th>
<th>Highest level of education</th>
<th>Year 11 science</th>
<th>Year 12 science</th>
<th>University science</th>
<th>Ability in biology</th>
<th>Time spent per week playing video/computer games</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aimee</td>
<td>17–19</td>
<td>HSC</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Tina</td>
<td>17–19</td>
<td>HSC</td>
<td>Biology</td>
<td>Senior</td>
<td></td>
<td>4</td>
<td>&lt;1 hour</td>
</tr>
<tr>
<td>Kristy</td>
<td>26+</td>
<td>TAFE</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>1–3 hours</td>
</tr>
<tr>
<td>Alice</td>
<td>26+</td>
<td>TAFE</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>&gt;3 hours</td>
</tr>
<tr>
<td>Mia</td>
<td>23–25</td>
<td>HSC</td>
<td>Biology and chemistry</td>
<td>Biology and chemistry</td>
<td>Biology and chemistry (changed degree)</td>
<td>8</td>
<td>&lt;1 hour</td>
</tr>
<tr>
<td>Lina</td>
<td>20–22</td>
<td>HSC</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>&lt;1 hour</td>
</tr>
<tr>
<td>Elisa</td>
<td>17–19</td>
<td>HSC</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>&lt;1 hour</td>
</tr>
<tr>
<td>Mary</td>
<td>17–19</td>
<td>HSC</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

#### 3.5.1 Main Demographic Characteristics of the Participants

The demographic survey results summarised in Table 3.1 reveal that 50% of participants were in the age range 17–19 years. Seventy-five % had begun their degree studies straight from high school, whereas two participants had completed other studies at Technical and
Further Education (TAFE) before entering university. Seventy-five % of the participants had not studied a science subject during their final 2 years of high school—where science is a non-compulsory component—or at university level (aside from the compulsory introductory science course in the primary education program). One participant had studied university-level science subjects because of a change in her degree but was nonetheless included in the study to complete the last dyad, although she did not strictly meet the criteria for a low background in science. Seventy-five % nominated a level of 5 or lower for their perceived ability in science, from a scale of 1 (lowest) to 10 (highest). The average perceived ability in science for the participants in the sample was 4.5, with a range of 2–8. Fifty % of the participants mentioned that they played video/computer games less than once a week.

3.6 Data Collection Instruments

A variety of data sources and methods was used to develop a richer understanding of the influence of the study intervention on participating preservice primary teachers’ knowledge and understanding of science concepts, confidence in science and how their experiences and perceptions contributed to the changes in their understanding and confidence. Data were collected from (1) four semi-structured interviews—two long (pre-test and post-test) and two short interviews (Appendix D); (2) participants’ concept maps (pre-test and post-test concept maps included in the interviews); (3) participants’ responses recorded in their guidebooks (Appendix B); and (4) Camtasia and audio recordings of the participants’ actions and interactions.

3.6.1 Semi-structured Interviews

Semi-structured interview is one of the most common methods of data collection in qualitative research to explore individual participants’ experiences, opinions, views and motivations (P. Gill, Stewart, Treasure, & Chadwick, 2008). Four semi-structured
interviews—two long and two short—were conducted with each dyad. The long interviews were developed and conducted as pre-test and post-test interviews and a short interview was conducted at the end of each learning resource session. The questions were developed for the purpose of this study, and they were moderated by two science experts at the University of Sydney to ensure that the questions were valid. All interviews were audio recorded and transcribed for data analysis (Appendix E).

The pre-test/post-test interviews (Appendix D) included sets of questions aimed at eliciting relevant information concerning participants’ knowledge and understanding, confidence and perceptions related to science. The first set included a series of background questions (included only in the pre-test interview) asking participants why they chose primary teaching as a career, why they chose not to study a science subject in Years 11 and 12 and why they agreed to participate in this study. The purpose of these questions was to gain further information about the participants to better know them and set the context for subsequent questions.

The second set of questions included confidence-related questions where participants were asked to self-rate their confidence in ability in science and learning to teach science on a scale from 1 (lowest) to 10 (highest), and to justify their scores. They were then asked if they thought that they would be more or less successful than other students in their study of the science unit in which they were currently enrolled, and to justify their response. They were also asked what might make them feel more confident about their ability to learn to teach science in a primary school. These confidence-related questions were included in both pre-test and post-test interviews. The purpose of these questions was to achieve insights into participants’ initial and final confidence levels and opinions about the factors that they thought might positively influence their confidence to learn to
teach science in a primary school, and compare these before and after exposure to the study intervention. The data collected from this set of questions was critical in answering the second research question.

The third set of questions was assessment-based questions. These questions were developed to obtain insights into the initial knowledge and understanding levels of participants and what knowledge and understanding they gained after being exposed to the study intervention. Two assessment questions were included in both the pre-test and post-test interviews (1) a list/recall question and (2) a concept map-constructing question (Novak, 1990). These questions were developed using recommendations from a biology expert, Dr Charlotte Taylor, from the University of Sydney. In the recall question, participants were asked to list all factors that negatively affect a particular ecosystem. Based on Bloom’s taxonomy (Bloom, 1956) this question was a low cognitive level question that prompted responses regarding knowledge (Tofade, Elsner, & Haines, 2013) and showed the ability of participants to recall information and knowledge related to the learning materials (knowledge). In the concept map-constructing question, participants were provided with a list of common ecological terms (selection of terms was based on recommendations from Dr Taylor) and asked to use as many of the terms as they could to construct a concept map in their dyads about the adverse effects on animals in an area. Based on Bloom’s taxonomy (Bloom, 1956) this question was a higher cognitive level question that allowed learners to demonstrate their knowledge and understanding to show their ability to make use of knowledge (application). Concept maps were used to investigate preservice primary teachers’ conceptual understanding of basic ecological concepts (Zak & Munson, 2008). Concept maps have been used to assess learners’ understanding and thinking in a range of domains and educational levels (Kinchin, 2000; Schwendimann, 2011; Vodovozov & Raud, 2015). The validity and reliability of concept
maps as assessment tools in science education has been established by several studies (McClure, Sonak, & Suen, 1999; Rye & Rubba, 2002; Shavelson, Ruiz-Primo, & Wiley, 2005; Wallace & Mintzes, 1990).

All of the dyads were provided with the same question and the same set of terms and were free to generate their own links and labels to construct their concept maps. Each term was printed on a small card and all cards were given to participants along with a large sheet of paper to construct a concept map. Additional blank cards were provided in case they wanted to add other terms they felt would make sense (Gerchak, Besterfield-Sacre, Shuman, & Wolfe, 2003; Zak & Munson, 2008). They were also told that two-directional arrows could be used and that they did not have to use all of the terms, or all or any of the blank cards. Participants were required to work and respond collaboratively to the assessment questions and return the sheet with their responses to the researcher for later evaluation, scoring and comparing. Although there was no time restriction for completing the concept maps, all of the participants completed them in less than 20 minutes (Gerchak et al., 2003; Zak & Munson, 2008). Conversations and interactions among participants while constructing concept maps were audio recorded to track and assess their understanding. The concept maps produced were photographed and collected to be assessed and analysed later.

Comparison of responses to pre-test and post-test assessment questions can provide insights into changes in participants’ knowledge and understanding. These assessment approaches are useful for assessing both the initial knowledge and understanding that participants have and their developing knowledge and understanding of the materials presented in technology-based resources. The data collected from this set of questions were critical in answering the first research question. The pre-test interview included two additional questions asking participants to define extinction and give an example of an
organism that had become extinct and why they thought this had occurred. These two questions were intended to stimulate participants’ prior knowledge related to the topic they would be learning in the technology-based resources.

The fourth set of questions was perception-related questions developed to collect information and gain understanding of participants’ initial and final perceptions of different ICT modes of presentation of information, including (i) text; (ii) pictures with title only; (iii) graphs showing relationships between two factors; (iv) virtual world simulations that they could explore (game-like environment); and (v) a graphical model in which they could make changes and monitor the effects of changes in other factors (interactive environment). This question was altered slightly from the pre-test to the post-test interview: in regard to parts iv and v, in the post-test interview participants were asked about Omosa and Omosa NetLogo resources in place of the words ‘game-like environment’ and ‘interactive environment’, which appeared in the pre-test interview. This was because during the pre-test interview participants were not yet familiar with Omosa and Omosa NetLogo. One limitation in this approach was that participants’ perceptions about Omosa and Omosa NetLogo in the post-test interview might be subject to the influence of their experiences with these resources shortly before the interview. The different ICT presentation modes included in this question were selected to ensure that participants were aware of the different ways in which information can be presented using ICT and the features of each, so their responses would be more consistent when placed in a clear context.

The post-test interview included additional perception questions asking participants in which environment they felt they learnt more about ecology and the factors that affect animal populations—the immersive or modelling environment, and why. This question
was developed to collect additional perception information specifically about the Omosa and Omosa NetLogo resources. This set of the perception-related questions provided data that contributed to answering the third research question.

The following two questions were also included in the pre-test/post-test interview:

- If someone asked you ‘What do scientists do?’, what would you tell them?
- How do scientists go about understanding what causes animals to become extinct?

These questions were asked to gather information related to what participants already knew about what scientists do and how they do it, mainly to determine if they were familiar with the scientific method before the study and if their experience in this study contributed to any change in their knowledge in this regard.

The two short interviews (Appendix D) included sets of questions aimed mainly to collect information concerning participants’ perceptions about the effectiveness of these learning resources for enhancing their understanding. In the Omosa short interview (Appendix D), participants were asked to identify the positive aspects of the immersive environment in supporting their learning and then the negative aspects and what could have been improved or changed to support their learning. Similarly, in the Omosa NetLogo short interview (Appendix D), participants were asked to identify the positive aspects of the modelling environment to support their learning, and then the negative aspects.

In addition, the short interviews included other questions to help identify whether participants’ responses to the synthesis question in the guidebook shortly before the short interview (see Section 3.6.2) were based on an understanding of the issue and whether they were aware of how they responded to the assessment question in the guidebook. In other words, they were asked to validate and support their responses to the guidebook
assessment questions, as they might express their thoughts and understanding better verbally during the interview. For these reasons, in the Omosa short interview, participants were asked how confident they were about identifying all the possible factors that might have caused the animal populations on Omosa to decline. They were also asked to identify the most important factor in causing the decrease in animal populations on Omosa, with reasons. In the NetLogo short interview they were asked about what they had done using Omosa NetLogo to test the factors they identified as possible factors causing the animal populations on Omosa to decline; if those factors did have an effect; and how did they know.

3.6.2 Guidebooks

In addition to the role of the Omosa and Omosa NetLogo guidebooks in supporting participants’ learning from the two technology resources, as indicated earlier in this chapter, the guidebooks were utilised as a data collection source for data related to participants’ knowledge and confidence. Such data could be triangulated with the relevant data collected during the pre-test/post-test interviews. The confidence-related data were collected through the guidebooks to track changes in participants’ confidence. To accomplish this, the confidence question ‘On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology? Why?’, which was similar to one of the confidence questions asked in the pre-test/post-test interviews, was presented at different stages throughout the guidebooks and participants were required to record their response in the space provided. The question was adapted from Aditomo (2012) science confidence scale; in that study he asked the question, ‘How confident are you in your ability to learn about science?’, to assess participating preservice teachers’ confidence in learning about science using Likert-type items with response options ranging from ‘no confidence’ to ‘very confident’. This scale had good reliability. Hibbs (2012) used similar question to measure participants levels of perceived self-efficacy in
math. The confidence question in the current study was asked twice in the Omosa guidebook and three times in the Omosa NetLogo guidebook to create a base measure of participants’ confidence in their ability in science, and to track changes in their confidence throughout the study. Therefore, it was hoped that it would be possible at the end of the study to identify and quantify the extent of any changes in participants’ confidence in their ability in science as a result for their engagement with the learning resources.

The knowledge and understanding data were collected from the guidebooks to assess participants’ knowledge and understanding. To accomplish this, the synthesis question, which was developed originally for the explain phase of the 5Es model (see Section 3.3.1 and Section 3.3.2) was used to assess participants’ knowledge and understanding. The question allowed participants to demonstrate their knowledge and understanding and show their ability to integrate their knowledge. It measured their ability to synthesise information from the learning resources to assess their knowledge. The content of the participants’ responses to this question should be based on the content of the learning environment about which the question was asked, to measure and track their knowledge and understanding in each session.

**3.6.3 Camtasia**

The audio/video capture software, Camtasia, was used to record participants’ actions, words and interactions during their work in the environments. This was based on the think-aloud protocol (Ericsson & Simon, 1993), where participants are asked to work together while engaging with learning environments. This aimed to collect data related to their experiences in and perceptions about Omosa and Omosa NetLogo by considering their engagement during the study, to explore how and why the study intervention might have contributed to changes in their knowledge and confidence: ‘in general, the literature
of think-aloud research shows its strong theoretical foundation and confirms its value as a way of exploring individuals’ thought processes’ (Charters, 2003, p. 80). By exploring participants’ thought processes throughout the study, changes in their knowledge and confidence could be tracked to explain and identify how their experiences in the two learning environments and their perceptions about their learning in these environments contributed to the changes in their knowledge and confidence.

Table 3.2 summarises the data collection sources in relation to each research question, as this is used as a basis for the data analysis process later in this chapter.
### Table 3.2: Research questions and data collection sources

<table>
<thead>
<tr>
<th>Research questions</th>
<th>Data collection instrument</th>
<th>Interview</th>
<th>Concept map</th>
<th>Guidebook</th>
<th>Camtasia recording</th>
<th>Audio recording</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-/post-test</td>
<td>Short</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. What is the effect of an intervention using an immersive environment (Omosa) and a modelling environment (OmosaNetLogo) on the development of first year preservice primary teachers’ knowledge and understanding in science?</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. What is the effect of an intervention using immersive and modelling environments on the development of first year preservice primary teachers’ confidence in science?</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3. How do the experiences and perceptions of participating preservice primary teachers about their learning in immersive and modelling environments influence their knowledge and understanding and confidence in teaching ecology in a primary school?</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Data source triangulation was applied in this study where different sources of data including interviews, participants’ concept maps, participants’ responses in their guidebooks and Camtasia and audio recordings of participants’ interactions were used to collect data regarding their knowledge, confidence, experiences and perceptions, to
answer the research questions (Table 3.2). The assessment of participants’ knowledge and understanding through the pre-test/post-test interviews and guidebooks using questions/tasks with different cognitive levels is an example of data triangulation to better understand the effect of the study intervention on participants’ learning. The data collected relating to participants’ confidence were also triangulated by collecting confidence oral information from participants during the pre-test/post-test interview and written information from the guidebook responses at different stages of the study. The data relating to participants’ experiences and perceptions also were triangulated utilising the different forms of data collected through the pre-test/post-test interview, short interviews, Camtasia and audio recordings. Perception data relating to the environments were collected through the pre-test/post-test interviews in a broader context and then in the short interviews, perception data were collected more specifically and supported by relevant data obtained from the Camtasia and audio recordings of participants’ engagement during the study. Evidence gathered from the different data sources using different methods, which aimed to enrich and support each other, was utilised in addressing the research questions.

**3.7 Implementation of the Learning Experiences**

After allocating the participants to dyads, the intervention was conducted over two sessions involving one dyad at a time. The interviews were conducted with each dyad of participants by the researcher. The confidence data were collected individually/orally during the interviews (which were all audio recorded) and individually/written in the guidebooks. One possible limitation might be with the question asking about participants’ confidence levels at different stages of the study, where individual responses were required from participants while they were interviewed and working in dyads; participants may have felt some peer pressure when responding about their confidence
level. The knowledge and understanding assessment data were all composed collaboratively within the dyads. During the pre-test/post-test interviews a sheet of paper with a written version of the assessment questions was handed to the participants to record their responses. The guidebooks included a space for participants to record their responses.

Figure 3.4 shows the overall design of the study, including the sequence of the study over two sessions and the data collection instruments.

<table>
<thead>
<tr>
<th>Session one</th>
<th>Session two</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pretest interview</strong></td>
<td><strong>Omosa technology-based resource</strong></td>
</tr>
<tr>
<td><em>(with concept map)</em></td>
<td><em>(with Omosa Guidebook)</em></td>
</tr>
<tr>
<td><em>(Approximately 35 minutes)</em></td>
<td><em>(Approximately 45 minutes)</em></td>
</tr>
<tr>
<td><strong>short interview</strong></td>
<td><strong>Omosa NetLogo technology-based resource</strong></td>
</tr>
<tr>
<td><em>(Approximately 10 minutes)</em></td>
<td><em>(with Omosa NetLogo Guidebook)</em></td>
</tr>
<tr>
<td><em>(Approximately 45 minutes)</em></td>
<td><em>(Approximately 45 minutes)</em></td>
</tr>
</tbody>
</table>

Figure 3.4: Overall design of the study

The pre-test interview was conducted at the beginning of session one for approximately 35 minutes. The immersive environment Omosa, installed on a computer, was then introduced to the participants to work on for approximately 45 minutes. The Omosa guidebook was provided and participants were asked to write their responses to the different tasks in the space provided. At the end of session one, the Omosa short interview was conducted for approximately 10 minutes.

In session two, the modelling environment, Omosa NetLogo, also installed on a computer, was introduced to the participants to work on for approximately 45 minutes. The Omosa NetLogo guidebook was provided and participants asked to write their responses to the
different tasks in the space provided. The Omosa NetLogo short interview was then conducted for approximately 10 minutes. At the end of this session the post-test interview was conducted for approximately 35 minutes.

3.8 Data Processing and Analysis

This section explains how changes in participants’ knowledge and understanding, confidence and perception were measured using the data collected from the different instruments. The data analysis is organised around the following issues based on the research questions:

- knowledge and understanding of ecology concepts
- confidence in ability to learn and teach ecology
- learning in immersive and modelling environments.

The study used a mixed method approach for data analysis, as Johnson and Onwuegbuzie (2004) define mixed methods research as “the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study” (p. 17). However, the study relied strictly on the qualitative data, but the analysis was quantified while analysing some of the qualitative data such as the data collected via concept maps and Camtasia and audio recordings of the participants’ actions and interactions. This method is similar to the method Chi (1997) introduced in her article that provided example of a method of analysing qualitative data in an objective and quantifiable way.

To support the data analysis, each learning session was divided into periods (P1, P2,...) based on the time of asking the confidence question in the guidebooks (see Figure 3.5). P1 is the period between the beginning of the learning session and when participants were
asked in the guidebook to rate their confidence for the first time; P2 is the period between when they were asked to rate their confidence for the first and second times, and so on.

Figure 3.5: The periods in each session

To simplify the process of tracking changes in participants’ understanding, confidence and engagement, the relevant data were assigned to each period: for example, the confidence data for each participant were assigned to each period as shown at the top of Figure 3.6. The results of a Structure of the Observed Learning Outcomes (SOLO) analysis for each dyad were also assigned. The frequency of the different engagement categories was obtained for these periods (as explained in the next two sections).

Figure 3.6: Example of assigning the available data for one group to each period

3.8.1 Knowledge and Understanding of Ecology Concepts

To assess changes in participants’ knowledge and understanding, multiple data analysis methods were used to analyse their responses to the two assessment questions presented
in the pre-test/post-test interviews (recall and concept map questions) and the assessment questions presented in the two guidebooks (synthesis questions). The number of factors listed by participants in the recall question in the pre-test and post-test interviews was recorded. The number of factors recalled correctly in the responses was compared between the pre-test and post-test to identify any increase in the number of factors recalled correctly with participants’ experiences in the study intervention. The assumption here was that there would be an indication of a positive effect of the study intervention on participants’ learning if the number of correct factors recalled increased with participants’ experiences in the study.

The number of links created, the amount of time spent and the number of groups (clusters) of concepts in the concept map were recorded for pre-test and post-test concept maps. The numbers were compared between pre-test and post-test sessions to identify any differences in these numbers with participants’ experiences in the study. The number of links in each concept map was found by summing the number of links to and from each concept. The time spent constructing each concept map was determined by recording the start and end time for each concept map during the sessions. The concept clusters were identified visually using the principle of proximity, with assistance from a biology expert. A group of concepts was considered a cluster if participants placed those concepts close to each other and organised them in a way that revealed their connectedness (similar to a unit).

There are several assumptions underlying the above approach. First, creating more accurate links in a concept map is an indicator of improvement in participants’ knowledge and understanding. Second, the total number of relationships/links is an indicator of how well a knowledge base is structured (Schaal, Bogner, & Girwidz, 2010). Third, creating
more accurate links in less time means that participants gained more knowledge and understood the materials better, so they needed less time to construct the concept map. Fourth, how participants make connections between concepts and how they cluster groups of concepts together is an indication of their understanding (Gericke & Wahlberg, 2013) as it represents their understanding of the interrelationships and connections among concepts. Finally, a reduction in the number of clusters in post-test concept maps means that there is a higher level of grouping of interrelated concepts into one cluster, suggesting that participants know more than isolated facts about the topic and can grasp relationships among different concepts.

An additional data analysis method was used to analyse the concept maps to track the level of participants’ understanding during the study. In this method, each concept map was analysed by classifying its content and structure according to the different levels of the SOLO taxonomy. The SOLO taxonomy was first described by Biggs and Collis (1982). Biggs (1996) explains SOLO as ‘a means of classifying learning outcomes in terms of their complexity, enabling us to assess students’ work in terms of its quality not of how many bits of this and of that they have got right’. SOLO taxonomy levels offer a systematic way of describing how a learner’s performance grows in complexity when mastering new learning (Biggs, 1996). SOLO has five levels of understanding/performance and features for each level, shown in the first column of Table 3.3. Table 3.3 is an assessment matrix for participants’ understanding created for this study based on Fetherston (2007) with some modifications (shown on the right-hand side of the table) to accommodate the nature of this study. All participants’ concept maps were analysed using the created assessment matrix, where both the generation process and the finished products of the pre-test and post-test concept maps were assessed. The SOLO levels identified in the created assessment matrix were applied to track and assess the
progress of participants’ knowledge and understanding of the presented materials by comparing assessment results between pre-test and post-test concept maps.
Table 3.3: Assessment matrix for participants’ understanding based on SOLO

<table>
<thead>
<tr>
<th>Stage/level</th>
<th>Fetherston</th>
<th>Modification for this study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Connection</td>
<td>Feature</td>
</tr>
<tr>
<td></td>
<td>Pre-structural</td>
<td>Acquire pieces of unconnected information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No organisation, no overall sense</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No connections provided between terms/concepts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• No knowledge about terms/concepts and relationships between them evident in concept map</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Everyday terms/concepts—never taught or used</td>
</tr>
<tr>
<td></td>
<td>Unistructural</td>
<td>Make simple and obvious connections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Significance of the connections not demonstrated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide a single (obvious) connection between terms/concepts that are directly related</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Apparent knowledge of some common terms/concepts and a single direct relationship between them evident in concept map</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Assumed/common language</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Familiar terms</td>
</tr>
<tr>
<td></td>
<td>Multi-structural</td>
<td>Make a number of connections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Significance of the relationship between connections not demonstrated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide number of connections between several terms/concepts that are directly related</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Knowledge of different terms/concepts and different relationships between these terms/concepts, but relationships not demonstrated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Terms/concepts not connected to a central concept</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• More concrete/specific examples</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Difficulty in focal point or links</td>
</tr>
<tr>
<td></td>
<td>Relational</td>
<td>Demonstrate the relationships between connections and the whole is demonstrated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Relationship between connections and the whole is demonstrated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide a number of connections between different terms/concepts and demonstrate the relationships between these terms/concepts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Relationships between terms/concepts demonstrated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Terms/concepts connected to a central concept</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lateral thinking evident</td>
</tr>
</tbody>
</table>
Participants’ responses to the guidebook assessment questions (synthesis questions) were also analysed using the SOLO taxonomy. The assessment matrix created (Table 3.3) was applied to all participants’ responses to the guidebook questions. The results were then compared to track the progress of participants’ knowledge and understanding. In order to validate the findings, Dr Charlotte Taylor, a biology expert from the University of Sydney, was involved in assessing participants’ concept maps and synthesis questions using SOLO levels to ensure the assessment of participants’ knowledge and understanding was accurate.

3.8.2 Confidence in Ability to Learn and Teach Ecology

As indicated earlier, participants were asked to self-rate their own confidence throughout the study by responding to the confidence question presented at the different stages of the pre-test/post-test interviews and the two guidebooks. To examine changes in participants’
confidence, the confidence-related data collected from the pre-test/post-test interviews and the guidebooks were analysed. Participants’ responses to these confidence questions were compiled and compared between the pre-test and post-test interviews with the guidebooks to explore changes in participants’ confidence through the study.

3.8.3 Learning in Immersive and Modelling Environments

This research went beyond documenting changes in participants’ science knowledge and confidence in ability in learning and teaching science; it aimed to understand in finer detail how these changes came about. In particular, understanding how participants’ experiences in the immersive and modelling environments and their perceptions of these environments contributed to the changes in their understanding and confidence in science. Also, the study aimed to explore how changes in one component may trigger or support a change in another, as this might inform the design of learning experiences to make them even more productive and for more preservice teachers.

This was investigated by exploring participants’ levels of engagement during the study, which evolved from the ability of the immersive and modelling environments to engage participants in the learning process and the effects of this on their knowledge, understanding and, therefore, confidence. As discussed earlier, all participants’ actions and interactions during their engagement with the Omosa and Omosa NetLogo resources, as well as during the concept map construction process, were recorded using Camtasia and/or audio recording. The aim of these recordings was to investigate how and why the study interventions may have contributed to changes in the participants’ understanding and confidence. The recordings were transcribed in full and then engagement coding categories and subcategories were developed based on the coding scheme of Ainsworth and Th Loizou (2003), with some additions and modifications to accommodate the nature
of this study (Table 3.4). Extra coding categories—flow of engagement (verbal and non-verbal), technical engagement (positive and negative) and collaborative engagement—and a subcategory checking understanding were added. Figure 3.7 shows all engagement categories and their subcategories developed for the study. Examples of these categories and subcategories and their definition are shown in the coding scheme provided in Table 3.4.

The qualitative analysis software NVivo was used for coding and analysing of the data included in the transcripts. Nodes were created in NVivo for all developed engagement categories and subcategories; each segment of the transcripts was dragged to the appropriate node (category).

Figure 3. 7: Engagement categories and subcategories developed for this study
Table 3.4: The engagement categories and subcategories developed for this study and their definition (coding scheme)

<table>
<thead>
<tr>
<th>Category</th>
<th>Ainsworth’s definition</th>
<th>Modified definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal-based explanation</td>
<td>Self-explanations classified as goal driven if student imposed a goal or purpose for an action</td>
<td>Cognitive engagement: Scored if participant made decision, structured, questioned, decided what to do next and how</td>
</tr>
<tr>
<td>Principle-based explanation</td>
<td>Category scored if participants made reference to underlying domain principles in an elaborated way</td>
<td>Scored if participants explained idea or concept with elaboration (relating the idea or concept to the condition or situation), consolidated, built new concept, words or knowledge</td>
</tr>
<tr>
<td>Paraphrasing</td>
<td>Includes elaboration of the current sentence/diagram</td>
<td>Scored if participant made meaning from relationships, related information, used terms provided in the learning environment using the same words from the information they had</td>
</tr>
<tr>
<td>Noticing coherence</td>
<td>Indicates when students related what they were presently studying to a previous item</td>
<td>Scored if participants related what they were presently studying to a previous item</td>
</tr>
</tbody>
</table>

Monitoring

| Positive                        | Statements indicating that student understands the material                           | Scored if participant indicated that they understood the material                    |
| Negative                        | Statements indicating that student did not understand the material                    | Scored if participant indicated that they did not understand the material            |
| Checking understanding          |                                                                                       | Scored if participant made sure they understood materials they were exposed to      |

Flow of engagement

| Verbal                          | (Dowling & Ahern, 2018)                                                               | Verbal expression that expressed participants’ engagement                           |
| Non-verbal                      | (Argyle, 1988; Dowling & Ahern, 2018)                                               | Physical behaviours including body movement, facial expressions, differences in spoken tone volume or gestures that expressed, demonstrated or implied participants’ enjoyment and engagement with the learning environment |

Technical engagement:

| Positive                        | Any positive technical issues participants faced while learning using the technology learning environment related to navigation and use of the technology environment |
| Negative                        | Any negative technical issues participants faced while learning using the technology learning environment related to navigation and use of the technology environment |

Collaboration engagement

| Collaboration                   | Scored if both participants were actively involved and working together towards the goal (answering the questions and writing the final report in the guidebook) |
The frequency of all engagement categories and subcategories and the time spent in each cognitive engagement subcategory was calculated for each session and for different stages during the sessions. The results of these calculations were examined in relation to participants’ understanding and confidence. Cognitive engagement of learners is of particular importance and concern because of its strong relationship with learning (Casimiro, 2016). Evidence of a high frequency of cognitive engagement indicates that participants spent a majority of their time cognitively involved in the learning resources, which was expected to have a positive effect on their knowledge and understanding. The calculation results from the other engagement categories and their subcategories were also investigated in relation to the participants’ understanding and confidence.

To examine the effect of participants’ perceptions about their learning in the immersive and modelling environments in terms of changes in their understanding and confidence, the perception data collected in the pre-test/post-test interviews and in the short interviews (Table 3.2) were transcribed and compiled. Possible associations between these perceptions and participants’ knowledge and understanding and confidence were explored.

To ensure that the data analysis was reliability, two people coded the data. Moreover, to ensure that there was inter-rater reliability, cross-coding was performed by a faculty member recoding one of the transcripts using the developed coding scheme matrix. The agreement was ~60%, which was considered low; it seemed there was an unclear grasp of the difference between two of the coding subcategories by the second coder. This issue was discussed with the supervisory team and, as a consequence a second cross-coding was performed by a PhD student with more clarification of the categories and
subcategories, after which the percentage agreement was ~76%. This was deemed an appropriate level of agreement by the supervisory team.

3.9 Summary

In summary, a small-N design study was conducted with a group of first year preservice primary teachers with low science CK and low confidence in their ability in science. The study consisted of engaging the participants to learn ecology concepts using inquiry activities in an immersive environment and a modelling environment. The study investigated the effect on their science CK and confidence in their ability in science of engaging preservice teachers with such environments. The study was conducted over two sessions; the immersive environment in the first session and the modelling environment in the second session. Two guidebooks were developed following the 5Es learning cycle model to help participants organise their learning and make meaning of their learning experiences. Data were collected from a variety of sources including survey, interviews, participants’ concept maps, participants’ responses in their guidebooks, and Camtasia and audio recordings of participants’ actions and interactions, to address the study research questions. Multiple data analysis methods, including quantitative and qualitative methods, were used to analyse the data and answer the research questions.

The following two chapters report the results of the study based on the methodologies applied to collect and analyse the data. The first results chapter provides examples of the data analysis processes for one dyad of preservice teachers and discusses the main findings in light of the research questions that the study sought to answer. The second results chapter reports the findings for all the dyads participating in this study.
CHAPTER 4: EXAMPLE DATA ANALYSIS

4.1 Introduction

This study used a qualitative small-N study research design to examine the effect of immersive and modelling environments on preservice teachers’ development of knowledge of ecology concepts and confidence in ability in science learning and teaching. An immersive environment (Omosa) and a modelling environment (Omosa NetLogo) were used to teach some ecology concepts to a group of preservice teachers in the first year of their bachelor of education primary degree. This chapter discusses the main findings and demonstrates the analysis of data from one group of participants (dyad of preservice teachers) in light of the research questions that the study sought to answer. Here, I focus on presenting the findings of one group in specific detail to demonstrate how the data were analysed. The improvement in understanding and confidence in ability in learning and teaching science for this group was tracked by investigating their engagement throughout the immersive and modelling intervention. The following points summarise several key findings regarding their engagement:

**Cognitive engagement.** The highest level of cognitive contribution of the participants during both sessions were goal-based explanation, principle-based explanation, paraphrasing and positive monitoring, which indicate the importance of these cognitive processes in improving participants’ understanding and confidence in science. When participants use explanation, paraphrasing and monitoring while learning, they can make more sense of the materials being studied, which accordingly can improve their understanding.

**Flow of engagement.** Both verbal and non-verbal flow of engagement were apparent during both the immersive and modelling environment sessions and mirrored changes in participants’ confidence and knowledge.
Collaboration engagement. Participants’ collaboration was high throughout both sessions as they took turns writing and did not move on until they both understood the materials, so that the immersive and modelling environments facilitated the dyad’s collaboration.

Technical engagement. Positive technical engagement was evident in both sessions.

The previous points suggest that the two environment, had positive effects on participants’ understanding and confidence mainly by supporting their cognitive and collaborative engagement. In both environments, the highest cognitive contributions were goal-based explanation, principle-based explanation, paraphrasing and positive monitoring; thus it can be argued that the high level of cognitive engagement might be important for changes in participants’ understanding and confidence.

The chapter is divided into the following sections: (a) background information, (b) knowledge and understanding of ecology concepts, (c) confidence in ability to learn and teach ecology and (d) learning in immersive and modelling environments. In the analysis of the other dyads in Chapter 5, the previous points are used to examine and test the above argument to determine if it is compatible across other groups.

4.2 Background Information

The two participants in this group were given the pseudonyms Aimee and Tina. This group was selected for in-depth analysis because of the changes in the participants’ levels of knowledge and understanding as a result of the intervention. In this sense, it is a subjective choice, but one that was made to demonstrate the analytical approach used in the study. The following background information was obtained from the demographic
surveys that were filled in by participants prior to the study. Aimee and Tina belong to the most common age group (17–19 years). Aimee had not studied any biology (or other science subject) since Year 10. When asked to rate her confidence in science on a Likert scale of 1 (lowest) to 10 (highest), Aimee rated her ability in science as 4. Tina, however, had studied biology in Year 11 and senior science in Year 12, although she still provided a low rating (4) of her ability in science. When asked how often they played video/computer games each week, Aimee indicated that she had no experience of playing video/computer games, whereas Tina had limited experience, reporting that she played games less than 1 hour per week.

4.3 Knowledge and Understanding of the Ecology Concepts

Changes in Aimee and Tina’s knowledge and understanding was evident in different situations. Analysis of the recall question and concept maps in pre-test/post-test and the synthesis questions in the guidebooks provided evidence for improvement in Aimee and Tina’s knowledge and understanding. The pre-test/post-test recall question and concept maps were first analysed quantitatively and then qualitatively to obtain more data about the changes in their knowledge and understanding. When asked in the recall question to list factors with negative effects on a particular ecosystem, both Aimee and Tina were able to recall and list correctly nine effects in the post-test, compared with five effects in the pre-test. This low cognitive level question based on Bloom’s taxonomy (Bloom, 1956), as shown in the methodology chapter, demonstrates Aimee and Tina’s cognitive learning and their ability to recall information and knowledge related to the materials about which questions were asked (knowledge). As the number of correct ecological impacts recalled increased with Aimee and Tina’s experiences in the study, this can be interpreted as indicating a positive effect of the study intervention on their learning.
When the recall question responses were analysed qualitatively, it appeared that the ecological effects the group had listed in the pre-test were related to everyday (common sense) meaning or current issues they may have learnt or heard about from the media or other public sources, such as global warming, pollution and overfishing. In contrast, responses in the post-test included more sophisticated answers reflecting the complexity of the issue. The list had expanded through the integration of appropriate information/concepts to include other effects. These ecological impacts were more focused and related to what was learnt from the immersive and modelling environments. Examples include environmental, humans, natural disasters, changes in weather, habitat destruction and introducing different animals/species. This may also be interpreted as indicating a positive effect of the study intervention on Aimee and Tina’s learning.

Quantitative analysis of Aimee and Tina’s pre-test and post-test concept maps (Appendix F) captured three pieces of evidence showing that their knowledge had improved. First, comparison of the pre-test and post-test concept maps showed an increase in the number of interrelationships they understood among concepts, revealing an improved ability to organise the concepts and place them within a structure of relationships. These relationships were represented by an increased number of links created in the post-test concept map (59) compared with the pre-test concept map (38) (Table 4.1).
Table 4.1: The total number of links for each term in the pre-test and post-test concept maps (both links to and from each concept)

<table>
<thead>
<tr>
<th>Pre-test concept map connections/links</th>
<th>Post-test concept map connections/links</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concept</strong></td>
<td><strong>Linked to</strong></td>
</tr>
<tr>
<td></td>
<td>concept</td>
</tr>
<tr>
<td></td>
<td><strong>concept</strong></td>
</tr>
<tr>
<td>Ecosystem</td>
<td>0</td>
</tr>
<tr>
<td>Energy</td>
<td>2</td>
</tr>
<tr>
<td>Birth rate</td>
<td>2</td>
</tr>
<tr>
<td>Death rate</td>
<td>2</td>
</tr>
<tr>
<td>Natural causes</td>
<td>1</td>
</tr>
<tr>
<td>Drought</td>
<td>1</td>
</tr>
<tr>
<td>Fire</td>
<td>1</td>
</tr>
<tr>
<td>Weather</td>
<td>1</td>
</tr>
<tr>
<td>Human impact</td>
<td>1</td>
</tr>
<tr>
<td>Hunting</td>
<td>1</td>
</tr>
<tr>
<td>Habitat destruction</td>
<td>1</td>
</tr>
<tr>
<td>Introduced species</td>
<td>1</td>
</tr>
<tr>
<td>Plants</td>
<td>1</td>
</tr>
<tr>
<td>Carnivore</td>
<td>1</td>
</tr>
<tr>
<td>Herbivore</td>
<td>1</td>
</tr>
<tr>
<td>Predator</td>
<td>0</td>
</tr>
<tr>
<td>Prey</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total links</strong></td>
<td>19</td>
</tr>
</tbody>
</table>

Creation of a larger number of links in the post-test concept map using the same concepts demonstrated that the group understood more connections between the concepts as a result of the intervention. Creation of additional links in the post-test concept map showed more details about the organisation of Aimee and Tina’s schema, which may be an indication that they had improved the organisation of their knowledge base, as the number of links in a concept map is an indication of participants’ schema (Schaal et al., 2010). Showing higher linkage (relationships) and better organisation may imply richer understanding. This concept of links was used by Hay (2007) as a criterion to identify deep learning with a group of postgraduate students using concept mapping for assessment of learning quality, which showed that concept maps are very useful for tracking changes in learning quality (deep or surface). Identification of increases in
preservice teachers’ CK on the basis of the number of new concepts added in relation to a pre-test concept map has also been undertaken in previous research (Hoban et al., 2009).

One example of a strong increase in the number of links created by Aimee and Tina in the post-test concept map involves the concept ‘habitat destruction’ (Table 4.1). Habitat destruction is linked in the pre-test concept map (Figure 4.1) to only one concept, human impact, whereas in the post-test concept map (Figure 4.2) it is linked to five concepts: energy, ecosystem, human impact, introduced species and natural causes. More details about habitat destruction and its link to the other concepts are provided later in this section while explaining the analysis of the concept maps according to the SOLO taxonomy.

Another example of an increase in number of links in the post-test concept map is the concept ‘introduced species’, which is connected to one concept in the pre-test but to three concepts in the post-test. This increase in number of linkages in the post-test concept map is indicative of a more complete perception of the different effects and their interrelationships, and may indicate that Aimee and Tina had developed and gained better understanding of these concepts compared with other concepts based on the constructivist view (Zak & Munson, 2008), which states that learners construct knowledge by creating relationships between their new and previous experiences.

The second piece of evidence that the dyad’s knowledge had improved was provided by a visual analysis of the structure of the pre-test and post-test concept maps. Based on the definition of a cluster of concepts identified for this study (see Section 3.8.1), there was a decrease in the number of clusters of concepts organised and grouped by the dyad in the post-test concept map. Aimee and Tina had organised the concepts in the pre-test concept map (Figure 4.1) into three clusters and those in the post-test concept map into two clusters (Figure 4.2). When analysing each concept map, clusters of concepts were
determined with the assistance of a biology expert and based on the definition of the cluster explained in Section 3.8.1. While determining the clusters in the pre-test concept map, it was noticed that from an organisational/structural perspective Aimee and Tina had located the concepts ‘birth rate’ and ‘death rate’ to one side of the concept map and drawn a rectangle around them to group these two concepts together. They then linked them as a group to other concepts but without linking the two concepts themselves together (Figure 4.1). It seemed that they may, in the pre-test, have considered this way of grouping was enough to show the relationship between these two concepts. It may also indicate that they knew these two concepts should be associated with one another but were uncertain of the relationship that exists between them or how to express this relationship. Accordingly, this group was considered a cluster even it lacked some of the features of the cluster identified for this study.

Organising concepts into bigger clusters may mean that Aimee and Tina knew more in the post-test than just isolated facts about the topic. It was evident from the post-test data that they grasped the relationships among concepts. They organised their knowledge into a coherent whole and grouped more related concepts within one cluster, as they became more aware of the interrelationships among different concepts. This in turn may indicate that they had developed a conceptual understanding of the topic (National Research Council, 2001). A detailed investigation of these clusters is presented later in this section through the qualitative analysis of the concept maps using the SOLO taxonomy matrix prepared for this study.
Third, there was a reduction in the time the dyad spent creating the post-test concept map, compared with the pre-test concept map. Although Aimee and Tina had created more links in the post-test concept map, they constructed the post-test concept map in approximately half the time taken in construction of the pre-test concept map. This may also be an indication that they had gained additional knowledge and understanding about
the topic and the concepts so needed less time to construct the post-test concept map. However, the longer time taken to construct the pre-test concept map might be a result of them being unfamiliar with the concept mapping method at that time; being more familiar with the method when it came time to construct the post-test concept map, they were able to achieve this more quickly. Unfamiliarity with the concept mapping method during the pre-test was evident from Tina asking, after being presented with the concept map question, ‘so do we draw arrows or…?’ and again, ‘Do we like do an arrow thing?’ When students become familiar with the concept mapping method, they can benefit more from their time and can use the method to easily structure any amount of information, enabling them to incorporate large knowledge structures in a single view (Van Zele, Lenaerts, & Wieme, 2004). The relationship between the time required to construct the pre-test/post-test concept maps and Aimee’s and Tina’s confidence is explicated in the next section.

The previous examples all indicate an improvement in Aimee and Tina’s knowledge and understanding as revealed by analysing their pre-test and post-test recall question responses and concept maps. However, the change in the total number of ecological impacts listed for the recall question between the pre-test and post-test, and the number of links, clusters and time spent in pre-test and post-test concept maps do not distinguish between levels of understanding or provide insights and details about how these changes occurred. For example, the number of links in a concept map can be easily counted but affords little insight into the level of a learner’s understanding, as a greater number of linkages does not necessarily mean that the learner understands the issue better: some linkages might be invalid or trivial as outlined by Schwendimann (2014).

Qualitative analysis offers a more informative and complete picture of students’ understanding. It allows examination of a learner’s CK structure in more detail (Van Zele
et al., 2004). Therefore, SOLO taxonomy, which has been previously used in educational research as a tool to measure the depth and complexity of students’ learning outcomes (Chan, Tsui, Chan, & Hong, 2002; Karaksha, Grant, Nirthanan, Davey, & Anoopkumar-Dukie, 2014), was chosen as an assessment rubric to qualitatively assess Aimee and Tina’s level of understanding as expressed in the concept map and guidebook synthesis questions. This was undertaken to obtain better insight into their development of knowledge in terms of the level of understanding they achieved as a result of the study intervention.

Analysing the clusters in the concept maps using the SOLO taxonomy matrix modified for this study as described in Chapter 3 revealed a considerable improvement in Aimee and Tina’s understanding of the materials presented. The study intervention appeared to significantly improve their level of knowledge and understanding, as scored by the SOLO taxonomy, after they engaged with the immersive and modelling environments. There was a development in the SOLO level from the pre-test to the post-test concept map, demonstrating an increase in structural complexity in their learning, which shifted from a surface to a deeper understanding. In Cluster 1 of the pre-test concept map (Figure 4.1) Aimee and Tina made simple and obvious connections between familiar concepts:

\[
\text{Carnivore} \xrightarrow{eats} \text{Herbivore} \xrightarrow{eats} \text{Plants} \quad \text{Predator} \xrightarrow{eats} \text{Prey}
\]

Apparent knowledge of common concepts and single direct relationships between these concepts is demonstrated in this cluster. Such links are classified as uni-structural according to the levels of the SOLO taxonomy. In Cluster 2 Aimee and Tina located the concepts birth rate and death rate to one side of the concept map and drew a rectangle around them with no connection shown between these two concepts (Figure 4.1). This gives the impression that they lacked knowledge about these concepts and the
relationships between them, which is classified as pre-structural. In Cluster 3, Aimee and Tina organised the concepts in a series of linear relationships:

```
Drought
Fire ← Natural Causes
Weather
```

They explained the relationships between natural causes and each of the three concepts drought, fire and weather by writing: ‘All impact environment’. In the same way they connected human influences to habitat destruction, hunting and introduced species (Figure 4.1). Again in these links they are showing knowledge of some of the common concepts and single direct relationships between them, classified as uni-structural.

The concept energy position in Cluster 3 indicates a shortcoming in knowledge (misconception or naïve understanding) about the relationships within an ecosystem. Aimee and Tina linked the energy concept to natural causes and human impact as follows:

```
Natural Causes ← Energy → Human Impact
```

They described the relationship between energy and natural causes as, ‘human can get energy from ecosystem’; and the relationship between energy and human impact as, ‘Use + create energy’. Missing relationships between energy and other concepts in Aimee and Tina’s pre-test concept map highlight their difficulties in understanding these relationships and shows that they lacked knowledge and understanding about this concept and its relationships with other concepts (Van Zele et al., 2004). This organisation is pre-structural, due to this is not a very useful way to examine the concept of energy in an ecosystem.
Finally, although Aimee and Tina placed the ecosystem concept at the top of their concept map, presenting it as the most general concept, it is isolated from the other factors (Figure 4.1). They linked it to the cluster that includes birth rate and death rate (Cluster 2), and that which includes carnivore, but it was not clear if they meant to link it to the entire cluster including carnivore (Cluster 1). Also, no concepts were linked back to the ecosystem concept. This suggests that Aimee and Tina recognised the concept but had a very limited understanding of the relationships and factors affecting populations within the ecosystem, so could not relate the concept appropriately to any of the other concepts in the cluster. Thus, their map is classified as pre-structural.

The post-test concept map, however, shows a change in the complexity of Aimee and Tina’s organisation of the concepts to incorporate and create more complicated interactions. While the overall structure of the pre-test concept map is more linear, the structure of the post-test concept map is more of a network. It is suggested that the structure of a concept map might be indicative of the knowledge and understanding of the person who created it, and that a network structure demonstrates a more coherent understanding (Schwendimann, 2011). Aimee and Tina organised the concepts in the post-test concept map into two clusters: Cluster A and Cluster B. Cluster 1 and Cluster 2 from the pre-test concept map were merged into one cluster in the post-test concept map, now identified as Cluster B (Figure 4.3). The relationships among the concepts predator, prey, carnivore, herbivore and plants remained similar to how they were shown in the pre-test concept map, which indicates that the dyad may have had a general understanding that relationships exist among these concepts. However, they also linked these concepts (as a group) to birth rate and death rate as a group, made new connections and moved
away from a series of linear, pre-structural-level relationships, to a more dynamic way of thinking about system relationships over time.

Figure 4.3: Aimee and Tina’s post-test concept map Cluster B with interpretations

The influence of the modelling environment (NetLogo) was clear in this cluster. Aimee and Tina used a two-way arrow between the two sets of concepts in this cluster (the first set included birth rate and death rate and the second set included predator, prey, carnivore, herbivore and plants). They then described the relationship between these two sets by writing, ‘e.g. higher predator numbers = less prey and Higher death= Lower birth’. Linking these two sets of concepts in this way gives the impression that they had grasped these relationships and reveals an improvement in their understanding of these concepts: this way of linking shows their understanding of the independent and dependent variables in the ecosystem, which they learnt about and experienced in the modelling environment. Linking these sets of concepts illustrates that they identified relationships among these concepts and shows a deeper understanding of the interrelationships among the different components of an ecosystem and their effects on each other. The dyad’s responses to the assessment question in the modelling guidebook suggest that they concluded this after conducting their experiences using the modelling environment, as shown later in this section. Therefore, these links are classified as at the relational and extended abstract levels.
In Cluster A (Figure 4.4), the concepts energy, ecosystem, habitat destruction, human impact, hunting, introduce species, natural causes, weather, fire and drought were retained together from the pre-test to the post-test concept map, but were now linked around a new focal point; habitat destruction.

![Figure 4.4: Aimee and Tina’s post-test concept map Cluster A with interpretations](image)

It is clear that these participants treated habitat destruction as an important concept, as they used this concept as the central concept. Habitat destruction was linked to five concepts: energy, ecosystem, human impact, introduced species and natural causes, as follows:

- Habitat destruction impacts Ecosystem
- Habitat destruction building infrastructure, globalization Human Impact
- Habitat destruction these affect the habitat, e.g. fire burns crops/food source Natural causes
- Habitat destruction is affect the habitat and can in some cases destroy Introduced Species
- Habitat destruction all need energy Energy

Linking habitat destruction to these concepts in the post-test map was important in terms of Aimee and Tina gaining a deeper understanding of ecological concepts and beginning to think laterally. It indicates a change in their understanding of ecology at a deeper level.

Using habitat destruction as a junction concept and linking it to natural causes, introduced
species and human impact reveals that Aimee and Tina had begun to understand the significance of habitat destruction as a cause of animal extinctions, and that there are important causes of habitat destruction other than just human impact, which they had indicated as the only cause in their pre-test concept map. They now realised that introduced species and natural causes, such as fire, drought and weather can also cause habitat destruction and contribute to animal extinctions. This is a sophisticated development in their understanding, moving their focus in the post-test concept map away from humans; it also shows that humans are central to many of the problems and were focused on habitat destruction. Therefore, these linkages are classified at the relational and extended abstract levels.

Aimee and Tina connected energy to human impact, habitat destruction and natural causes, which they wrote, ‘all need energy’. These links demonstrate Aimee and Tina’s linear thinking; they seemed to continue to struggle with this concept and to have difficulties in thinking across scales, possibly because it can be applied at a wide range of scales within the system—that is, to individual plants/animals, or populations or a whole system. Misconceptions related to the concept energy among K–12 and college students has been reported previously (Hartley, Wilke, Schramm, D’Avanzo, & Anderson, 2011). Aimee and Tina seemed to still have difficulties connecting the ecosystem concept. Similar to what they had done in the pre-test concept map, they placed the concept ecosystem near the top of their concept map as a general concept, but it remained isolated from the rest of the organisation (Figure 4.4). They did not link it to other concepts and only one concept (habitat destruction) was linked back to it, suggesting that Aimee and Tina recognised the concept but had very limited knowledge and understanding of its relationships with other concepts so they could not relate it appropriately to any of the other concepts.
The above analysis demonstrates how Aimee and Tina’s understanding grew in complexity as they were learning. This indicates that they had grasped ecology knowledge to a higher level in the study, providing evidence that learning in an immersive and modelling environment had a positive effect on their understanding of ecology concepts.

Additional evidence for an improvement in Aimee and Tina’s knowledge and understanding was revealed by analysing their responses to the guidebook synthesis questions (Appendix H and Appendix I) according to the levels of the SOLO taxonomy. Aimee and Tina’s responses to these questions included causes from the context of each learning environment and they provided some reasons and examples in their responses. For example, in their response to the immersive guidebook question they mentioned drought, overhunting and fire farming as major causes for declines in the populations of animals on planet Omosa, and demonstrated relationships and justified their answers. For overhunting effects, they justified their answer as, ‘Overhunting of the people, they don’t stop/wait for the breeding cycle’, and for fire effects they wrote, ‘Burning/fire farming—worse because there’s a drought now and it makes a huge impact’. Their responses provided good explanations for causes of the issue as they grouped together some of the listed factors and explained the interrelationship between these factors when they related drought to fire farming, revealing an understanding of the different effects and their relationships. Accordingly, this knowledge is classified at the multi-structural and relational levels according to the SOLO taxonomy.

In their response to the modelling guidebook assessment questions Aimee and Tina combined what they learnt from the two environments and provided evidence and examples of what has caused the decline in the population of animals on Omosa. They
included in their response human and environmental impacts, which they had learnt about in the immersive environment. They added examples: ‘high density/population of Omosans’ and ‘environmental impacts e.g. drought’. They also included an example of dependent and independent effects, about which they had learnt in the modelling environment: ‘populations of other species e.g. yernts die out—toorus die out’. In their response they demonstrated that they were thinking quite holistically, listing different terms that were appropriately used and well integrated; these terms were more technical/scientific and related to overarching concepts/biological systems. Thus, knowledge is classified at the relational and extended abstract levels.

Aimee and Tina’s responses to the guidebook assessment questions revealed progress in their knowledge and understanding throughout the study, mirroring their organisation of ideas in the post-test concept map (Figure 4.2).

In summary, development of Aimee and Tina’s knowledge and understanding was evident in different situations. Triangulation of evidence was undertaken to support and validate the data on knowledge and understanding derived from different sources including pre-test/post-test recall questions and concept maps, guidebook synthesis questions and Camtasia recordings as discussed later in this chapter.

In the recall question, they correctly listed more factors in the post-test than in pre-test. In the concept map question, there was an increase in the number of links created in the post-test concept map. Most concepts had a larger number of links in the post-test concept map. There was a decrease in the number of clusters of concepts in the post-test concept map and a reduction in the time spent creating the post-test concept map. The discussion of insights from the clusters in the pre-test/post-test concept maps and their analysis
according to the levels of the SOLO taxonomy revealed a shift in Aimee and Tina’s knowledge and understanding from pre-structural and uni-structural levels in the pre-test concept map to relational and sometimes extended abstract levels in the post-test concept map. Their response to the synthesis assessment questions in the guidebooks also showed advancement in the level of their understanding throughout the learning sessions.

The next section examines the development of Aimee’s and Tina’s confidence in ability in learning and teaching science. How the organisation of their learning experiences using the two environments contributed to the development in their confidence and knowledge and understanding is then examined. The extent to which this pattern was reproduced across the other dyads is examined and discussed in the following two chapters.

4.4 Confidence in Ability to Learn and Teach Ecology

Development in Aimee’s and Tina’s confidence was evident in different situations. Analysing their individual responses to the self-rating confidence perception questions in the pre-test/post-test interviews and in the guidebooks provided evidence for an overall development in their confidence from the pre-test to the post-test period. At the end of the study both had shown an improvement in their confidence in their ability to learn and teach ecology, but there was no consistent improvement in their confidence across their experiences in the two environments, Omosa and Omosa NetLogo, as shown in Table 4.2.

<table>
<thead>
<tr>
<th></th>
<th>Pre-test interview</th>
<th>Omosa (1)</th>
<th>Omosa (2)</th>
<th>Omosa NetLogo (1)</th>
<th>Omosa NetLogo (2)</th>
<th>Omosa NetLogo (3)</th>
<th>Post-test interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aimee</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Tina</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>
At the introduction to the immersive environment (Omosa) and after they had worked for a short time in this environment, there was no improvement in Aimee’s or Tina’s confidence. Tina felt less confident and Aimee’s confidence stayed the same. A similar pattern was noted at the introduction to the modelling environment (Omosa NetLogo): both Aimee and Tina felt less confident after working in this environment for a short time. One explanation for the decline/stability in their confidence after working for a short time in each environment might be that they had overestimated their initial level of confidence, thinking that they already knew the content. Research has shown that overconfidence in a student’s self-efficacy judgment is not uncommon (Cervone & Wood, 1995; Klassen, 2002; Pajares & Miller, 1994; Stone, 1994).

Another explanation for this decline/stability in Aimee’s and Tina’s confidence may be their unfamiliarity with the learning resources. Lack of prior experience with technology-based resources, as reported in their demographic surveys and during the pre-test interview, suggests they may have been adversely affected by the challenges associated with new technology learning environments, particularly as they reported earlier that they did not have much gameplay experience and had not experienced the use of such technology during their school years. For example, Aimee reported that she had never played games on her computer/phone and Tina reported that she played less than 1 hour per week. However, the declines in their initial levels of confidence was overcome after they had experienced the immersive and modelling environments for a longer time and completed all the activities in each. At the end of the study (in the post-test interview) both participants reported improvement in their confidence.

To support and validate the confidence data collected from Aimee and Tina via self-rating in pre-test/post-test interviews and guidebooks, data triangulation was performed by
using data derived from observations and the recordings made while they were constructing the pre-test/post-test concept maps. Aimee and Tina were observed to be more confident in the construction of the post-test concept map than in the pre-test concept mapping task. They created more links in the post-test concept map and spent approximately half the time constructing the post-test concept map compared with the pre-test concept map. Creating more links in a shorter time might be an indicator that Aimee and Tina had gained more confidence during the study, which was manifested as more links in the post-test concept map and in the post-test concept map being completed more quickly. The recording made of Aimee and Tina captured comments that revealed their confidence: for example, during the pre-test concept map construction Aimee said, ‘don’t know whether that makes sense at all’. In contrast, during post-test concept map construction both appeared more confident and now knew what they are doing: Aimee made comments like ‘here we go’ and ‘cool’ after linking a new concept in the map.

The above analysis highlights the role of the immersive and modelling environments in facilitating and providing appropriate confidence-building opportunities for Aimee and Tina. The evidence presented indicates that they had learnt and understood the content presented in the learning resources and this helped in increasing their confidence in their ability to learn and teach ecology at the end of the study.

4.4.1 Changes in Knowledge and Confidence

To understand the effect of the intervention, it is necessary to understand the changes in knowledge and confidence. Figure 4.5 provides a summary of all the data collection points, showing a change in Aimee’s and Tina’s confidence and understanding as discussed in previous sections. Measures of the initial and final level of understanding were recorded by analysing the dyad’s pre-test and post-test concept maps. The levels of
understanding at the end of each session were used to track changes in understanding throughout the intervention and were assessed by analysing responses to the synthesis question at the end of each session. The participants’ individual confidence levels were a record of their responses to the confidence questions asked throughout the study.

An interesting finding was that both Aimee and Tina not only showed improvement in their science CK and confidence in ability in learning and teaching science, but also altered their language and vocabulary; from generic non-discipline-based language to the use of scientific language and vocabulary. The analysis of responses to the questions in the pre-test and post-test interviews asking what scientists do and how they go about understanding what causes animals to become extinct revealed that Aimee and Tina used
more scientific language in the post-test interview and avoided naïve explanations. For example, in the pre-test interview about what scientists do, Tina responded:

*I guess they do experiments to help the world ... they will find you solutions to help, as well as testing things doing different, doing, like testing different circumstances to ... you know, make the place a bit better.*

With regard to how scientists go about understanding what causes animals to become extinct, Tina responded in the pre-test interview with:

*I think they count how many in the world first and then they list it as in dangers if it falls below and put tags on them unless they are already extinct. I think they just follow and track what it does and check the health once in a while and see if it is depreciating and if it is they will follow, you know, what did it do compared to something else that has health that still high.*

whereas in the post-test interview about what scientists do, Aimee responded:

*they look at the relationships between things and then what impacts what....related to ecology: relationships between things like, you know, the impacts on each other and the animals then people and animals and other animals, animals and plants and stuff, say like the relationships and the impacts of those.*

With regard to how scientists go about understanding what causes animals to become extinct, Aimee responded:

*They look at what is impacted them and then they look at how it impacted them and to what extinct and what factors had changed to make them going to extinct.*

And Tina responded:
They test animals in specific habitat and see which one is the healthiest and which one is seems to becoming weaker and then they will test more stuff.

The improvement in Aimee and Tina’s language and vocabulary might result from their exposure to the scientific approaches, scientific metalanguage and activities (hands-on, inquiry instruction) they participated in during the study. Research has identified the benefits of hands-on, inquiry-based science instruction and activities for language development, along with developing CK (Carrier, 2013; O. Lee, Buxton, Lewis, & LeRoy, 2006).

What aspects of the immersive or modelling environments, or of the designed activities helped in improving Aimee’s and Tina’s knowledge and confidence? The way in which the organisation of the learning experiences using Omosa and Omosa NetLogo (the structure of the environments and the representation of data in the spaces) might have contributed to the improvement in Aimee’s and Tina’s understanding and confidence is investigated in the next section, which explores their perceptions and engagement during the intervention.

4.5 Learning in Immersive and Modelling Environments

The contribution of Aimee’s and Tina’s perceptions about their learning in the immersive and modelling environments to the changes in their understanding and confidence was investigated by exploring their responses to the perception questions asked in the short interviews at the end of each session, and the post-test interview. The analysis showed that in general they both had a positive perception about these environments and about learning in these environments; thus, their experiences in these environments might have contributed to the change (improvement) in their understanding and confidence. Positive
perceptions about a learning environment and tasks are essential for learning to occur; otherwise, learners have only a slight chance of learning effectively (Marzano, 2006).

Aimee’s and Tina’s positive perceptions about the immersive and modelling environments and their learning experiences in these environments were clear in their responses during the two short interviews and the post-test interview; they both identified many positive aspects of these environments but almost no main negative aspects. They demonstrated clear perceptions regarding particular features of the immersive and modelling environments as influential factors in their learning. The general consensus was that the visual representations in both environments positively influenced their overall learning experience and helped them understand and learn the content. For example, in the short interview after their experience in the immersive environment (Omosa), their comments about Omosa indicated their understanding and learning from this environment and revealed their positive perceptions:

It is very helpful having the visual and everything … it was good to be able to see it and to be able to understand that there is different, all different factors influence it and it is not, you are not going to necessarily get all your information from one source because you can go around, and you can find out directly from the people, you can find from researchers in the area … In learning about the concept and understand the influences it is really good.

Aimee

you can go around and ask, you could see the environment, so you could see what the animals were doing. Tina

Similarly, in the modelling short interview their comments indicated their understanding and learning from this environment and revealed their positive perceptions:
It was really good, I liked it. It is visually was good to be able to see the relationship ... it was very much finding out through learning ourselves and through doing it, which is good and helpful for me. **Aimee**

I liked it how we had the graph, you can pin point to different spots to see several levels ... I liked it, I found it interesting. **Tina**

In the post-test interview when asked about their perceptions of the two environments in general, Aimee and Tina acknowledged their understanding and learning from both environments. A positive view with regard to incorporating the two environments was revealed by Aimee. Examples of their comments—referring to the immersive environment (Omosa) as the ‘first one’ and the modelling environment (Omosa NetLogo) as the ‘second one’—were:

*I think in the end I learnt more about the actual factors and stuff in the second one but the first one helped me understand the whole concept ... I think I learnt easier in the second one but I still learn a lot from the first one, because I found that, I ..., you know, it took consideration of different point of view of the people who actually lived there and the metrologies people and all of that and so demonstrated a different approach to it in the second, so I think I probably learnt more factual stuff from the second one but the first one defiantly did teach me a lot. **Aimee**

The second because you are able to see differences and you are able to change the levels, in the first one you only just asking questions and you are only getting prediction from the different people rather than actual facts. **Tina**

To understand the contribution of their learning experiences in the environments to the
changes in their understanding and confidence, Aimee’s and Tina’s engagement during the learning experiences was investigated based on analyses of their interactions with the learning resources and with each other while working in the environments. The analysis focuses on the participants’ learning processes and how they developed confidence and understanding of ecology concepts by using the immersive and modelling environments. The analysis of their interactions during the study showed that they were engaged cognitively and collaboratively; evidence for the verbal and non-verbal flow of engagement and technical engagement were also apparent, which might have contributed to the improvement in their understanding and confidence as a result for their experiences in the environments.

As indicated in Chapter 3, recordings of participants’ interactions during their engagement with learning from both environments were used to explore their thought processes during the study and track changes in their confidence and understanding. The recorded data for each dyad were transcribed in full and coded using the engagement coding categories and subcategories shown in Table 3.4. Detailed analysis of these interactions was then undertaken. In the following section the analysis results for cognitive, collaborative, flow and technical engagement are discussed separately for the immersive and modelling environments.

4.5.1 Engagement in the Immersive Environment
Aimee and Tina showed a high degree of collaborative engagement when using the immersive environment. They were working together taking turns writing their responses to the different tasks and not moving on until they both understood the material; however, because of this high level of collaboration only situations when their collaboration was particularly noticeable were coded according to the collaborative engagement category
In addition, Aimee and Tina exhibited positive responses to the immersive environment in the form of verbal and non-verbal flow of engagement. Their verbal comments, such as ‘it is such a cool game, I like this game’ (Aimee), their facial expressions (both smiling, laughing and seemed happy) and their body movements (getting closer to the screen) were all examples for their flow of engagement within the space. Verbal and non-verbal reactions were coded for the participants separately and collaboration engagement was coded as a dyad. Figure 4.6 shows the frequency of coding under each category for each of the participants separately and then for the dyad by adding the two frequencies together; and the number of activities they were performing together.

Aimee’s contribution was greater than Tina’s to both verbal and non-verbal flow of engagement. Aimee seemed very excited and provided many verbal comments as well as non-verbal reactions, which is concordant with the greater improvement in her confidence compared with Tina’s at the end. Technical engagement was also shown in Aimee’s and Tina’s interactions with the immersive environment (Figure 4.6); positive technical engagement was shown by them navigating the planet Omosa without difficulty and using the map with ease. Some negative technical engagement occurred but they managed to correct this easily by becoming more experienced with the environment. An example of this is when they were trying to travel in the environment and Aimee said, ‘how do we turn around?’, ‘wait, where is the turn-around thing?’ and then they re-read the orientation page in the guidebook to determine how to do this. From the evidence of engagement presented in this section, it can be argued that the immersive and modelling environments represented engaging learning environments that contributed to the improvement in Aimee’s and Tina’s understanding and confidence.
Cognitive engagement was also evident in Aimee’s and Tina’s interactions, which is of particular importance and concern because of its strong relationship with learning (Casimiro, 2016). Cognitive contributions were coded under the following subcategories: goal-based explanation, principle-based explanation, noticing coherence, paraphrasing, monitoring-positive, monitoring-negative and checking understanding (Figure 4.7). During the immersive intervention, there was evidence of a high frequency of goal-based explanation, principle-based explanation and paraphrasing, which are categorised as self-explanation. Such a high frequency of these subcategories indicates that Aimee and Tina spent the majority of their time cognitively involved in the learning resources. The high contribution of goal-based explanation, principle-based explanation and paraphrasing was witnessed when the pair spent more time performing specific actions such as 1/ making a decision about which question to choose to ask first, when Tina said, ‘which one? ... maybe this one’, pointing at question 9 on the screen; 2/ planning, when Aimee said ‘first thing we need to do is decide on her name’ and then they clicked the first
question, ‘who are you?’; 3/ explaining ideas and concept with elaboration, when they were reading an answer from one of the Omosan people and trying to summarise and conclude information from that answer and Aimee said, ‘they are only ... so basically they started overhunting’, and Tina continued, ‘without letting them breed and stuff’; 4/ making meaning from relationships and linking information, when they were reading from the data book for Omosa and trying to answer the question regarding patches of burnt out areas of bush alternating with clumps of dry grass, and Aimee said ‘so they explain that some plants grew better’ and ‘their plants are burnt off and the ones that don’t grow back as quickly it would be the ones that don’t cope as well’ and Tina agreed.

Evidence for Aimee’s and Tina’s monitoring of their learning (monitoring-positive, monitoring-negative and checking understanding) was also revealed in the study where a number of their interactions coded under the subcategories of monitoring. This may also be indicative of their cognitive engagement, which might have led to improvements in their knowledge and understanding. Aimee and Tina were monitoring their understanding, indicating whether they understood the materials or not. They were also checking their understanding as they worked in the immersive environment. For example, Aimee checked with Tina before responding to a task in the guidebook, ‘the yernt is the thing we are trying to find out, right?’ and Tina replied, ‘aha, I think so’; then Aimee asked ‘in food chains you have ... it is what has impact on food chain as well, isn’t it?’, and Tina replied ‘Yeah’. These types of interactions meant that Aimee and Tina did not move forward until they both understood the material. Being able to monitor their understanding and progress at their own rate may have contributed to the increase in their understanding of the concepts. This is in line with research showing that monitoring and regulating activities are good indicator of learners’ cognitive engagement, which is allied with better learning and improved level of achievement and, subsequently, to higher self-
efficacy (Linnenbrink & Pintrich, 2003). Evidence of Aimee and Tina relating what they were currently studying to a previous item was also seen during their interactions, and was coded under noticing coherence.

Aimee’s contribution was higher than Tina’s for all of the cognitive engagement subcategories with the exception of the subcategory monitoring-positive where the contribution for both was equal. The most frequent contributions for the dyad were goal-based explanation, paraphrasing and principle-based explanation (Figure 4.7 and Table A1 in Appendix G). Evidence of planning to achieve their goal (goal-based explanation); relating information to important concepts in ecology (principle-based explanation); and making meaning from relationships was clear in Aimee’s and Tina’s interactions as shown above. All indicate that they were generating many explanations for themselves. Generating a high number of explanations for themselves might have contributed to the enhancement in their understanding and knowledge, consistent with Ainsworth and Th Loizou (2003), who indicate that self-explanation is a functional strategy that can support learning and that generating explanations for themselves while learning will help learners develop a deeper understanding of material they are studying.

As pointed out in Section 3.8, to simplify the process of tracking changes in participants’ understanding and confidence, the learning sessions were divided into periods related to when the confidence question was asked. Accordingly, the immersive session was divided into three periods (P1, P2, P3) as shown in Figure 4.8 and Table 4.3.
Based on the activities and directions provided in the immersive guidebook, which were designed according to the 5Es model as clarified in Section 3.3.1, the first period (P1) involved a series of activities that represented the engage, explore and explain phases of the 5Es model (Table 4.3). The main activities were:

(i) initial explorations

(ii) collecting information at the different locations

(iii) making sense of the information and beginning to answer the guidebook questions
(iv) collecting more information and continuing to answer the guidebook questions.

Table 4.3: The sequence of the participants’ cognitive activities across time in the immersive session

<table>
<thead>
<tr>
<th>Period</th>
<th>Stage</th>
<th>The most frequent cognitive activities</th>
<th>Frequency</th>
<th>Aimee</th>
<th>Tina</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 (~17 min)</td>
<td>(i) Initial explorations</td>
<td>Monitoring-positive</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0–1.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Checking understanding</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(ii) Collecting information at the different locations</td>
<td>Monitoring-negative</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1.41–3.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technical engagement</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(iii) Making sense of the information and starting to answer guidebook questions</td>
<td>Paraphrasing</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>3.33–5.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goal-based explanation</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Principle-based explanation</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(iv) Collecting more information and continuing to answer guidebook questions</td>
<td>Paraphrasing</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>5.36–17.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goal-based explanation</td>
<td>28</td>
<td>18</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Principle-based explanation</td>
<td>17</td>
<td>12</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>P2 (~5 min)</td>
<td></td>
<td>Paraphrasing</td>
<td>15</td>
<td>9</td>
<td>6</td>
<td>17.17–22.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goal-based explanation</td>
<td>10</td>
<td>3</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Principle-based explanation</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Aimee and Tina’s initial explorations were characterised by instances of checking understanding. Both checked their understanding with the other and with the researcher, and these activities appeared to be motivated by their desire to conform to the instructions: for example, Aimee asked, ‘do we need to write stuff down or not?’, and Tina asked, ‘ok,
During the subsequent stage (collecting information at the different locations) they continued to collaborate with each other. Their most significant additional activities were their monitoring/negative and technical engagement/positive. They appeared to be concerned about how to navigate to the specified locations and demonstrated an effort to understand the material. Indications of this were when one or both declared that a specific material was not clear and tried to understand it by either reading the material again or discussing it with the other (monitoring/negative). They also showed positive technical engagement by navigating around planet Omosa without difficulty.

In the third (making sense of the information and starting to answer the guidebook questions) and fourth (collecting more information and continue answering the questions in the guidebook) stages, Aimee and Tina gathered additional information by undertaking more exploration and meeting more characters in the environment. They then started to make sense of the information to gain a better understanding of what was occurring on planet Omosa. They showed a high degree of collaboration by discussing the material with each other to gain consent before writing the answer in the guidebook. There were other indications of their engagement and attempts to understand the information. They began to paraphrase the information and provide explanations. For example, they started to use the same terms/words used in Omosa: Aimee said, ‘Nina (hunter) hunts yert for their meat’. They also began to relate the information to important concepts in ecology (principle-based explanation). One example of this is Aimee’s response to the information they collected at the village: ‘so basically, they started overhunting’. Finally, they engaged in a significant level of planning to achieve their goal (goal-based explanation). For example, Aimee said, ‘first thing we need to do is decide on her name’, indicating
that she was aware of a deficit in their present knowledge and where to go to address this problem.

In the shorter P2 period, Aimee and Tina continued to paraphrase the information, plan further actions, use goal-based explanation, relate the ideas to ecological concepts and use principle-based explanation. The frequencies in each of these categories was less, which may be partly because P2, which is approximately 5 minutes, was shorter than P1, which was around 17 minutes. Alternatively, it might be because the two participants had internalised many of the concepts.

Finally, during P3 (reporting findings) they used the data they had collected to answer the questions presented in the guidebook. Unfortunately, there was a problem with the recording software so the reported findings are based on the researcher’s written notes for this period. The notes showed that Aimee and Tina were able to answer the guidebook synthesis question using the insights they had gained in the previous periods. Their responses to the synthesis question were also used to obtain an indication of their final level of knowledge, as shown in Section 4.3. Their responses to this question included good explanations of causes of the problem. They linked some of the factors they listed together to explain the interrelationships between them, which demonstrates their understanding of the different ecological impacts and their relationships.

### 4.5.2 Engagement in the Modelling Environment

As with the immersive session, Aimee and Tina showed a high degree of collaborative engagement, some verbal and non-verbal flow of engagement and technical engagement while using the modelling environment (Figure 4.9).
Figure 4.9: The frequency of contributions by Aimee and Tina in the modelling environment session, as a group and individually (collaborative, flow and technical categories)

Regarding cognitive contributions (Figure 4.10), their most frequent contributions were goal-based explanation, paraphrasing and principle-based explanation, which was similar to their contributions in the immersive intervention.

Figure 4.10: The frequency of cognitive contributions by Aimee and Tina in the modelling environment session, as a group and individually
Table 4.4: The sequence of the participants’ cognitive activities across time in the modelling session

<table>
<thead>
<tr>
<th>Period</th>
<th>The most frequent cognitive activities</th>
<th>Frequency of both</th>
<th>Aimee</th>
<th>Time</th>
<th>Tina</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Goal-based explanation</td>
<td>17</td>
<td>13</td>
<td>0:44.0</td>
<td>4</td>
<td>0:10.0</td>
</tr>
<tr>
<td></td>
<td>Checking understanding</td>
<td>11</td>
<td>5</td>
<td>0:13.0</td>
<td>6</td>
<td>0:10.0</td>
</tr>
<tr>
<td></td>
<td>Monitoring-positive</td>
<td>11</td>
<td>9</td>
<td>0:10.0</td>
<td>2</td>
<td>0:02.0</td>
</tr>
<tr>
<td></td>
<td>Principle-based explanation</td>
<td>6</td>
<td>3</td>
<td>0:10.0</td>
<td>3</td>
<td>0:08.0</td>
</tr>
<tr>
<td>P2</td>
<td>Goal-based explanation</td>
<td>23</td>
<td>13</td>
<td>0:32.0</td>
<td>10</td>
<td>0:24.0</td>
</tr>
<tr>
<td></td>
<td>Paraphrasing</td>
<td>16</td>
<td>10</td>
<td>0:43.0</td>
<td>6</td>
<td>0:27.0</td>
</tr>
<tr>
<td></td>
<td>Principle-based explanation</td>
<td>13</td>
<td>7</td>
<td>0:26.0</td>
<td>6</td>
<td>0:17.0</td>
</tr>
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<td></td>
<td>Monitoring-positive</td>
<td>10</td>
<td>7</td>
<td>0:11.1</td>
<td>3</td>
<td>0:03.0</td>
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<tr>
<td></td>
<td>Checking understanding</td>
<td>9</td>
<td>7</td>
<td>0:20.0</td>
<td>2</td>
<td>0:05.0</td>
</tr>
<tr>
<td>P3</td>
<td>Goal-based explanation</td>
<td>35</td>
<td>20</td>
<td>0:46.0</td>
<td>15</td>
<td>0:51.0</td>
</tr>
<tr>
<td></td>
<td>Paraphrasing</td>
<td>35</td>
<td>20</td>
<td>1:43.0</td>
<td>15</td>
<td>1:21.0</td>
</tr>
<tr>
<td></td>
<td>Principle-based explanation</td>
<td>18</td>
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<td>1:11.0</td>
<td>8</td>
<td>0:35.0</td>
</tr>
<tr>
<td></td>
<td>Monitoring-negative</td>
<td>12</td>
<td>8</td>
<td>0:44.0</td>
<td>4</td>
<td>0:07.0</td>
</tr>
<tr>
<td></td>
<td>Checking understanding</td>
<td>9</td>
<td>6</td>
<td>0:15.0</td>
<td>3</td>
<td>0:07.0</td>
</tr>
<tr>
<td>P4</td>
<td>Paraphrasing</td>
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<td>2</td>
<td>0:12.0</td>
<td>1</td>
<td>0:06.0</td>
</tr>
<tr>
<td></td>
<td>Goal-based explanation</td>
<td>2</td>
<td>1</td>
<td>0:05.0</td>
<td>1</td>
<td>0:03.0</td>
</tr>
<tr>
<td></td>
<td>Principle-based explanation</td>
<td>2</td>
<td>1</td>
<td>0:05.0</td>
<td>1</td>
<td>0:06.0</td>
</tr>
<tr>
<td></td>
<td>Monitoring-positive</td>
<td>1</td>
<td>0</td>
<td>0:00.0</td>
<td>1</td>
<td>0:02.0</td>
</tr>
</tbody>
</table>

The sequence of activities they undertook, based on the activities and directions provided in the modelling guidebook, is shown in Table 4.4. In P1, participants read an introduction to computational experiments in the modelling environment and practised the procedures for running a simulation in such an environment. An outline of the steps required to perform experiments was provided in the guidebook. This period showed a similar pattern of checking understanding to that seen at the beginning of the immersive environment session. Other activities included principle-based explanation when both were consolidating their understanding and building new knowledge. Goal-based explanations were also revealed when they were planning and making decisions to achieve their goal (e.g. Aimee said, ‘let’s press go, leave it awhile and then press stop’ and Tina said, ‘we can look at the time, or we just stop every 250’). Monitoring/positive indications were
shown as well during this period. This was clear when they were confirming their understanding of the material (e.g. Aimee said, ‘ok, alright’).

In P2 participants read and practised how to move the sliders and switches in the Omosa NetLogo model, how to change parameters and perform experiments. They were then asked to perform an experiment (Study 1) using the model. During P2 participants continued their activities from P1 and began paraphrasing as they were relating the information and making meaning of relationships, modelling relationships and developing hypotheses using terms/words they learnt in the immersive intervention. They also learnt new concepts/thinking in addition to the terms they had learnt and used earlier. They demonstrated more scientific thinking through their use of these terms and concepts: for example, ‘umm, so we can say the higher the drought severity level’ (Tina); ‘the lower the population’ (Aimee); ‘so the more grass the more yernt’ (Tina).

In P3 participants had to choose and test one of two possibilities for the cause of the decline in the populations of animals using what they had done in Study 1 as a guide to assist them to answer the guidebook questions. During this stage they engaged in almost the same pattern of activities as in P2: goal-based explanation, paraphrasing, principle-based explanation and checking understanding. In addition, monitoring/negative was shown in this period. Both participants demonstrated efforts to understand the materials, as evidenced by one or both declaring a specific material was not clear and trying to understand it by discussing it with the other: ‘why are there more yernt?’, ‘that makes no sense’, ‘I don’t understand this’ (Aimee).

Finally, during P4 (reporting findings) Aimee and Tina used the data they had collected to answer the questions posed in the guidebook. In this period, they continued to
paraphrase the information, plan further actions (goal-based explanation), relate the ideas to ecological concepts (principle-based explanation) and confirm their understanding of the material (monitoring/positive).

4.6 Summary

In summary, this chapter presented the findings from the analysis of data from one dyad of preservice teachers (Aimee and Tina) to demonstrate how the data in this study were analysed in detail. Changes in Aimee and Tina’s knowledge and understanding was evident in different situations. Analysis of the recall question and concept maps in pre-test/post-test and the synthesis questions in the guidebooks provided evidence for improvement in Aimee and Tina’s knowledge and understanding. Development in Aimee’s and Tina’s confidence was evident in different situations. Analysing their individual responses to the self-rating confidence perception questions in the pre-test/post-test interviews and in the guidebooks provided evidence for an overall development in their confidence from the pre-test to the post-test period. This chapter confirmed that the immersive and modelling environments are engaging learning environments. Learning experiences by preservice teachers in such environments helped them improve their understanding and confidence. This was evidenced through the improvement in their understanding and confidence, as shown in Sections 4.3 and 4.4. This approach supports the use of the 5Es model for designing learning experiences, which also seemed to be successful in improving participants’ understanding and confidence.

The next chapter presents results from the analysis of data collected from different sources for the four dyads of preservice teachers who participated in the study.
CHAPTER 5: RESULTS

5.1 Introduction

This chapter presents the results of the analysis of data collected from different sources for the four dyads that participated in the study. The key findings from the study can be summarised as follows:

**Cognitive engagement.** The highest level of cognitive contribution of all participants during both sessions were goal-based explanation, principle-based explanation and paraphrasing, which indicates the importance of these cognitive processes in improving participants’ knowledge and confidence.

**Flow of engagement.** Verbal and non-verbal flow of engagement were exhibited in both sessions and mirrored changes in participants’ knowledge and confidence.

**Collaboration engagement.** Participants’ collaboration was high throughout both sessions. Participants in all dyads took turns writing and not moving on until both participants in the dyad understood the materials. Both the immersive and modelling environments facilitated participant collaboration.

**Technical engagement.** Positive technical engagement was evident in both sessions.

These summary points suggest that the two environments had a positive effect on participants’ understanding and confidence, primarily by supporting their cognitive and collaborative engagement. There is also evidence of consistency across the findings presented in this chapter and in Chapter 4. It is evident from the analysis in both the immersive and modelling environments that the highest number of cognitive contributions were goal-based explanations, principle-based explanations and paraphrasing. It can be argued that this high level of cognitive engagement, collaboration
and flow of engagement might be important for changes in participants’ understanding and confidence, which was found to be common to all dyads. The chapter is divided into the following sections: background information; knowledge and understanding of ecology concepts; confidence in ability to learn and teach ecology; and learning in immersive and modelling environments.

5.2 Knowledge and Understanding of Ecology Concepts

As indicated in the previous chapter regarding the in-depth analysis, to obtain more data about the changes in participants’ knowledge and understanding, the pre-test/post-test recall question and concept maps were first analysed quantitatively and then qualitatively. The guidebook synthesis question responses were also analysed qualitatively. Analysis of responses to the recall question in the pre-test and post-test asking dyads to list factors that negatively influence a particular ecosystem showed that all groups listed more factors in the post-test than in the pre-test period (Table 5.1).

Table 5.1: Number of factors listed by dyads in response to pre-test and post-test recall questions

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of factors listed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
</tr>
<tr>
<td>G1 (Aimee and Tina)</td>
<td>5</td>
</tr>
<tr>
<td>G2 (Kristy and Alice)</td>
<td>8</td>
</tr>
<tr>
<td>G3 (Mia and Lina)</td>
<td>5</td>
</tr>
<tr>
<td>G4 (Elisa and Mary)</td>
<td>3</td>
</tr>
</tbody>
</table>

Analysis of the participants’ concept maps (Appendix F) quantitatively captured three pieces of evidence of change in knowledge and understanding. First, comparison of the pre-test and post-test concept maps revealed that all dyads created more connections/links between ecosystem concepts in the post-test concept map than in the pre-test concept map (Table 5.2).
Second, there was a reduction in the time spent by dyads creating post-test concept maps. All dyads created more links in their post-test concept map in a shorter time (Table 5.2).

Table 5.2: Number of connection/links between ecosystem concepts created by dyads in their pre-test and post-test concept maps

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test concept map</th>
<th>Post-test concept map</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># of links</td>
<td>Approx. time taken (min)</td>
</tr>
<tr>
<td>G1</td>
<td>38</td>
<td>14</td>
</tr>
<tr>
<td>G2</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td>G3</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>G4</td>
<td>21</td>
<td>18</td>
</tr>
</tbody>
</table>

Third, a visual analysis of the structure of the pre-test and post-test concept maps based on the definition of the cluster of concepts identified for this study (see Section 3.8.1), showed a decrease in the number of clusters of concepts. Comparison of the pre-test and post-test concept maps showed that three of the four dyads had organised the concepts in their post-test concept map into fewer clusters than in their pre-test map. The fourth dyad had organised the concepts in their post-test concept map into the same number of clusters as in the pre-test concept map, with slight changes in the arrangement of concepts in each cluster (Table 5.3).

Table 5.3: Number of clusters into which dyads organised concepts in their pre-test and post-test concept maps

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of clusters in pre-test concept map</th>
<th>Number of clusters in post-test concept map</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>G2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>G3</td>
<td>2</td>
<td>1 cluster with central theme around human impact and natural causes</td>
</tr>
<tr>
<td>G4</td>
<td>2</td>
<td>1 cluster with central theme</td>
</tr>
</tbody>
</table>
An analysis of the recall question responses revealed differences in the content of responses from pre-test to post-test for all dyads. The responses to the pre-test questions were more general. For example, one dyad mentioned human impacts and another mentioned disasters, without identifying what precisely are these effects and what they include. In addition, most of the factors listed pre-test seemed to be related to everyday (common sense) meaning or current issues they may have learnt or heard about from the media or other public sources. Such effects included global warming and pollution, which were mentioned in the responses of half of the dyads to the pre-test questions. Further, although ecology teachers are expected to be aware of different ecology concepts and ecosystems, some participants seemed poorly informed about ecosystems such as forests, woodlands and deserts: the factors listed by one dyad in the pre-test period were all related to one type of ecosystem—aquatic biomes.

In contrast, analysis of the responses to the post-test questions showed that they were more specific. Participants listed more factors related to what they had learnt from the immersive and modelling environments during the study. For instance, most of the dyads listed drought and hunting among ecological impacts; these two factors are among the prominent issues pointed out in the immersive (Omosa) and modelling (Omosa NetLogo) environments. The dyad that seemed not much informed about a range of ecosystems in the pre-test was found to be more aware of other environments in the post-test period, when they listed additional ecological impacts that can influence different ecosystems rather than being specific to one ecosystem, as per their responses to the pre-test questions.

Qualitative analysis of the pre-test/post-test concept maps by applying the SOLO taxonomy and comparing the outcomes for each dyad revealed a shift in the level of
understanding from the SOLO pre-structural, uni-structural and multi-structural levels in pre-test concept maps to multi-structural, relational and extended abstract levels in post-test concept maps (Table 5.4).

Table 5.4: SOLO levels for each dyad in the pre-test and post-test concept maps

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of clusters</td>
<td>SOLO level</td>
</tr>
<tr>
<td>G1</td>
<td>3</td>
<td>Uni-, pre- and multi-structural</td>
</tr>
<tr>
<td>G2</td>
<td>3</td>
<td>Multi-structural</td>
</tr>
<tr>
<td>G3</td>
<td>2</td>
<td>Multi-structural</td>
</tr>
<tr>
<td>G4</td>
<td>2</td>
<td>Multi-structural</td>
</tr>
</tbody>
</table>

G1. In their pre-test concept map, Aimee and Tina arranged the concepts in three clusters. Connections between some concepts were missing and some connections were simple and obvious, so the map is classified as pre-structural and uni-structural (Figure 5.1).

Figure 5.1: G1 pre-structural and uni-structural levels in the pre-test concept map

However, in the post-test concept map they arranged the concepts in two clusters and more complicated interactions were evident. Participants integrated their understanding from both sessions, made new connections and moved away from a series of linear pre-
structural relationships to a more dynamic way of thinking about system relationships over time (Figure 5.2), classified as relational and extended abstract levels.

Figure 5.2: G1 relational and extended abstract levels in the post-test concept map

**G2.** In their pre-test concept map, Kristy and Alice arranged the concepts in three clusters and provided a number of connections between several concepts within and between clusters that are directly related. They then connected some of the concepts from each cluster to a central theme that they called ‘EXTINCTION’, classifying the organisation as multi-structural (Figure 5.3).

Figure 5.3: G2 multi-structural level in the pre-test concept map
In the post-test concept map, the ‘EXTINCTION’ theme and same number of clusters were retained but more links were created between concepts with a slight change in the arrangement of the concepts in each cluster. There was little change between pre-test and post-test concept maps and little evidence of an effect of the intervention in the dyad’s post-test concept map. Thus, this map is classified as multi-structural (Figure 5.4).

Figure 5.4: G2 multi-structural level in the post-test concept map

G3. In their pre-test concept map, Mia and Lina arranged the concepts in two clusters and provided a number of connections between several concepts that are directly related. However, few explanations were provided about each link and no focal point was clear, leading to a multi-structural classification (Figure 5.5).
In their post-test concept map, they arranged the concepts in one cluster and provided good examples of relationships that indicated their understanding of interactions. Input from the intervention was obvious in their post-test concept map, which is classified as relational (Figure 5.6).

G4. In their pre-test concept map, Elisa and Mary arranged the concepts in two clusters with sensible relationships and explanations, demonstrating appropriate use of simple theoretical everyday terms. The concepts are well organised but the links are not justified and the central theme is not clear, leading to classification as multi-structural (Figure 5.7).
In their post-test concept map, they arranged the concepts in one cluster and provided sensible links to central and peripheral concepts—for example, ‘Herbivore > plants’—with better justification and integration. However, they still used descriptive and everyday terms, so that the result was more like an essay, which classifies it as relational with some extended abstract levels (Figure 5.8).

For the guidebook assessment (synthesis) questions about what had caused the decline in the populations of animals on Omosa, participants’ responses included at least two main points in the context of each environment, along with reasons and examples of each (Table 5.5).
Table 5.5: Number of factors included in the dyads’ responses for the assessment (synthesis) question in each guidebook

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of the main points mentioned in the synthesis question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immersive environment (Omosa)</td>
</tr>
<tr>
<td>G1</td>
<td>3</td>
</tr>
<tr>
<td>G2</td>
<td>5</td>
</tr>
<tr>
<td>G3</td>
<td>3</td>
</tr>
<tr>
<td>G4</td>
<td>3</td>
</tr>
</tbody>
</table>

For example, in their response to the immersive (Omosa) guidebook assessment question, participants in G4 (Elisa and Mary) mentioned drought, firestick farming and changing hunting practices (Figure 5.9), about which they had learnt while navigating the immersive environment. Similarly, in their response to the modelling (Omosa NetLogo) guidebook assessment question their responses included drought and hunting. They included these two factors in their hypothesis for testing in the modelling environment (Figure 5.10). (See Appendix H and Appendix I for more examples of participants’ responses to the guidebooks assessment questions).

Figure 5.9: G4 response to Omosa guidebook assessment question
Applying the SOLO taxonomy to dyad responses to the synthesis questions revealed a shift in understanding for all groups, as shown in Table 5.6 and explained in the following paragraphs.

Table 5.6: SOLO levels for each dyad in the assessment (synthesis) question in each guidebook

<table>
<thead>
<tr>
<th>Group</th>
<th>SOLO level for responses to synthesis questions in the immersive (Omosa) and modelling (Omosa NetLogo) guidebooks</th>
<th>Omosa</th>
<th>Explanation</th>
<th>Omosa NetLogo</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>Multi-structural and relational</td>
<td>Providing number of factors; demonstrating relationships and justifying their answers; their response has some good explanations of causes for the issue; they are thinking quite holistically</td>
<td>Relational and extended abstract</td>
<td>Making arguments with evidence, examples and justification; listing different terms that are more technical/scientific and related to overarching concepts/biological systems; much clearer relationships; incorporation of Omosa and Omosa NetLogo is shown; more precise thinking after using Omosa NetLogo; ‘thinking like scientists’</td>
<td></td>
</tr>
<tr>
<td>G2</td>
<td>Multi-structural and relational</td>
<td>Providing a number of factors; demonstrating relationships; thinking laterally and providing evidence</td>
<td>Relational and extended abstract</td>
<td>Making predictions, recommendation and interpretations based on their ‘experimental results’</td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>SOLO level for responses to synthesis questions in the immersive (Omosa) and modelling (Omosa NetLogo) guidebooks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Omosa</td>
<td>Explanation</td>
<td>Omosa NetLogo</td>
<td>Explanation</td>
<td></td>
</tr>
<tr>
<td>G3</td>
<td>Multi-structural and relational</td>
<td>Consistent listing, providing a number of factors and evidence with some justification; difficult to precisely identify the level but at least relational</td>
<td>Multi-structural</td>
<td>Providing a number of factors</td>
<td></td>
</tr>
<tr>
<td>G4</td>
<td>Multi-structural</td>
<td>Providing a number of factors</td>
<td>Relational and extended abstract</td>
<td>Following more advanced stages of scientific method; discussing concept of ‘no right answer’ and justifying the changes in relationships. In the scientific method these are good examples of the first stage of making observations</td>
<td></td>
</tr>
</tbody>
</table>

**G1.** Aimee and Tina’s response to the assessment question in the immersive (Omosa) guidebook (Figure 5.11) shows that they had demonstrated relationships and justified their answers; they provided good explanations of causes of the issue and were thinking quite holistically; classified as multi-structural and relational levels.

![Figure 5.11: G1 response to the immersive (Omosa) guidebook assessment question](image)

In their response to the assessment question in the modelling (Omosa NetLogo) guidebook (Figure 5.12), they provided evidence, examples and justifications for their
arguments. They used terms that were more technical/scientific and were related to overarching concepts/biological systems with much clearer relationships. The terms were also appropriately used and well integrated. Incorporation of ideas and concepts between the environments was shown and there was evidence of more precise thinking after using the modelling environment; they were ‘thinking like scientists’. Their knowledge is classified as relational and extended abstract levels.

Figure 5.12: G1 response to the modelling (Omosa NetLogo) guidebook assessment question

G2. Kristy and Alice’s response to the assessment question in the immersive (Omosa) guidebook (Figure 5.13) includes a number of factors and demonstrates the relationships among them. They were thinking laterally and provided evidence, so that their knowledge is classified as multi-structural and relational levels.
Their response to the assessment question in the modelling (Omosa NetLogo) guidebook (Figure 5.14) shows that they were making predictions, recommendations and interpretations based on their experimental results; classified as relational and extended abstract knowledge.

**G3.** Mia and Lina’s response to the assessment question in the immersive (Omosa) guidebook (Figure 5.15) shows that they provided consistent listing with a number of factors and evidence with some justification. It was difficult to define the precise level, but it goes to the relational level, so that this is classified as multi-structural and relational levels of thinking.
Figure 5.15: G3 response to the immersive (Omosa) guidebook assessment question

Their response to the assessment question in the modelling (Omosa NetLogo) guidebook (Figure 5.16) includes a number of factors, but the relationships among them are not demonstrated, so this is classified as multi-structural knowledge.

Figure 5.16: G3 response to the modelling (Omosa NetLogo) guidebook assessment question
**G4.** Elisa and Mary’s response to the assessment question in the immersive (Omosa) guidebook (Figure 5.17) includes good examples of the first stage of making observations according to the scientific method, so this is classified as multi-structural level.

Figure 5.17: G4 response to the immersive (Omosa) guidebook assessment question

Their response to the assessment question in the modelling (Omosa NetLogo) guidebook (Figure 5.18) shows that they appreciated the concept of there being ‘no right answer’ and explained and justified the changes in relationships; this is classified as relational and extended abstract knowledge levels.

Figure 5.18: G4 response to the modelling (Omosa NetLogo) guidebook assessment question

Table 5.7 shows the changes in the SOLO levels for each dyad throughout the two sessions.
Table 5.7: The development in SOLO levels for each group throughout the two sessions

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test concept map</th>
<th>Immersive guidebook synthesis question</th>
<th>Modelling guidebook synthesis question</th>
<th>Post-test concept map</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 (Aimee and Tina)</td>
<td>Uni-, pre- and multi-structural</td>
<td>Multi-structural and relational</td>
<td>Relational and extended abstract</td>
<td>Relational and extended abstract</td>
</tr>
<tr>
<td>G2 (Kristy and Alice)</td>
<td>Multi-structural</td>
<td>Multi-structural and relational</td>
<td>Relational and extended abstract</td>
<td>Multi-structural</td>
</tr>
<tr>
<td>G3 (Mia and Lina)</td>
<td>Multi-structural</td>
<td>Multi-structural and relational</td>
<td>Multi-structural</td>
<td>Relational</td>
</tr>
<tr>
<td>G4 (Elisa and Mary)</td>
<td>Multi-structural</td>
<td>Multi-structural and relational</td>
<td>Relational and extended abstract</td>
<td>Relational with some extended abstract</td>
</tr>
</tbody>
</table>

Several patterns arose from the analysis of responses to the assessment tasks, including pre-test/post-test recall question, pre-test/post-test concept maps, and synthesis questions, for all dyads:

**Improved recall.** All dyads listed more factors in their post-test assessment (recall) question response than in their pre-test question response.

**Stronger connections.** All dyads created more connections/links in their post-test concept map than in their pre-test concept map, and in a shorter time. Also, three out of four dyads organised and grouped the concepts in their post-test concept map into fewer clusters than in their pre-test concept map. The fourth dyad organised concepts into the same number of clusters in both the pre-test and the post-test concept map.

**Shift in understanding (concept maps).** Comparison between the pre-test and the post-test concept map for all dyads indicate a shift in the level of understanding from SOLO pre-structural, uni-structural and multi-structural levels in the pre-test concept map, to multi-structural, relational and extended abstract levels in the post-test concept map.
**Shift in understanding (synthesis question).** In their response to the guidebook synthesis questions all dyads were able to include at least two main points in the context of each environment as well as some reasons and examples. Applying the SOLO taxonomy to these responses identified a shift in the level of understanding from SOLO multi-structural and/or relational to multi-structural and/or relational and extended abstract.

In the concept map participants were able to integrate their understanding across the two learning environments. Moreover, analysis of dyad responses to the questions in the pre-test and post-test interviews (‘If someone asked you “What do scientists do?” what would you tell them?’ and ‘How do scientists go about understanding what causes animals to become extinct?’) showed that in post-test, all dyads used more scientific language in their responses. Table 5.8 provides examples of participants’ responses to the two questions in the pre-test and post-test interviews.

Table 5.8: Participants’ responses to the questions: ‘What do scientists do?’ and ‘How do they go about understanding what causes animals to become extinct?’

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 (Aimee and Tina)</td>
<td>I guess they do experiments to help the world, they will find you solutions to help, as well as testing things doing different, doing, like testing different circumstances to ... you know, make the place a bit better</td>
<td>They look at the relationships between things and then what impacts what ... related to ecology: relationships between things like, you know, the impacts on each other and the animals then people and animals and other animals, animals and plants and stuff, say like the relationships and the impacts of those</td>
</tr>
</tbody>
</table>
### G2 (Kristy and Alice)

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. How do scientists go about understanding what causes animals to become extinct?</td>
<td>I think they count how many in the world first and then they list it as in danger if it falls below and put tags on them unless they are already extinct ... I think they just follow and track what it does and check the health once in a while and see if it is deprecating and if it is they will follow, you know, what they do compared to something else that has health that is still high compared to the subject</td>
<td>They look at what is impacting them and then they look at how it impacts them and to what extent and what factors had changed to make them go extinct ... they test animals in specific habitats and see which one is the healthiest and which one seems to be becoming weaker and then they will test more stuff</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. If someone asked you ‘What do scientists do?’ what would you tell them?</td>
<td>A lot, I mean just from my aunty like she has a lot so she is actively involved in research and trying to get grants for the university and teaching and being a mentor and replying to many emails a day, doing admin ... if you had to give one sentence for scientists—someone actively investigating the world, how the world works and theorising, experimenting and observing, and also coming up with new ideas and then innovation—getting rid of the old ideas so it is an ever-changing discipline</td>
<td>Testing hypotheses and constantly reinventing concepts and ideas about things that we think we already know</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. How do scientists go about understanding what causes animals to become extinct?</td>
<td>I mean with scientists it is always testing hypotheses and testing everything when you have new ideas implementing the idea and if it is successful. If you’re talking about particular species I would mention that they study species and their environments to see and observe exactly what is happening and what could be the effects</td>
<td>Observations and experiments, yeah observation is probably the biggest one they can’t really control drought or anything that we did in Omosa but by observation they can document and maybe create like one of those mathematical equations and graphs; as well as prediction, tagging of animals to catch more events to collect data that provide them with the information</td>
</tr>
</tbody>
</table>

### G3 (Mia and Lina)

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. If someone asked you ‘What do scientists do?’ what would you tell them?</td>
<td>They find out like how things work and they do all the tests and they do experiments to find out that</td>
<td>They investigate the hows and whys of just general things, about things in the world around us, just how things work and why they work</td>
</tr>
<tr>
<td>Question</td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2. How do scientists go about understanding what causes animals to become extinct?</td>
<td>They do research, they have to look at what animals need when they were alive or what similar animals need when they are alive and then maybe how that wasn’t provided to see like maybe that’s why they went extinct, if something that they needed to stay alive was taken away; so looking at the environment at the time that they wouldn’t have been alive</td>
<td>Tracing populations, and like so you have to trace populations and I suppose that they have to hypothesise like factors that would influence and then also trace that; so say if it is drought then you trace the population in correlation with drought being present or not ... They also work on like prior theories as well; I mean I don’t know if there are prior theories for Omosa but they might already know</td>
</tr>
<tr>
<td>G4 (Elisa and Mary)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. If someone asked you ‘What do scientists do?’ what would you tell them?</td>
<td>Research, hypothesise, experiment</td>
<td>investigate things ... they search, establish hypotheses and research it for any field</td>
</tr>
<tr>
<td>2. How do scientists go about understanding what causes animals to become extinct?</td>
<td>They go to the habitat where they lived and understand the area that they live in—the foods that they eat, and like the other species around them, and the human population</td>
<td>make a hypothesis and then like independent and dependent variables and then test it over a period of time</td>
</tr>
</tbody>
</table>

**5.3 Confidence in Ability to Learn and Teach Ecology**

This section presents the findings on the participants’ confidence in their ability to learn and teach ecology. The averages of participants’ response scores for the confidence perception questions in the pre-test/post-test interviews and guidebooks suggested an overall increase in confidence perception after participating in the activities (Figure 5.19).

For example, at the beginning of the study, at the pre-test interview, the average score for participants’ confidence perception was 4.75 with and range of 2–8; whereas at the end of the study, at the post-test interview, the average score was 7.50 with a range of 5–9.

At the beginning of the intervention in the immersive environment the average score for participants’ confidence perception was 4.75 (range 3–9) and at the end the average was 6.25 (range 4–9). For the modelling environment, at the beginning of the intervention the
average confidence score for participants was 6.38 (range 3–9) and at the end, the average was 7.75 (range 5–9).

Figure 5.19: The average score for participants’ confidence perception during different stages of the study (bars show the range of values)

Individual responses to the confidence perception questions during the study showed an overall improvement in their confidence perception, although this was not consistent across the participants’ experiences in the two environments, as illustrated in Figure 5.20.

Figure 5.20: Participants’ individual confidence perception during the study sessions
The introduction to the immersive environment had varied effects on most participants’ confidence; four participants felt more confident and three felt less confident. The confidence level of Mia, who had studied science up to the end of first year university, stayed the same. The drop in confidence for some participants was overcome after they had completed all the activities, with almost all reporting higher levels of confidence at the end of the immersive intervention.

The same pattern of change in confidence was observed with the modelling environment, where four participants felt less confident, one participant stayed the same, and three participants felt more confident after they began working in the modelling environment. After completing the modelling intervention most participants either felt more confident or stayed the same (the participants who stayed the same were those who had a high prior confidence rating: 8 or 9). For most participants their level of confidence was maintained or increased in the post-test interviews, with two participants reporting a slight drop in their level of confidence.

The change in participants’ confidence perception during the study was also evident when examining the differences between consecutive stages (Table 5.9 and Figure 5.21).

Table 5.9: The change in participants’ confidence between consecutive stages

<table>
<thead>
<tr>
<th>Participant</th>
<th>Pre-test–Omosa (1)</th>
<th>Omosa (1)–Omosa (2)</th>
<th>Omosa (2)–NetLogo (1)</th>
<th>NetLogo (1)–NetLogo (2)</th>
<th>NetLogo (2)–NetLogo (3)</th>
<th>NetLogo (3)–Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aimee</td>
<td>0</td>
<td>2</td>
<td>−1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tina</td>
<td>−2</td>
<td>2</td>
<td>−1</td>
<td>1</td>
<td>−1</td>
<td>2</td>
</tr>
<tr>
<td>Kristy</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Alice</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>−2</td>
</tr>
<tr>
<td>Mia</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>−1</td>
</tr>
<tr>
<td>Lina</td>
<td>1</td>
<td>1</td>
<td>−1</td>
<td>5</td>
<td>0</td>
<td>−1</td>
</tr>
</tbody>
</table>
The patterns arising from Table 5.9 and Figure 5.21 can been understood in terms of general improvement in confidence across all of the participants, and particularly through the individual improvement of Lina:

**Improvement in confidence.** The values in the categories Omosa (1)–Omosa (2) and NetLogo (1)–NetLogo (2) are all either zero or positive, which indicates an improvement in participants’ confidence after they had worked for a while in each environment.

**Individual improvement in confidence.** One interesting issue that is investigated and discussed in the next chapter is the change in Lina’s confidence, which increased from 3 to 8 between the NetLogo (1) and NetLogo (2) stages.

Comparing the confidence perception of all participants between the pre-test (before starting the interventions) and post-test (after applying the interventions) periods, Table
5.10 and Figure 5.22 show an increase in confidence for all participants (the confidence of Mia, which was high from the beginning, stayed the same).

Figure 5.23 demonstrates that as the study progressed, participants felt more confident in their ability in learning and understanding science; however, they apparently did not become more confident at the same rate.

Table 5.10: Participants’ confidence perception in the pre-test and the post-test periods

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre-test interview</th>
<th>Post-test interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aimee</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Tina</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Kristy</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Alice</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Mia</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Lina</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Elisa</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Mary</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

Figure 5.22: Participants’ individual confidence perception in the pre- and post-test periods
Learning in Immersive and Modelling Environments

The contribution of participants’ perceptions about their learning in the immersive and modelling environments to the changes in their understanding and confidence was investigated by exploring their responses to the perception questions asked in the two short interviews and in the post-test interview. The outcome of the analysis showed that, in general, the participants had a positive perception about these environments and about learning in these environments, which may have contributed to the general improvement in their understanding and confidence as a result of their experiences in the immersive and modelling environments. Participants demonstrated clear perceptions regarding particular features of the immersive and modelling environments as influential factors in their learning. The general consensus among participants was that the visual
characteristic/visual representations of both environments positively affected their overall learning experience and helped them understand and learn the content.

Participants’ comments about the immersive environment included:

it was good to be able to see it and to be able to understand that different factors influence it and it is not—you are not going to necessarily get all your information from one source because you can go around, and you can find out directly from the people, you can find out from researchers in the area.

G1 / Aimee/

Had lots of fun, it was good to be in like that character’s shoes and exploring it and seeing everything, so it gave me better understanding of the setting and saying it for myself. That was good. G2 / Kristy

It is good, it is fun because it is like going somewhere and actually talking (not actually talking to people), but it is close to little conversation with them—say reading from the text, you can choose which questions you want to ask based on your understanding. I thought was very helpful. G3 / Lina

I liked it because you see the environment, you could see like the colours of the grass and like the sky, and you like actually can see the physical environment and be able to move around it, so it is helpful; like a lot better than just like reading like dry grass, which like I would forgot in like 5 seconds. G4 / Mary
Similarly, for the modelling environment, participants’ comments indicated their understanding and learning from this resource and revealed their positive perception. For example:

*It was really good, I liked it. It visually was good to be able to see the relationship….. it was very much finding out through learning ourselves and through doing it, which is good and helpful for me.*  
**G1 / Aimee**

Yeah I liked it, I liked how we had the graph, you can point to different spots to see several levels … Yeah I liked it, I found it interesting.  
**G1 / Tina**

I liked it when we tried to predict what happened and then we tested it and we could see what was happening and we were happy…… it makes you think of different possibilities and understand in different ways that you did not before. I like actually seeing more of what happens, and seeing the graph like you predict something and then you see it happening and then you can reevaluate and test another theory and actually see it.  
**G2 / Kate**

I enjoyed it; I am like seeing the graph and then like I can see how it moves in correspondence with the image and also seeing the exact numbers of the population so you can see. So I think it is really good, really clear precise visual information.  
**G3 / Lina**

I like being able to change the independent variable and then see the result is good, see on the graph is good, you can see like sharp declines and increases something.  
**G4 / Mary**
Participants’ perceptions of the learning environments acknowledged their understanding and learning in both environments. When participants were asked about the environment in which they felt they had learnt more about ecology and the factors that affect animal populations—the immersive or the modelling environment, and why—most stated that they had learnt more in, and preferred, the modelling environment. Some participants referred to the immersive environment (Omosa) as the ‘first one’ and to the modelling environment (NetLogo) as the ‘second one’. Some examples of their responses were:

*The second, because you are able to see differences and you are able to change the levels, in the first one you only just asking questions and you are only getting predictions from the different people rather than actual facts.*  
G1 / Tina

*NetLogo, because I could actually see the overview; you have the data to reflect and you are also using all the controls and stuff, but a child might like the VLE more because it is more of an environmental world that the child is playing a game in—the child may not understand the graph—but also with the game if you don’t have a clear set of like definitions or values within it, then it can be up to the person’s interpretation, and how they wanna draw information from it.*  
G2 / Kate and Alice

*I liked the NetLogo better; I liked it because it is more straightforward. I think children might find interactively going talking to people but I think I prefer the NetLogo.*  
G3 / Lina

*I preferred NetLogo because you could see the relationships, which is kind of what we were being asked about more; whereas, over there it is kind of like*
you had to talk to different people and you are kind of getting fed information rather than saying it to for yourself. G3 / Mia

Only one dyad (G4) indicated they learnt more about ecology and the factors that affect animal populations in the immersive environment than in the modelling environment. Their comments included:

the first one, Omosa, yeah because they actually give you paragraph information rather than the graphs, you have to make the connections yourself. G4 / Elisa

I would say Omosa probably the same reason because I think there is more information. G4 / Mary

However, participants expressed a positive view with regard to incorporating the two environments, as highlighted in the following comments:

I think the fact that we saw Omosa before this was helpful as well because we already knew about like what a yernt was like if I just like saw that straight away that would be like what is this and what is that, why, why, or like no idea about where Omosa was, what kind of habitat was in because it was good to see exactly what it looked like. Lina

I think in the end I learnt more about the actual factors and stuff in the second one but the first one helped me understand the whole concept like I mean that what explained to me what the yernts were and all of that and it also helped me see, I don’t know, I think I learnt easier in the second one but I still learnt a lot from the first one, because I found that, I ... you know it took
consideration of different points of view of the people who actually lived there and the meteorology people and all of that and so demonstrated a different approach to it in the second; so I think I probably learnt more factual stuff from the second one but the first one definitely did teach me a lot. Aimee

However, participants’ responses to the question about the negative aspects of the immersive and modelling environments that could have been improved or changed to support their learning, were not really negative comments:

_I don’t know, they don’t really have anything negative yeah I liked it, I found it interesting._ Tina

_I don’t think there is anything negative._ Kate

_I am not sure; I can’t think of any. It is pretty easy to use._ Elisa and Mary

_I think it is not negative so much as just, I think it would take a little bit of getting used to it, like if you are using it for kids as well; people do it in different ways so you have to account for that time period because it is exploring and wherein some people will kind of go just for just the basics where some people like to be more thorough._ Mia

Most of the comments were providing suggestions and recommendations or expressing concern about an issue related to learning using these environments. For example, two dyads suggested that some kind of feedback would be useful, so they would know if they were heading in the right direction. These comments were related to the immersive environment:
I guess I would like clarification; maybe like having questions come up in the game and then you explore to find these questions so you have like a good direction. Alice

I think it is really good; I just think like you don’t know if what you are including from the information is correct, so I feel like missing something I guess. Mary

Similar suggestions were made regarding the modelling environment:

Not particular, I mean it is just with the activity because you have to kind of make like you don’t kind of get feedback as to whether you are doing this correct; do you know what I mean? Mia

Despite their positive perceptions about learning in the two environments, one participant expressed concern about the time it would take to study for an exam using these environments. Regarding the immersive environment, the comments was:

I think it would take a long time, well, I mean it is very helpful having the visuals and everything but it seems like if you were studying it, as you know, as studying for an exam or something. For learning about the concepts and understanding the influences it is really good, but I think it would be a bit difficult to practice for exams or something like that just because of the time it would take, because it is so, you do need to travel, in these things you need to travel from one place to another; you need to ask a certain amount of questions and look for certain things, which is very life like and good in that sense but it could be also kind of difficult if you are trying to learn a concept quickly or get an overview of an idea. Aimee
Regarding the modelling environment, the comment was:

> Just the fact that even though like you could see the graphs and stuff, I don’t know whether they would actually accept that as an answer. If they actually accept that as an answer in the exam like as this goes up and this goes down, I don’t know, it is just different; it lets you describe in your own words which is good when you are learning it but not necessarily so good because you don’t know if you are on the right track, well you kind of can see if you are on the right track but I mean trying to explain it to someone else could be a bit, when trying to explain it in an exam context, like if you are explaining it to someone else just talking to them that would be fine and it would be a lot easier to explain it to them going off, this is the grass level, go up, then the yernt can go up as well because they have more food, but if you try to write it down in an exam this doesn’t sound good.

Figure 5.24 summarises the findings in relation to the changes in participants’ confidence and knowledge presented in the previous sections.

To understand the contribution of participants’ learning experiences in the immersive and modelling environments to the changes in their understanding and confidence, their engagement during the learning experiences was investigated by analysing their interactions with the learning resources and with each other while working in the environments. As indicated in Section 3.8.3, participants’ actions and interactions were recorded, transcribed in full and then coded using the engagement coding categories and subcategories in Table 3.4. Detailed analysis of these interactions was then undertaken to identify possible factors associated with changes in knowledge and confidence. The
analysis focused on the participants’ learning process and how they developed confidence and understanding of ecology concepts using the immersive and the modelling environments.

The analysis of these interactions showed that they were engaged cognitively and collaboratively. Evidence for verbal and non-verbal flow of engagement and technical engagement was also displayed. The following sections present the analysis results for their engagement in both environments.
Figure 5.24: The changes in participants’ confidence and knowledge during the study
5.4.1 Engagement in the Immersive Environment

All dyads showed a high degree of collaborative engagement and positive responses to the immersive environment, as indicated by the frequency of their verbal and non-verbal flow of engagement coded using the flow of engagement categories (verbal and non-verbal) (Figure 5.25 and Appendix G). Examples of verbal comments include, ‘it is such a cool game, I like this game’, ‘so exciting’, ‘cool, it will really be exciting if we can see the fire’, ‘I think that it is interesting; like I liked the fire stick farming; it is cool’. Examples of non-verbal actions were participants’ facial expressions such as smiling and looking happy; and body movements including moving closer to the screen. A low frequency of technical engagement positive/negative was shown by dyads while learning using the immersive environment.

![Figure 5.25: The frequency of contributions made by all dyads during the immersive session](image)

With regard to cognitive contributions, the most frequent contributions for all dyads were goal-based explanation, paraphrasing and principle-based explanation. A lower frequency was shown for checking understanding, monitoring-negative, monitoring-positive and noticing coherence (Figure 5.26 and Appendix G).
5.4.2 Engagement in the Modelling Environment

As in the immersive environment, the dyads showed a high degree of collaborative engagement, verbal and non-verbal flow of engagement while using the modelling environment (Figure 5.27 and Appendix G). Participants’ verbal responses indicated they were excited and engaged in the learning environment, for example: ‘that is exciting’, ‘that is interesting’, ‘it is really interesting that the grass went up and the yernts went down, they went really low’ and, ‘It is awesome’.
Figure 5.27: The frequency of contributions for all dyads during the modelling session

Figure 5.28: The frequency of cognitive contributions for all dyads during the modelling session

Similar to the immersive environment, the most frequent cognitive contributions for all dyads were goal-based explanation, paraphrasing and principle-based explanation. Lower frequency was seen for checking understanding, monitoring-negative, monitoring-positive and noticing coherence (Figure 5.28 and Appendix G).
5.5 Summary

In summary, this chapter presented the findings from the analysis of data from four dyads of preservice teachers. The study found an overall improvement in participants’ science CK and confidence in their ability in science learning and teaching from pre-test to the post-test assessment. Evidence for the contribution of participants’ learning experiences in the immersive and modelling environments and their perception about their learning in these environments and the changes in their understanding and confidence were also revealed. The findings suggest that the two environments had a positive effect on participants’ understanding and confidence, primarily by supporting their cognitive and collaborative engagement. The next chapter discusses each of these findings for all dyads.
CHAPTER 6: DISCUSSION

6.1 Introduction

This chapter presents a discussion of the findings reported in Chapters 4 and 5. The first section summarises the purpose and the research questions. The second section summarises the study and major findings. The third section provides a discussion of the main findings.

6.2 Restatement of Aim and Research Questions

The purpose of this study was to determine how to improve knowledge and understanding of science concepts and confidence in ability in science for preservice primary teachers. The study examined the effect of a twofold immersive and modelling intervention. The intervention used two platforms: Omosa, a game-like environment that provides an immersion experience; and Omosa NetLogo, a computer modelling environment. The participants, who were first year preservice primary teachers, worked in dyads. The intervention explored the development of the preservice teachers’ (a) knowledge of ecology concepts, and (b) confidence in ability in science learning and teaching. The study also examined (c) participants’ perception about their learning in the immersive and the modelling environments, and (d) the contribution of participants’ experiences and perceptions about their learning in these environments to changes in their understanding and confidence in teaching ecology in a primary school. Specifically, there were three research questions:

1. What is the effect of an intervention using an immersive environment (Omosa) and a modelling environment (Omosa NetLogo) on the development of first year preservice primary teachers’ knowledge and understanding in science?
2. What is the effect of an intervention using immersive and modelling environments on the development of first year preservice primary teachers’ confidence in science?

3. How do the experiences and perception of participating preservice primary teachers about their learning in immersive and modelling environments influence their knowledge and understanding and confidence in teaching ecology in a primary school?

6.3 Restatement of the Study and Main Findings

The research problem outlined in Chapter 1 highlights that preservice primary teachers often have limited science CK and low confidence in their ability in science learning and teaching. To address these critical ongoing issues in primary preservice teachers’ science education, this study used a small-N study design to determine whether a study intervention—using technology-based resources and constructivist approaches and activities—results in improved preservice teachers’ science CK and confidence in their ability in science learning and teaching. The 3D virtual environment, Omosa and the modelling environment, Omosa NetLogo, were used to help teach some ecology concepts to a group of preservice teachers in the first year of their bachelor of education primary degree, at a university in Australia. This combination of immersion and modelling environments provided different but complementary learning experiences.

Data were collected from a variety of sources including surveys, interviews, participants’ concept maps, participants’ responses in their guidebooks, and Camtasia and audio recordings of participants’ actions and interactions to address the study research questions centred on the effectiveness of the described intervention for improving participants’ understanding, confidence, engagement and perception of the learning experience. It was
found that both environments afforded similar learning opportunities. The results suggest that the benefits were enhanced visualisation, interaction and collaboration with peers, and engagement with the experience. The benefits identified in this study corroborate those reported in other studies that used similar technology-based environments (Blikstein et al., 2005; Dede et al., 2005a, 2005b; Dede, Nelson, et al., 2004; Gobert et al., 2004; Grotzer et al., 2015; Grotzer et al., 2016; Jacobson & Kozma, 2000; Ketelhut, 2007; Metcalf et al., 2011; Wilensky & Reisman, 2006). Overall, positive effects of the intervention were demonstrated.

The study first examined if there were changes in participants’ understanding and confidence and then examined how and why these changes occurred. The main findings are discussed in the following sections with reference to the research questions that the study sought to answer. The study found an overall improvement in participants’ science CK and confidence in their ability in science learning and teaching from the pre-test to the post-test assessment. The study supports the effectiveness of such intervention and suggests that the immersive and modelling environments Omosa and Omosa NetLogo, along with the constructivist approaches and activities applied in this study, facilitated and provided appropriate knowledge and confidence-building opportunities for the participants.

6.4 Discussion of Main Findings

This section presents each of the main findings separately. It should be noted here that the researcher acknowledges that this is a small scale study. The data has been discussed here in respect of other studies in order to build strength to the claims being put forward. However, it is accepted that learning gains and deepened levels of understanding are hard to measure in a short-term intervention.
6.4.1 Knowledge and Understanding of the Ecology Concepts

The first research question addressed was ‘What is the effect of an intervention using an immersive environment (Omosa) and a modelling environment (Omosa NetLogo) on the development of first year preservice primary teachers’ knowledge and understanding in science?’. A change (gain) in participants’ knowledge and understanding of ecology concepts was shown in all dyads, which would suggest learning had occurred in both environments, which may facilitated and supported participants’ understanding of ecology concepts and provided appropriate knowledge-building opportunities that allowed these participants to acquire new knowledge. This result accords with findings reported by Jacobson et al. (2016) of significant learning gains by participants when an immersive environment in conjunction with a modelling environment were used with secondary school students to help them learn general principles of scientific knowledge about biological systems.

The results of this study are generally consistent with prior research reporting a positive effect of immersive and modelling environments similar to Omosa and Omosa NetLogo on learners’ science CK. For instance, several studies reported learning gains in science-related areas using VLEs and game-like virtual environments (J. Anderson & Barnett, 2011; Barker & Gossman, 2013; Ketelhut, Clarke, & Nelson, 2010; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014) and computer modelling environments (Blikstein & Wilensky, 2010; Wilensky & Reisman, 2006) separately.

The findings in this study suggest that the combination of immersive and modelling environments was among the factors contributing to the improvement in participants’ science CK in this study. Because earlier studies that utilised the combination of such
environments were limited and performed with secondary school students, it is difficult to make direct comparisons between this study and previous research.

Analysis of the dyads’ responses to pre-test and post-test assessment questions (recall question and concept map question) asked during interview, as well as their responses to assessment (synthesis) questions presented in each guidebook, indicates that all four dyads experienced improvement in their knowledge and understanding of ecology concepts during the intervention. Pre-test and post-test assessment results have been utilised in many studies to examine the effect of different interventions on preservice teachers’ knowledge in science and science-related fields. J. Anderson and Barnett (2011), for example, used pre-test and post-test assessment scores to explore the effect of using a video gaming technology on preservice teachers’ understanding and learning of physics concepts. Similarly, Baser (2006) used pre-test and post-test assessment scores to investigate the effects of using simulations on preservice primary teachers’ understanding of physics concepts.

Analysing participants’ responses to the assessment tasks revealed improved recall, stronger connections and shifts in understanding:

1. **Improved recall.** The assessment (recall) question in the pre-test and post-test asked dyads to list factors that negatively influence particular ecosystems. Analysis of their responses showed that participants gained more understanding as they progressed through the intervention. There were differences in the number of factors they listed and content of responses between pre-test and post-test for all dyads, showing that science CK was gained. Although differences were observed between dyads’ responses, it was found that in the post-test responses all dyads listed more factors; their responses were more specific; they listed more factors related to what they learnt
from the two learning environments during the study; and they demonstrated
knowledge of different ecology concepts and ecosystems. Thus, the results from
comparing the pre-test and post-test responses to this low cognitive level question,
based on Bloom’s taxonomy (Bloom, 1956), demonstrate participants’ learning and
show their ability to recall information and knowledge related to the materials about
which they were asked. Further, the number of correct influencing factors recalled
increased with participants’ experiences in the study, which can be interpreted as an
indication of a positive influence of the study intervention on their learning.

Although analysis of the recall questions indicated that participants had gained
knowledge throughout the study, there were few details about progress in their
understanding. Thus, and as indicated in Chapter 3, other assessment tasks were used,
including pre-test and post-test concept maps and synthesis questions in each session.
The analysis of participants’ responses to these tasks revealed more accurate
connections and shifts in understanding.

2. **Stronger connections.** A concept mapping tool was used to assess participants’
learning outcomes (Novak, 2003; Rice, Ryan, & Samson, 1998) and monitor their
learning progress (Kennedy-Jones, Naji, & Ennals, 2015) throughout the study. Using
concept maps to collect data to assess changes in participants’ science knowledge
after their learning in two technology-based resources in this study is similar to the
approach taken by Hoban et al. (2009). In their study, concept maps created by
preservice teachers were analysed and compared from the beginning to the end of the
study to monitor changes in their science CK after they had used technology to learn
science content.
A combination of quantitative and qualitative analysis techniques was used to analyse participants’ concept maps and allow triangulation of indicators of change in their understanding. The analysis provided evidence for an improvement in participants’ CK. Comparing the total number of links and clusters in pre-test and post-test concept maps and the time spent by participants to construct these maps, revealed that all groups created more links in post-test concept maps, and in less time. Also, there were smaller numbers of clusters in most dyads’ post-test concept maps. This may indicate that participants had gained more knowledge in the study, which they expressed via more links in the post-test concept maps and resulted in post-test concept map being completed more quickly. Identifying increases in preservice teachers’ CK based on the number of new concepts added to pre-test concept maps has also been done in previous research (Hoban et al., 2009). In addition, the increase in the total number of relationships/links in the learners’ concept map after an intervention has been used as an indicator of a well-structured knowledge base (Schaal et al., 2010).

The reduction in the number of clusters in post-test concept maps—that is, the grouping of more interrelated concepts into one cluster—might be a result of gaining more understanding because clusters can be seen as a demonstration of learners’ knowledge structures (Gericke & Wahlberg, 2013). Organising concepts into bigger clusters might mean that participants hold more than isolated facts about a topic and can grasp relationships between different concepts. Thus, the participants organised their knowledge into a coherent whole and grouped more related concepts within one cluster as they became more aware of the relationships among concepts. Identifying improvements in participants’ knowledge and understanding based on an increased number of ideas/concepts within a cluster is consistent with the National Research Council (2001), who state that normally the structure of learners’ understanding is
hierarchical; as learning increases, clusters of simple ideas accumulate into larger, more complex clusters.

However, the changes in the total number of links and clusters between the pre-test and post-test concept maps did not distinguish between levels of understanding or provide details about how these changes had occurred. As Schwendimann (2014) points out, the total number of links and concepts provides little insight into a learner’s understanding; a greater number of links does not mean that the learner understands the subject better. Therefore, to triangulate the results and achieve more useful insights into participants’ development of understanding, an additional method was used to analyse and score these concept maps. An assessment matrix for the analysis was developed based on the SOLO taxonomy (Biggs & Collis, 1982) to qualitatively analyse the concept maps.

3. **Shift in understanding (concept maps).** The participants’ pre-test and post-test concept maps were analysed and assessed according to the levels of the SOLO taxonomy using a matrix developed for this study (see Section 3.8.1) The focus was on differences in structural complexity of concept maps (McPhan, 2008) that can be observed in participants’ concept maps over time. Applying the levels of the SOLO taxonomy to the concept maps allowed assessment and examination of increases in participants’ level of understanding of ecology concepts. The SOLO level considerably improved from pre-test to post-test concept maps for all groups, demonstrating an increase in structural complexity in participants’ learning, shifting from a surface to a deeper understanding. The results showed how participants’ understanding grew in complexity as they were learning. None of the pre-test concept maps were categorised as having a relational or extended abstract level of structure, while most of the post-test concept maps fell were categorised at the relational or
relational and extended abstract level (Table 5.4). This indicates that participants had grasped a higher level of ecology knowledge during the study, moving from a surface to a deeper level of conceptual understanding (Bakouli & Jimoyiannis, 2014).

It is also worth noting that all or part of the created pre-test concept maps, as shown in Table 5.4, were categorised as having a multi-structural SOLO level, in that they included a number of connections between several concepts that are directly related. All groups showed, either in parts or the whole of their pre-test concept map, knowledge of different concepts and different relationships between these concepts; however, the relationships were not demonstrated, there was no clear central concept and it seemed that participants had difficulty identifying focal point or links, all of which indicate more concrete and surface-level understanding. This is in line with research pointing out that uni-structural and multi-structural responses reveal surface learning (Dudley & Baxter, 2009; Hattie & Brown, 2004).

One interesting finding was that G1 demonstrated multi-structural as well as pre-structural and uni-structural SOLO levels in their pre-test concept map (Appendix F). A pre-structural level was assigned to part of this group’s pre-test concept map, as it showed discrete pieces of information and disconnected concepts: no knowledge about the concepts birth rate and death rate and the relationships between them is shown in the concept map. Rather, the participants placed these two concepts to one side of the pre-test concept map without connecting them to any other concept or even to each other (Figure 5.1). This suggests that those students had no knowledge related to these concepts; thus the map is classified as pre-structural based on the definition of the SOLO levels (Table 3.3). However, the pre-structural SOLO level did not appear in the pre-test concept maps of any other group.
One participant in G1 reported having previous knowledge in science/biology. This suggests that the presence of the pre-structural SOLO level in their pre-test concept map may be due to lack of experience with creating concept maps. Indeed, one participant seemed unsure about what to do in the concept map question and asked, ‘do we draw arrows?’. Another reason might be that the participants in this group had misconceptions in their understanding of some relationships within the ecosystem; it has been shown that a large percentage of primary teachers have misconceptions regarding a variety of science concepts (Dahl, Anderson, & Libarkin, 2005; Gèonen, 2008; Kikas, 2004; Koc, 2006; Schoon, 1995; Trumper, 1997, 2003). According to Biggs’s (1982) definition of the SOLO levels, the uni-structural SOLO level was assigned to part of G1’s pre-test concept maps as the participants demonstrated knowledge of some common and familiar concepts, but with a single direct relationship between them (Figure 5.1 and Appendix F).

However, in the post-test concept maps most dyads demonstrated a deeper understanding as they were able to provide a number of connections between concepts and demonstrate relationships between them. In three groups the concepts were clearly connected to a central concept, which is classified as the relational level based on the definition of the SOLO levels identified for this study in Table 3.3. Two groups even reached the extended abstract level where they were able to provide connections between concepts that are not directly related, and connections that were more sophisticated than those provided at the relational level (Table 5.4 and Appendix F).

However, as shown in Table 5.4, one group (G2) stayed at the multi-structural level between the pre-test and post-test concept map. The G2 participants were unfamiliar
with concept maps. After they had read the concept map question, one of the participants asked, ‘Are we like linking them to each other?’, and when the researcher asked if they had any ideas about concept maps they replied, ‘no, not really ... we’ve never done one before’, which may explain why their pre-test and post-test concept maps did not show clearly any change/improvement in their understanding. However, their responses to the other assessment questions clearly showed improvement in their understanding.

4. **Shift in understanding (synthesis question).** Similarly, using the SOLO taxonomy levels to analyse participants’ responses to the assessment questions (synthesis questions) in the immersive (Omosa) and modelling (Omosa NetLogo) guidebooks revealed that almost all responses fell into the relational or relational and extended abstract category levels (Table 5.6). This might also indicate an increased understanding and level of understanding after learning in the immersive and modelling environments. Identifying improvement in participants’ knowledge from surface to deeper knowledge based on a change in classification of their responses to assessment activities, from uni-structural and multi-structural SOLO levels to relational and extended abstract levels, supports research that has connected relational and extended abstract responses to the conception of deep learning, while uni-structural and multi-structural responses reveal surface learning (Dudley & Baxter, 2009; Hattie & Brown, 2004).

Additionally, the analysis results for the synthesis questions showed that participants’ responses included content related to what they had learnt in each technology-based resource. This included key concepts in the context of each technology-based resource in each of their responses. For example, in their response to the Omosa guidebook
assessment question, all groups mentioned drought and firestick farming; three of the four groups also referred to hunting practices. These were all factors introduced in Omosa. Moreover, in their responses to the Omosa NetLogo guidebook assessment question it was clear (see Figures 5.14, 5.16, 5.18) that they had become more aware that no single factor causes a decline in populations of animals; it could be a combination of different factors. This also may indicate that participants had gained more understanding as they progressed through the study.

The improved levels of participants’ understanding throughout the study were verified through the results obtained by analysing and triangulating the dyads’ responses to the concept map question and the assessment questions presented in the pre-test and post-test interviews and in the two guidebooks. The results were positive in regard to the students’ learning in the immersive and modelling environments.

This research went beyond simply documenting changes in participants’ knowledge and understanding of ecology concepts. These changes may have occurred for multiple reasons, and the study aimed to understand in finer-grained detail how these changes came about. The aspects of the interventions used in this study that may have had a positive effect on participants’ understanding of ecology concepts and caused their knowledge to improve are discussed in Section 6.4.3.

6.4.2 Confidence in Ability to Learn and Teach Ecology

The second research question was, ‘What is the effect of an intervention using immersive and modelling environments on the development of first year preservice primary teachers’ confidence in science?’ It was found that the study intervention not only resulted in improved knowledge of participants regarding ecology concepts, but also in
improving their confidence in their ability in learning and teaching ecology. The data analyses demonstrated an effect of the immersive and modelling environments in boosting participants’ confidence in learning and teaching science.

Participants were asked to report their confidence using Likert scale responses from 1 to 10. A confidence self-assessment question was asked of the participants several times during the study: before and after the intervention based on the pre-test–post-test design; and while they worked on the technology-based resources via the guidebooks. This was done so that the researcher could identify and assess progress in participants’ confidence in their ability to learn and teach ecology. The data obtained from analysing participants’ responses to the confidence assessment question showed an increase in confidence from the pre-test to the post-test period for all participants (Figure 5.23). The study was able to clearly identify an increase over time in participants’ confidence in their ability to learn and teach ecology. This suggests that the immersive and modelling environments had a positive effect on participants’ confidence. This aligns with research findings of an increase in participants’ confidence in their ability in science and science-related areas using VLEs and game-like virtual environments (Dede, Ketelhut, et al., 2004; Kandi, 2013; Ketelhut, 2007; Meluso, Zheng, Spires, & Lester, 2012) and simulation and modelling environments (Urban & Falvo, 2016). Analysis of the pre- and post-test responses, the self-assessment question and guidebooks confirms that the immersive and modelling environments provided opportunities for the participants to develop their confidence in science and scientific CK.

By the end of the study, all participants had shown improvement in their confidence in their ability to learn and teach ecology; however, there was no consistency among participants in the rate of improvement in their confidence across the study (Figure 5.20).
The introduction to the immersive environment had varying effects on participants’ confidence levels; four participants felt more confident, three felt less confident and one experienced no change. A similar pattern of change in confidence was observed for the modelling environment, where four participants felt less confident, three felt more confident and one stayed the same after working on the Omosa NetLogo environment for a while (Table 5.9). One potential explanation for the decline in the confidence of some participants after working for a while with each learning resource is that they overestimated their initial level of confidence, thinking that they already knew the content. The decline in their initial level of confidence was reversed at the end of their time in each learning environment. This may indicate that they had learnt and understood the content presented in the learning resources, which helped increase their confidence in their ability to learn and teach ecology at the end of the study. This is in line with the study of Cervone and Wood (1995), which used a research game model involving experimental simulations (Wood & Bailey, 1985) to simulate organisational environments in which participants engaged in decision making. The authors provided evidence that self-efficacy judgments might reflect overconfidence, particularly judgments made at the outset of the experiment, before subjects had acquired any first-hand task experience. Similar evidence was reported by Stone (1994). Moreover, the literature includes examples of many other studies that show that overconfidence in students’ self-efficacy judgments is not uncommon (Cervone & Wood, 1995; Klassen, 2002; Pajares & Miller, 1994; Stone, 1994).

Another potential reason for the decline in the confidence of some participants may have been their lack of prior experience with technology learning resources. Participants might have been adversely affected by the challenges of the new technology, particularly as those who felt less confident after working for a while in the technology learning
environments were the ones who did not have much gameplay experience, as reported in the demographic survey conducted before the study. For example, all participants who experienced a decline in their confidence after working in one or both of the environments were those who had reported that they never played games on their computer/phone or they played less than 1 hour per week. In contrast, the two participants who experienced an increase in their confidence in both environments played games more frequently: one reported that she played games on her computer/phone for 1–3 hours per week and the other reported that she played for more than 3 hours a week. Thus, being comfortable with the technology learning resources because of previous experiences with technology, such as in game playing, might be reason for the increase in confidence of some participants after working in the technology environments for a short time. It is worth mentioning here that the high frequency of playing games appears to have a positive effect on participants’ confidence; its effect on their understanding and knowledge was not clear.

One interesting issue was the confidence of one participant (Lina), which increased as she worked in the modelling environment. She started with a self-reported confidence level of 3 when she began working with Omosa NetLogo and ended with a confidence level of 8. An examination of the comments made by this participant suggested she found the use of the modelling environment enjoyable and beneficial to her learning. She commented positively on the way in which information was presented for learning (visually/visual representations), which may be what made her enjoy the learning experience using the Omosa NetLogo resource, as per her comment:

*I enjoyed it, I like seeing the graph and then like I can see how it moves in a correspondence with the image and also seeing the exact numbers of the*
The noticeable increase in her confidence during her use of Omosa NetLogo might be a result of her enjoyment, which was based on her positive perception of the learning method in the modelling intervention. According to the literature, having a positive perception of the value of a learning technique enhances a learner’s enjoyment (Frenzel, Pekrun, & Goetz, 2007) and engagement in the learning (Komarraju & Karau, 2008). This helps build their CK because of the positive relationship between engagement and learning, and simultaneously increases their confidence in their ability because of the significant relationship between CK and confidence in ability (Appleton, 2008; Enochs & Riggs, 1990). For example, Wimsatt (2012) examined the relationship between science CK and self-efficacy, concluding that to increase teachers’ science self-efficacy, they need to be given opportunities to improve their CK.

The results of the study also revealed the positive effect of the intervention on participants’ science language and vocabulary. In the pre-test and post-test interviews, participants were asked about what scientists do and how they go about understanding what causes animals to become extinct. Analysis of participants’ responses to these two questions in the pre-test and post-test interviews revealed that they used more scientific language and vocabulary post-test. The reason for this result is likely to be that exposure to scientific approaches and activities (hands-on, inquiry instruction) during the study improved participants’ vocabulary in addition to their CK, as shown in the previous section. This agrees with research that has identified the benefits of hands-on, inquiry-based science instruction and activities in language development along with developing CK (Carrier, 2013; O. Lee et al., 2006).
6.4.3 Learning in Immersive and Modelling Environments

The third research question was, ‘How do the experiences and perception of participating preservice primary teachers about their learning in immersive and modelling environments influence their knowledge and understanding and confidence in teaching ecology in a primary school?’. The main data for analysis consisted of the participants’ responses to the perception questions, which largely demonstrated positive views and feelings about the learning experience. The perception questions asked participants to name some positive aspects of the environments in supporting their learning and some negative aspects that could be improved or changed to support their learning. At the end, participants were asked to comment about in which of the environments—the immersive or the modelling environment—they felt they had learnt more about ecology and the factors that affect animal populations, and why this was the case.

Data obtained from participants’ responses to the perception questions during the interviews (Appendix D) were examined to determine how they perceived the immersive and modelling environments and their experience of learning ecology using these platforms. The results suggest that the participants generally had positive perceptions of both environments and their learning experiences using these two resources. The following section identifies why changes in participants’ knowledge and understanding of ecology concepts might occur.

6.4.3.1 Participants’ engagement with the immersive environment and the modelling environment

To understand the changes in participants’ ecology CK, participants’ engagement in this study was examined based on analysis of their interactions with the learning resources
and with each other while working in the environments, and while constructing the concept maps (think-aloud data captured by Camtasia and audio recordings). The analysis focused on the participants’ learning process and how they developed understanding of ecology concepts. The results from analysing and assessing participant engagement in this study showed that participants were engaged in the learning process throughout the study. This suggests that the immersive and modelling environments were engaging for the participants and contributed to the changes in their understanding of ecology concepts, as revealed during the concept mapping and the other assessment activities. This is in line with many studies that have examined the effect of technology on enhancing learner engagement (Barab & Dede, 2007; Eady & Lockyer, 2013; Marshall, 2002; J. J. Smith & Greene, 2013; Watters & Diezmann, 2007; Wrzesien & Alcañiz Raya, 2010). Analysis of participants’ interactions during the study showed that they were engaged cognitively and collaboratively. Verbal and non-verbal flow of engagement and technical engagement was also evident.

Cognitive engagement of learners is of particular importance and concern because of its strong relationship with learning (Casimiro, 2016) and its significant role in learners’ achievement (Akyol, Sungur, & Tekkaya, 2010; Pintrich, Smith, Garcia, & McKeachie, 1993). There was evidence of a high frequency of cognitive engagement (goal-based explanation, principle-based explanation and paraphrasing) by all dyads during both sessions; participants spent most of their time cognitively involved with the learning resources. The high contribution for all groups in goal-based explanation, principle-based explanation and paraphrasing (self-explanation) was witnessed in this study as dyads spending more time performing specific actions such as making decisions, ‘should I go talk to the old man?’, ‘yeah just go to the hall and see if we can get in’; planning, ‘first thing we need to do is decide on her name’; explaining ideas and concept with elaboration,
‘fire stick farming is pretty much like burning; it is a kind of aboriginal stick burning of trees’; and building new concepts, ‘Yernt is prey’; making meaning from relationship and linking information, ‘ok, so because of changes in vegetation from fire stick farming plus drought, yernt aren’t reproducing at the same rate as before’. Participants in all groups were generating many explanations for themselves. For example, evidence of planning to achieve their goal (goal-based explanation), of relating information to important concepts in ecology (principle-based explanation) and of making meaning from relationships was clear in all groups’ interactions. Generating a large number of explanations for themselves might have contributed to the enhancement in participants’ understanding and knowledge. This is consistent with Ainsworth and Th Loizou (2003), who indicate that self-explanation is a functional strategy that can support learning, and that generating explanations for themselves while learning will help learners develop a deeper understanding of material they study.

The intervention was found to encourage participants to generate self-explanation, but seemed to be more beneficial for participants with prior education in science than those with no previous education in science. All dyads showed evidence for high levels of cognitive engagement; however, G1 and G3 had the highest cognitive engagement frequency in general. This might be because of their previous education in science: one of the participants in each of these groups had reported a background in science during the demographic survey, which could have stimulated their cognitive engagement with the immersive and modelling environments. With regard to the performance of the two groups with the highest cognitive engagement frequency (G1 and G3), based on their post-test concept map assessment using SOLO, they showed a deeper understanding of ecology concepts in their post-test concept map, moving from pre-structural, un-structural and multi-structural and from multi-structural to relational and extended
abstract and to relational, respectively. However, G4 exhibited a remarkably low frequency of cognitive engagement in general during both sessions compared with other groups, although their achievement at the end was high. They showed deeper understanding of ecology concepts in the post-test concept map compared with the pre-test concept map, moving from multi-structural to relational and extended abstract. In this group specifically, cognitive engagement did not successfully predict their achievement, similar to findings of Bircan and Sungur (2016). In my study, this may be because of the characteristics of some participants (e.g., shyness), which may influence other dimensions of engagement, including cognitive engagement (Olitsky & Milne, 2012).

It could be argued here that the intervention, in conjunction with the presentation of information in the resources, stimulated and encouraged all participants to engage in generating self-explanation. This, in turn, enhanced their knowledge and understanding of ecology concepts. Although there was a difference in levels of engagement, all participants were engaged in both learning environments (Appendix G). Finally, all showed an improvement in their knowledge of ecology concepts as demonstrated in their concept maps and responses to other assessment questions.

A number of participants’ interactions were also coded under the monitoring subcategory. Evidence of participants monitoring their learning (checking understanding, positive, negative) was revealed in the study. This might also be an indicator of participants’ cognitive engagement, which might have led to an improvement in their knowledge. Participants were checking their understanding as they worked with the learning resources: ‘the yernt is the thing we are trying to find out, right?’, ‘in food chains you have ... it is what has impact on food chain as well, isn’t it?’, ‘Yeah’, ‘so humans will have the most impact, the tooru will have the second and then the yernt, right?’. These
types of interactions meant that participants did not move forward until they both understood the materials. Being able to monitor their understanding and progress at their own rate may have contributed to the increase in their understanding of the concepts. This is in line with research that has revealed that monitoring and regulating activities are good indicators of learners’ cognitive engagement, which is allied with better learning and improved level of achievement and, subsequently, to higher self-efficacy (Linnenbrink & Pintrich, 2003).

Another factor examined for a possible effect on participants’ engagement during the study was their experience with playing games. It seems that the frequency of playing games on a computer or phone was not an influential factor in helping participants to engage more with technology learning resources or to gain more knowledge through technology-based resources (Kennedy-Clark, 2011). For example, the frequency of playing games for participants in G2 was the highest among all groups, according to the demographic survey (Table 3.1); however, their cognitive engagement frequency was ranked third and their performance at the end was no higher than that of other groups with little or no game playing experience. However, G1, which showed the highest frequency of cognitive engagement, had little to no game playing experience, as was also true for G4, which had the lowest frequency of cognitive engagement.

Participants’ engagement during the study might also be because of enjoying and being comfortable with the immersive and modelling environments as a learning resource. Research has demonstrated that learners who view an activity as enjoyable are more likely to engage in that activity and expend more effort (Cole, Bergin, & Whittaker, 2008). Participants’ engagement in the present study was apparent from the researcher’s observation and the frequency of the participants’ flow of engagement, coded as verbal
or non-verbal flow of engagement. A verbal flow of engagement of 10–19 instances was seen in both the immersive and modelling environments (Figure 5.25 and Figure 5.27), except G4 exhibited only two instances of verbal flow of engagement in the immersive environment and no verbal flow of engagement in the modelling environment. Based on the observations, participants in this group seemed very quiet and shy, which may have prevented them from showing cognitive engagement or making verbal comments showing their flow of engagement. The fact that non-verbal flow of engagement for this group was high may reflect a level of shyness in verbal communication. Of interest here is that despite their limited verbal communication, the performance of this group was found to be high at the end of the study. A possible explanation for this is that they were engaged in the learning process but did not show their engagement.

Learning in collaborative groups has been shown to be more powerful than working individually or competitively with one another (Osman, Duffy, Chang, & Lee, 2011). Exchange of ideas within group participants has been claimed to increase interest among participants and promote critical thinking (Gokhale, 1995). Thus, working collaboratively might be one of the factors that had a positive effect on participants’ engagement and therefore on their knowledge in this study. This is consistent with research that has shown that collaborative learning can enhance students’ engagement in teaching and learning (Law, Chung, & Leung, 2017), which is directly correlated with academic achievement (Heng, 2014; Scheidler, 2012). Participants’ collaborative engagement was found to be high in both environments for all dyads. Collaborative work was the basis of all of the work that participant undertook as they were required to work in dyads for the study. Evidence for collaborative engagement was exhibited by all groups during the study: all participants were actively involved and working together towards their goal (e.g. answering the questions and writing the final report in the guidebook). The frequency of
collaborative engagement for all groups was comparable: no differences were found between groups based on participant age, science background or frequency of playing games. This is in line with other research reporting that collaborative learning is a preferable learning arrangement for both male and female students (Uzuntiryaki, Bilgin, & Geban, 2004). Although this study showed that there were benefits of a collaborative design it could not conclude that collaborative engagement was an effective factor in enhancing participants’ understanding, as this was not a focus of the study. However, based on the literature, collaborative engagement is likely to be among the factors that enhanced the participants’ learning and understanding (Thompson & Reimann, 2007).

This study applied a 5Es inquiry model in the design of the learning resources and activities. Hence, an inquiry approach may also be among the features that assisted participants’ engagement and understanding of ecology concepts. Inquiry-based learning has been identified in research as a common strategy that advances learner engagement (Taylor & Parsons, 2011). The immersive and modelling experiences offered a space for inquiry-based learning. The inquiry-based immersive tasks directed participants to explore the environment, make observations on animal populations, talk with people and scientists, collect data and generate hypotheses to address an ecological problem. Modelling guidebook tasks then guided the participants to test these hypotheses.

The immersive and modelling environments had a positive effect on participants’ knowledge mainly by supporting their cognitive engagement and collaboration, and providing an enjoyable and comfortable learning environment. One of the positive effects of using technology in education is the amplified intensity of student engagement; technology may be among the solutions required to increase the number of engaged students their knowledge (Wardlow, 2016). It is widely recognised that engagement is
key to the learning process: it is crucial to have learners engaged in the learning process for learning to occur (Prensky, 2001).

6.5 Summary

In summary, the findings suggest that the combination of an immersive and a modelling environment presented the participants with an engaging learning experience. The study supports the effectiveness of such intervention and suggests that the immersive and modelling environments Omosa and Omosa NetLogo, along with the constructivist approaches and activities applied in this study, facilitated and provided appropriate knowledge and confidence-building opportunities for the participants. The findings also have a range of implications that can be integrated into primary preservice teacher education programs to improve their confidence in teaching, pedagogical strategies and scientific CK.
CHAPTER 7: CONCLUSIONS AND IMPLICATIONS

7.1 Conclusions of the Study

This study was underpinned by research that demonstrated that the lack of quality science education in primary schools is an area of growing concern both in Australia and internationally (Aubusson et al., 2015; Avery & Meyer, 2012; Fitzgerald & Smith, 2016; Woolcott & Whannell, 2017). Research has shown that primary teachers often have a poor background in science and may feel particularly under-prepared to teach science effectively (Appleton, 2002, 2003; Bayer Corporation, 2004; Bleicher, 2007, 2009; Harlen, 1997; Harlen & Holroyd, 1997; Howitt, 2007; Palmer et al., 2015). This study aimed to develop a focused intervention to build preservice primary teachers’ confidence in teaching science, understanding of scientific pedagogical approaches and scientific CK in the area of ecology.

As researchers examine the ways and means of improving the quality of primary teachers, they need to consider new teaching and learning tools to be utilised in teacher education programs to improve preservice primary teachers’ science CK and confidence in their ability in science teaching. These approaches may address the deficiencies in the teaching of science in primary schools. This study examined a combination of immersive and modelling environments as teaching tools. The research was concerned with determining whether a combination of an immersive environment and a modelling environment along with 5Es inquiry activities resulted in improved preservice teachers’ knowledge and confidence. The outcomes considered were:

- knowledge and understanding of ecology concepts
- confidence in ability to learn and teach ecology
- perceptions about learning in immersive and modelling environments
The study found an overall improvement in participants’ science CK and an increase of confidence in their ability in science learning and teaching from the pre-test to the post-test period. The study revealed that teaching science concepts to first year preservice primary teachers through immersive and modelling environments enhanced their understanding of ecosystems. This was shown through higher levels of engagement and improved learning outcomes at the conclusion of the study.

The findings of the study support the effectiveness of the intervention and suggest that these immersive and modelling environments, along with inquiry activities, provided appropriate knowledge and confidence-building opportunities for the participants. The quantitative gains in both their understanding and confidence; their comments relating to their perceptions of the learning experience in this study; and the indications of their engagement as revealed in this study are all evidence for a positive effect of the intervention.

Technology-based resources are abundant and utilising these resources in instruction during teacher education programs is appropriate—particularly for teaching science—on the basis of a number of studies that have investigated preservice teachers’ TPACK. It was demonstrated that drawing on the combined affordances of immersive and modelling environments had a positive effect on preservice teachers’ confidence and scientific CK.

7.2 Implications and Recommendations
This study contributes to the improvement of science education in teacher education programs. It also contributes to research on how to prepare preservice primary teachers
for the demands of the 21st-century classroom, and adds to the body of knowledge on the use of immersive and modelling environments in science teacher education. This is the first study, to the candidate’s knowledge, to have investigated the combination of an immersive and a modelling environment on preservice primary teachers’ understanding and confidence in science. The main findings of the study have several implications that can inform the design of preservice primary teacher education programs:

1. *Immersion and modelling environments.* The goal of this study was to determine the effectiveness of teaching a targeted group of preservice primary teachers some ecology concepts by engaging them in learning using the combination of an immersive environment and a modelling environment. These environments have been used separately in science education and found to be effective and beneficial in teaching science in school, as well as at university level. The combined use of these two environments was found in this study to enhance visualisation, increase collaboration and promote engagement. Hence, preservice teacher science courses should consider using a combination of both environments to enhance preservice teachers’ experience in using these tools in science education.

2. *Increased confidence.* One of the main findings of the study was the increased confidence of all participants, both in terms of their science CK in ecology and their ability to use both of the environments. In this respect, the intervention addresses the requirements of the new digital technologies curriculum (ACARA, 2014) that students engage with modelling and visualisation. This intervention can be considered to prepare preservice primary teachers for the requirements of the 21st-century classroom.
3. *Improved CK.* It was clear from participants’ comments that the combination of the two resources was useful in helping them understand and learn science concepts. The general consensus among participants was that the visual characteristics/representations of both technology learning resources had a positive effect on their overall learning experience and helped them understand and learn the content. By itself this offers support for the idea that both immersive and modelling environments should be utilised in teacher education programs to better prepare these future teachers for the demands of the 21st-century classroom.

4. *Addressed Science, Technology, Engineering, and Mathematics (STEM requirements).* An additional finding of this study was that it provided an opportunity for preservice teachers to develop their confidence and understanding of integrated STEM subjects in a cross-curriculum learning and teaching experience. Technology and science were integrated in this study. As a modelling experience, in the sense of modelling good practice, this intervention provided preservice teachers with an authentic experience of integrated learning.

5. *Developed TPACK.* One of the outcomes of this study was that it provided an opportunity for preservice teachers to develop their TPACK, which is necessary for effective teaching with technology. This kind of experience allows preservice teachers to expand their vision of the technologies available and the role that technology resources can play in science education, and thus incorporate these technologies into their future classrooms. According to Schwarz et al. (2007), ‘One way of addressing technology integration is by further incorporating strong examples of technology within teacher preparation programs and helping preservice teachers think about how to infuse strong examples of technology in
their own future classrooms’ (p. 243). L. Gill and Dalgarno (2017) also reported similar results from their recent longitudinal study of Australian preservice teachers and the development of their TPACK over a period of 4 years. University lecturer modelling of ICT use proved to have a positive influence on the development of preservice teachers’ TPACK and the successful uptake of ICT in the classroom. This is confirmed by the statement that ‘Providing experiences for the preservice teachers to use the technologies while student teaching and to see the technologies being modelled, continued to increase the preservice teachers’ confidence and use of the technologies’ (Pope et al., 2005, p. 574). While TPACK was not a central focus of this study, the findings are linked to the TPACK model and are worth mentioning here.

Several recommendations can be drawn from the findings and implications. Educators may consider modifications in preservice preparation programs that involve implementation of these interventions in such programs to provide a stronger basis for preparing primary teachers to teach primary school science. The study provides information that can help educators develop and scaffold learning activities to enhance preservice primary teachers’ science CK and confidence in their abilities in science during their education program, by utilising ICT resources. Positive change might occur as improvement in primary teachers’ science CK can potentially lead to improvements in students’ learning outcomes in science. The importance of these experiences in modelling 21st-century skills with preservice teachers by demonstrating teaching approaches for these future teachers that might be applicable in their classrooms in the future should also be kept in mind. As primary teachers are required to use and teach technology in their classrooms, this will encourage and support them in achieving these cross-curriculum capabilities.
Teacher education programs should make use of newly available technologies such as immersive and modelling environments to address the problem of how to better prepare primary teachers to teach science effectively. Incorporating learning experiences that utilise these technologies in primary teachers’ education programs seems to make a difference in helping preservice teachers understand science concepts and, as a consequence, improve their confidence in teaching science, even in a relatively short time. The study revealed that a short intervention, which consisted of two 90-minute sessions, can offer the opportunity for preservice teachers to develop their science knowledge and confidence. Therefore, these experiences should be part of quality primary teacher education programs. It is hoped that these findings will encourage teacher educators to adopt new approaches for teaching using technology as an effective teaching strategy that will benefit their students.

7.3 Limitations of the Study and Areas for Future Research

This research has limitations. The target population consisted of a small number of first year preservice teachers enrolled in the bachelor of education primary degree at the University of Sydney, and because of the nature of the study the number of participants was small. Statistical generalisations from a small sample are by and large not valid. However, this shortcoming was addressed by utilising different data collection methods and sources to gain a better understanding of the effect of the study intervention, thus providing a basis for theoretical generalisation. Also there were only females in the study and that is due to the fact that there are almost only females enrolled in the Bachelor of Education primary degree.
Second, the study was conducted with participants working in dyads. The confidence data were collected during the interviews (which were all audio recorded) and was also written in the guidebooks. One possible limitation might be the question asking about participants’ confidence levels at different stages during the study. Because individually self-reported responses were required from participants who were interviewed and had worked in dyads, they may have felt pressure or anxiety around providing a true estimate of their confidence level. However, it did not seem that the participants in this study experienced peer pressure in reporting their confidence, as they initially participated in the study because they had low confidence in their ability in science and wanted to participate in the learning experience to help them enhance their confidence.

Finally, deeper misconceptions and fundamental epistemic beliefs as well as motivational dispositions are difficult to change with a short intervention. It would be worth conducting a longitudinal study to gain an understanding of knowledge retention. Replication of this study on a more diverse sample of students over a longer period might allow for more comprehensive results.

Future potential research areas include a longer study that follows preservice primary teachers from their first year through to the final year of their degree. It would also be useful to gain an understanding of how preservice primary teachers teach science when they are on professional experience. Another area of research would be to investigate the development of preservice teachers’ TPACK as this would demonstrate their understanding of how to use technology to support their learning and teaching decisions.
7.4 Final Words

At the start of this study, I had no expectations of what I would uncover during the intervention. I was not expecting such positive results. One of the main benefits of the study was seeing all of the preservice primary teachers that participated in the study report that the experience was positive and that their knowledge and confidence had increased. While there was only a small number of participants in the study, this small positive step forward may result in their increased confidence when they make their way into the classroom as teachers in future years.
REFERENCES


Proceedings of the Symposium on Theory of Modeling & Simulation-DEVSI Integrative M&S Symposium, San Diego, California


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Nussli, N., Oh, K., & McCandless, K. (2014). Collaborative Science Learning in Three-Dimensional Immersive Virtual Worlds: Pre-Service Teachers' Experiences in


Scheidler, M. J. (2012). The Relationship Between Student Engagement and Standardized Test Scores of Middle School Students: Does Student Engagement Increase Academic Achievement? (Doctoral Dissertation), University of Minnesota.


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APPENDICES

Appendix A: Study Documents

Ethics Approval letter

Research Integrity
Human Research Ethics Committee

Friday, 17 May 2013

Dr Louise Sutherland
School Development & Learning, Faculty of Education & Social Work
Email: louise.sutherland@sydney.edu.au

Dear Louise

I am pleased to inform you that the Humanities Low Risk Subcommittee has approved your project entitled “Using technology to support students engagement in science.”

Details of the approval are as follows:

Project No.: 2013/285
Approval Date: 17 May 2013
First Annual Report Due: 17 May 2017

Authorised Personnel: Sutherland Louise; Mohammed Reem Turki Abdallah; Schwendimann Beat; Walker Richard;

Documents Approved:

<table>
<thead>
<tr>
<th>Date Uploaded</th>
<th>Type</th>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/03/2013</td>
<td>Interview Questions</td>
<td>Interviews Questions</td>
</tr>
<tr>
<td>11/03/2013</td>
<td>Participant Consent Form</td>
<td>Participant Consent Form</td>
</tr>
<tr>
<td>19/04/2013</td>
<td>Recruitment Letter/Email</td>
<td>Email Modification</td>
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<tr>
<td>19/04/2013</td>
<td>Questionnaires/Surveys</td>
<td>Demographic Survey Modified</td>
</tr>
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</table>

HREC approval is valid for four (4) years from the approval date stated in this letter and is granted pending the following conditions being met:

**Special Condition(s) of Approval**

Participant Information Statement:
- Please change to the same font size for consistency and readability
- Please provide the updated version number and date in the footnote on the amended document

**Condition(s) of Approval**

- Continuing compliance with the National Statement on Ethical Conduct in Research Involving Humans.
- Provision of an annual report on this research to the Human Research Ethics Committee from the approval date and at the completion of the study. Failure to submit reports will result in withdrawal of ethics approval for the project.
- All serious and unexpected adverse events should be reported to the HREC within 72 hours.

Research Integrity
Level 2, Margaret Tetter
The University of Sydney
NSW 2006 Australia

T +61 2 9351 8111
F +61 2 9351 8177
E humanethics@sydney.edu.au
Sydney, 2006 Australia
• All unforeseen events that might affect continued ethical acceptability of the project should be reported to the HREC as soon as possible.

• Any changes to the project including changes to research personnel must be approved by the HREC before the research project can proceed.

**Chief Investigator / Supervisor’s responsibilities:**

1. You must retain copies of all signed Consent Forms (if applicable) and provide these to the HREC on request.

2. It is your responsibility to provide a copy of this letter to any internal/external granting agencies if requested.

Please do not hesitate to contact Research Integrity (Human Ethics) should you require further information or clarification.

Yours sincerely

[Signature]

Dr Fiona Gill  
Chair  
Humanities Low Risk Subcommittee

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This HREC is constituted and operates in accordance with the National Health and Medical Research Council’s (NHMRC) National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007) and the CPMP/ICH Note for Guidance on Good Clinical Practice.
Participant Consent Form

Dr. Louise Sutherland
Senior Lecturer in Science Education
Master of Teaching coordinator
louise.sutherland@sydney.edu.au

Reem Mohammed
PhD Student
rmoh5350@uni.sydney.edu.au

PARTICIPANT CONSENT FORM

I,................................................................. [PRINT NAME], give consent to my participation in the research project

TITLE: Using technology to support students’ engagement in science

In giving my consent I acknowledge that:

1. The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Statement and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

3. I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher(s) or the University of Sydney or the NSW Department of education and Training now or in the future.

4. I understand that my involvement is strictly confidential and no information about me will be used in any way that reveals my identity.
5. I understand that being in this study is completely voluntary – I am not under any obligation to consent.

6. I understand that I can stop my participation in the project at any time if I do not wish to continue, the audio and video recording will be erased and the information provided will not be included in the study.

7. I consent to:

   - Audio-recording      YES ☐  NO ☐

   - Video-recording      YES ☐  NO ☐

   - Receiving Feedback   YES ☐  NO ☐

If you answered YES to the “Receiving Feedback” question, please provide your details i.e. mailing address, email address.

**Feedback Option**

**Address:** ________________________________

______________________________

**Email:** ________________________________

........................................................................................................

Signature

........................................................................................................

Please PRINT name

........................................................................................................

Date
Recruitment Email

Dear [Name],

Thank you for agreeing to participate in my research which aims to examine the impact of using technology and a set of interventions on preservice teachers' perceptions of their ability to learn and understand biology concepts. I would like to thank you for your valuable support with this study and I hope you will enjoy the experience.

As you are aware, the study is planned to run over two sessions; I would very much like to arrange for the first session, and this would take place in the University of Sydney at a time and place convenient to you. Each session would last about 60-90 minutes and would involve working in a computer environment and interviews about your study background and your perception towards science.

Before that I would like to confirm that:

- With your permission the interviews will be recorded.
- Your anonymity will be maintained and no comments will be ascribed to you by name in any written document or verbal presentation nor will any data be used from the interview that might identify you to a third party.
- You are free to withdraw from the research at any time and/or request that your transcript not be used.
- I will write to you on completion of the research and a copy of my final research report will be made available to you upon request.

You will be working in pairs so please let me know if you prefer to work with certain partner and the best time for you.

Finally, can I thank you for taking the time to help me with my research. It really is much appreciated. If you have any queries concerning the nature of the research please contact me.

Thank you for considering this project. I look forward to talking with you.

Yours sincerely,
Reem
Using technology to support students’ engagement in science

PARTICIPANT INFORMATION STATEMENT

(1) What is the study about?

This research aims to examine the impact of a set of interventions on primary preservice teachers’ perceptions of their ability to learn and understand biology concepts. We are interested in recruiting participants who have not studied science for the HSC (or equivalent). The interventions will be the use of two different modes of computer-supported learning (ICT), a virtual world (VLE), computer modelling (NetLogo) and two different strategies to improve students’ self-efficacy. The research will examine the interaction between these strategies and the modes of computer supported learning to identify how to enhance students understanding of science concepts. The results from this project will provide information about how to design and scaffold learning activities to enhance preservice teachers’ confidence in their abilities in science through using ICT. On the basis of the result of the study, a set of strategies will be developed that may help educators to develop materials and approaches to teaching science using ICT.

(2) Who is carrying out the study?

The study is being conducted by Reem Mohammed as a basis for the degree of PhD at The University of Sydney under the supervision of Dr. Louise Sutherland.

(3) What does the study involve?

The study is in two parts. First is a short survey to find out the background details of all the students studying Science Concepts. This survey should take approximately 10 minutes.
In the second part we are hoping to recruit students who have not studied science for the HSC. In part of the study you will be using two different modes of technology (ICT) to learn more about ecosystems and ecology.

This part of the study consists of three different activities. Longer interviews at the beginning and end of the study, short interviews at the end of your work in the different modes of technology and a record of your actions and reactions as you use technology and the guidebook to examine the factors contributing to the death of animals in a virtual world. You will be asked to think aloud about your thoughts and feelings as you navigate the two different ICT modes (VLE and NetLogo). A video camera will capture your statements as well as your reactions.

(4) How much time will the study take?
Implementing the study requires two sessions on at least two different days, with maximum 90 minutes for each session. The sessions will be scheduled at your convenience, however, times for the interview will depend on the amount of information you wish to provide.

(5) Can I withdraw from the study?
The study is voluntary, so you are not under any obligation to participate. You may withdraw your participation, video recordings, or audio recordings from the study at any time. You may stop the interview at any time if you do not wish to continue, the audio and video recordings will be erased and the information provided will not be included in the study.

(6) Will anyone else know the results?
All individually identifiable information obtained in the study will be kept strictly confidential. Only the researchers involved with the project will have access to specific information about participants. Reports about the study may be presented at meetings and conferences and in publications, but only aggregate information will be provided and individual participants will not be identifiable in such reports.

(7) Will the study benefit me?
The project will be a valuable professional learning opportunity for you as a future teacher. It will provide you with opportunities to increase your understanding of ecology and ecological principles. You will be introduced to new and innovative ways, which you might use in the future to enhance your students’ learning.

(8) Can I tell other people about the study?

Yes

(9) What if I require further information about the study or my involvement in it?

If you would like to know more at any stage, please feel free to contact Reem Mohammed (Mobile: + 61415264049, Email: rmoh5350@uni.sydney.edu.au) or Dr Louise Sutherland (Office: + 61 2 9351 6258, Email: louise.sutherland@sydney.edu.au).

(10) What if I have a complaint or any concerns?

Any person with concerns or complaints about the conduct of a research study can contact The Deputy Manager, Human Ethics Administration, University of Sydney on +61 2 8627 8176 (Telephone); +61 2 8627 8177 (Facsimile) or ro.humanethics@sydney.edu.au (Email).

This information sheet is for you to keep
Appendix B: Guidebooks

Omosa Guidebook

Phase one guidebook to accompany the VLE “Omosa”

Student name: ____________________________________________
Dear Scientist,

Welcome to planet Omosa. My name is Dr. Sarah Newton and I am the Chief Scientist at the IEIA (Interplanetary Environmental Investigation Agency) in charge of environmental affairs affecting terrestrial type worlds. Recently, planet Omosa has been showing signs of ecosystem change. The indigenous people who live there have reported that the populations of certain species of animals, including those that are an important food source in their society, are declining.

The Omosans have agreed to allow scientists to come and study the situation. We think you can help our investigators and the people of Omosa in understanding their ecological crisis. During your trip, you will learn a lot about planet Omosa. The inhabitants know that you are coming and they are looking forward to talking with you.

The IEIA team and I are excited to be working with you in trying to solve these problems. Your main job is to conduct investigations into possible reasons for the animal population decline using your scientific knowledge and inquiry skills. I know you will do your very best job in helping to solve the mysteries of Omosa.

Sincerely,

Sarah Newton

Chief Scientist, Interplanetary Environmental Investigation Agency
Orientation
At the beginning you need to learn the basic skills of moving around Omosa. Here are the main areas and icons of the Omosa VW.

Navigation
You may navigate through Omosa using these keys:
- Arrow keys: use the arrow keys to move forward, backward, left, and right.
- Q key: use Q key to pan 360 degrees. Top view (bird eye view) ????
- Shift key + arrow keys: hold down shift plus arrow key to increase the speed
- Click the on screen map in the top left-hand corner of the Omosa screen to quickly travel around the island, such as the weather station, the research station, the hunting grounds, and the village.

When you click on the map, you will see an image like the one below.

- Click on the backpack icon and see what, if any, objects you have collected.
- Try moving around Omosa.
  ➢ Can you talk to a character? How do you know if they can talk to you?
You will use observations to investigate Omosa ecosystem and investigate the relationships between the ecosystem components to answer the questions.

1. Do an initial exploration on planet Omosa. Make some brief notes below about things you observe as you explore.

2. Can you think of the predator-prey based on your observation? Draw a food chain, which includes this predator-prey relationship. Identify the predator and the prey and what the arrows mean?

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology? Why?
3. In certain areas on Omosa, there are patches of burnt out areas of bush alternating with clumps of dry grass (see images below). Think about:

a. Why this pattern is occurring?

b. What it might mean for the survival of the animals.

4. What do you think are three factors, which might be causing the decline of the animals on Omosa?

1.

2.

3.
5. As you know, the Chief Scientist would like to get information about what is impacting the predator-prey ecosystem on Omosa. Use the table below to summarise and organise your findings.

<p>| | |</p>
<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a.</strong> The hunter Lyina. She’s usually in the village unless she is off on a hunting expedition. What does she say about the population of the animal?</td>
<td></td>
</tr>
<tr>
<td><strong>b.</strong> The wise old village man Omeweye. He’s usually in the village at a table holding consultations with villagers to resolve disputes. What does Omeweye say about Omosan hunting practices?</td>
<td></td>
</tr>
<tr>
<td><strong>c.</strong> The climate scientist Zafirah. She is located in the weather station (click on the weather station in the map). What do you learn from her about the weather patterns on Omosa?</td>
<td></td>
</tr>
<tr>
<td><strong>d.</strong> The ecologist Charlie. He is located in the IEIA Research Lab (see the map for help). What does Charlie think about the declining animal populations?</td>
<td></td>
</tr>
<tr>
<td><strong>e.</strong> Research Lab data book.</td>
<td></td>
</tr>
<tr>
<td><strong>f.</strong> Weather Station data book.</td>
<td></td>
</tr>
</tbody>
</table>

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology?
6. Based on your exploration of Omosa and the data you have collected what would you put into the report to the chief scientist about what has caused the decline in the population of animals on Omosa?

Outline the points you would include in the space below. Provide any evidence you have to support each of your points.
Omosa NetLogo Guidebook

Phase two guidebook to accompany the Omosa NetLogo model

Student name: ________________________________
Introducing computational experiments using NetLogo

Many areas of modern science use computer models to run experiments—sometimes called computational experiments or simulations. These computer experiments are usually based on data scientists have collected from observations. Scientists can use such a model to carry out virtual experiments by changing an independent variable and taking measurements of the dependent variable in the computational experiment. Each time the scientist run a virtual experiment, the mathematic model in the computer program can calculate changes in the relative numbers of animals and plants. This means that scientists can use a mathematic model to test their ideas about the factors impacting an ecosystem.

You will use a powerful computer modelling program called NetLogo to run computational experiments about Omosa. Below you will find a screenshot of the NetLogo model for Omosa world.

To run a simulation, you go through the following procedure:
1. Press the SETUP button.
2. Press the GO button to begin the simulation.
3. Look at the monitors to see the current population sizes
4. Look at the POPULATIONS plot to watch the populations fluctuate over time

To stop and start the simulation click the GO button
1. Run the simulation twice (1. The pilot simulation and 2. The experimental simulation) with the default settings listed in the previous steps. Stop the run in different stages (by clicking the GO button):

a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The pilot simulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. The experimental</td>
<td></td>
<td></td>
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</tbody>
</table>

b. Describe the most common pattern for the various populations you have observed

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b. Explain why this pattern is occurring.

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On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology?
In the model, there are sliders to set and adjust (see picture below) the three initial population parameters of interest:

- Initial number of Yernts
- Initial numbers of Toorus
- Initial numbers of Omosan people

There are also on-off switches (see picture below) that allow you to manipulate the independent variables:

- Drought
- Fire-stick farming
- Hunting

In the next phase you will have an opportunity to test two of these independent variables.

2. After reviewing reports from research teams on Omosa, the Chief Scientist has decided that there are several experiments that could be done in order to find out more about the possible causes of the decline of the population of animals. One possibility is that the decline in the population has a natural cause – the ongoing drought. Another possibility is that one of the Omosans’ practices such as fire stick farming or the over hunting are causing the decline in the population of animals.

In the next stage in this study you will test some of these possibilities using the NetLogo model.
Study 1: Testing how drought impacts on the population of animals.

In this study you will examine how a long period of drought might impact on the population of animals.

Before running the experiment think about why the drought might cause a decrease in the population of animals.

Scientists test their ideas by writing testable questions. Please specify the design for your experiment by filling in the table below. Some parts have already been completed for you.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research question.</td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td>Does the level of drought impact the population of the animals?</td>
<td></td>
</tr>
<tr>
<td>2. Your hypothesis.</td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
</tbody>
</table>
| if there is an increase in the level of drought, then__________________________ | if there is__________________________ ,
| __________________________________ | then__________________________,
| because__________________________ | because ____________________________ . |
| 3. Independent variable.        | The independent variable is an “if”—it is what may cause the change. |
| drought severity level           | |
| 4. Dependent variable.           | The dependent variable is the “then”—it is the thing that you measure. |
| ________________________________ | |
• Turn the **drought** switch “On”, set the **drought severity level** to 20 or 30 and run the model two times

• Conduct two runs using the same settings
  
  a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
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<tbody>
<tr>
<td>Run 1</td>
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<td></td>
</tr>
<tr>
<td>Run 2</td>
<td></td>
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</tbody>
</table>

b. What do you notice about the pattern of on the graph and the relative numbers of Yernt, Toorus, and the amount of grass for each of these runs of the model?
c. Is this what you expected? Why or why not?

Now increase the severity of the drought to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

b. Draw the graph for three different stages in each run

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<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
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<tbody>
<tr>
<td>Run 1</td>
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<tr>
<td>Run 2</td>
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</tbody>
</table>

c. What has changed in the pattern and why might this occur?
What would you report to the chief scientist? Is the drought contributing to the decline in the population of the animals? What evidence do you have to support your answer?

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding the factors impacting the population of animal in an ecosystem?

You can now examine the impact the Omosans might be having on the size of the animal populations. You need to choose one of the following possibilities:

**Study 2**: Is it likely to be the **fire-stick farming** that is causing the decline in the population of the animals?

**Study 3**: Is it likely to be the **hunting** practices of the Omosans that are causing the decline in the animal population?

You can use the work you did for **Study 1** as a guide to assist you answer the questions.

- Go to the next page if you decide to do **Study 2 (fire-stick farming)**
- Go to page 12 if you decide to do **Study 3 (hunting practices)**

**Study 2**: In this study you will examine the impact of **fire stick farming** on the population of the animals.
Remember to turn the drought off and turn on the fire stick farming.

Please specify the design for your experiment by filling in the table below.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research question.</td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td>Does the <strong>fire stick farming</strong> impact the population of the animals?</td>
<td></td>
</tr>
<tr>
<td>2. Your hypothesis.</td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
<tr>
<td>if there is an increase in the percent-burned-grass then</td>
<td>if there is _______________.</td>
</tr>
<tr>
<td>__________________________________</td>
<td>then _______________.</td>
</tr>
<tr>
<td>because_________________________</td>
<td>because _______________.</td>
</tr>
<tr>
<td>3. Independent variable.</td>
<td>The independent variable is an “if”—it is what causes the change.</td>
</tr>
<tr>
<td>________________</td>
<td></td>
</tr>
<tr>
<td>4. Dependent variable.</td>
<td>The dependent variable is the “then”—it is the thing that you measure.</td>
</tr>
<tr>
<td>________________</td>
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</tr>
</tbody>
</table>
- Turn the **fire stick farming** switch “On”, set the **percent-burned-grass** to 30 and run the model
- Conduct two runs using the same settings
  - a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
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<tbody>
<tr>
<td>Run 1</td>
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<tr>
<td>Run 2</td>
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</table>

b. What do you notice about the pattern of the graph and the relative numbers of Yernt, Toorus, and the amount of grass for each of these runs of the model?

c. Is this what you expected? Why or why not?
Now change the level of **percent-burned-grass** to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

b. Draw the graph for three different stages in each run

<table>
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<tr>
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<tr>
<td>Run 2</td>
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</tr>
</tbody>
</table>

c. What has changed in the pattern and why might this occur?

What would you report to the chief scientist? Is the **fire stick farming** contributing to the decline in the population of the animals? What evidence do you have to support your answer?

**Go to page 15**
**Study 3:** In this study you will examine the impact of the **Omosans’ hunting** practices on the population of animals. The Omosans don’t change their hunting practices but the size of the Omosan population determines how many animals are killed in each hunt.

Remember to turn the drought and the fire stick farming switches to off.

Please specify the design for your experiment by filling in the table below.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research question.</td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td>Do the hunting practices impact the population of the animals?</td>
<td></td>
</tr>
<tr>
<td>2. Your hypothesis.</td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
<tr>
<td>if there is an increase in the Omosans</td>
<td>if there is________________________.</td>
</tr>
<tr>
<td>then_____________________________</td>
<td>then ______________________________.</td>
</tr>
<tr>
<td>_________________________________</td>
<td>because ____________________________</td>
</tr>
<tr>
<td>3. Independent variable.</td>
<td>The independent variable is an “if”—it is what causes the change.</td>
</tr>
<tr>
<td>_________________________________</td>
<td></td>
</tr>
<tr>
<td>4. Dependent variable.</td>
<td>The dependent variable is the “then”—it is the thing that you measure.</td>
</tr>
<tr>
<td>_________________________________</td>
<td></td>
</tr>
</tbody>
</table>
- Turn the *omosan* switch “On”, set the *initial-number-OMOSANS* to 20 or 30 and run the model

- Conduct two runs using the same settings
  a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. What do you notice about the pattern on the graph and the relative numbers of Yernt, Toorus, and the amount of grass for each of these runs of the model?

------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------

c. Is this what you expected? Why or why not?

------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------
Now change the level of initial-number-Omosans to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

b. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 2</td>
<td></td>
<td></td>
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</tbody>
</table>

c. What has changed in the pattern and why might this occur?

What would you report to the chief scientist? Are the Omosan hunting activities contributing to the decline in the population of the animals? What evidence do you have to support your answer?
Are there any other tests you would like to make before you create your report for the Chief Scientist? Why?

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding the factors impacting the population of animal in an ecosystem?

What would put into the report to the chief scientist about what has caused the decline in the population of animals on Omosa?
Appendix C: Demographic Survey

Demographic Survey
Completing this survey is voluntary

Gender:
☐ Male ☐ Female

Age:
☐ 17 – 19 ☐ 20 – 22 ☐ 23 – 25 ☐ 26+

Highest level of education:
☐ High School
☐ TAFE
☐ Tertiary
☐ Other (Please specify) ________________

Please indicate what science courses you have taken in year 11 and year 12 by ticking the appropriate subject/year.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Year 11</th>
<th>Year 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemistry</td>
<td></td>
<td></td>
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<tr>
<td>Physics</td>
<td></td>
<td></td>
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<tr>
<td>Earth and Environmental Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senior Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Have you taken university-level science subjects aside from the compulsory introductory science course in the primary education program?
☐ Yes (please specify) ____________________________
☐ No

If you were asked to rate your ability in biology on a scale of 1 to 10, where would you be?
(Please circle)
1 2 3 4 5 6 7 8 9 10

How often do you play video/computer games each week?
☐ Less than 1 hour
☐ 1 hour- 3 hours
☐ More than 3 hours
☐ Never

Are you interested in becoming involved in a research project using technology to support students learning in science?
☐ Yes
☐ No

If yes, please write your name ____________________________________________

Your email address _______________________________________________________

Your mobile phone number ________________________________________________

Thank you
Appendix D: Interviews

Pre-Interview

1. Background information
   a. Why did you agree to participate in this study?
   b. Why did you choose primary teaching as a career?
   c. Why did you choose not to study a science subject in Years 11 & 12?

2. Confidence in science: self-assessment of abilities in learning and understanding science
   a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?
   b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?
   c. Do you think you will be more or less successful than other students in your study of the Science Concepts unit? Why?

   If they don’t think they will be successful:
   • What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

3. Can you define extinction and give an example of something which has become extinct?

4. Why do you think the organism you described became extinct?

5. List all impacts which negatively impact a particular ecosystem?
6. **Using as many of the terms as you can, construct a concept map about the adverse impact on animals in an area:** Terms: ecosystem, predator, prey, herbivore, carnivore, plants, hunting, weather, drought, fire, birth rate, death rate, human impact, natural causes, habitat destruction, energy, introduced species.

- Blank cards are provided if you want to use them to add any other terms that you feel can make sense. You don’t have to use all of the terms or all or any of the blank cards
- Please label the connections
- Two direction arrows can be used

7. **Perceptions about ICT modes of presentation of information**

   a. Did your teachers use computer games to support students’ learning?

      How?

   b. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate you perceptions of how easy it would be for you to learn science if the information was presented as:

      i. Text

      ii. Pictures with title only

      iii. Graphs showing relationships between two factors

      iv. Virtual world simulations that you could explore (game-like environment)

      v. A graphical model in which you can make changes and monitor the impact of changes on other factors. (interactive environment)
c. Do you think that you will learn more about ecology, using virtual world simulations (game-like environments) and graphical representation?

Why or why not?

8. If someone asked you “What do scientists do?” what would you tell them?

9. How do scientists go about understanding what causes animals to become extinct?
Omosa Short-Interview

1. What do you remember about the virtual world “Omosa”?

2. The challenge you were set was to identify the possible factors which might cause the animal population on Omosa to decline. How confident are you that you identified all the factors?

3. Which, if any factor, is the most important in causing the decrease in the animal population in Omosa? Why?

4. What did it feel like to use this approach as a method to assist you to understand ecology?
   a. Tell me about some positive aspects of the VLE “Omosa” in supporting your learning.
   b. Tell me about some negative aspects of the VLE “Omosa” or about things that could have been improved or changed to support your learning.
Omosa NetLogo Short-Interview

1. The challenge you were set was to identify the possible factors, which might cause the animal population on Omosa to decline. You decided that YYY was important.

   a. What did you do using NetLogo to test this relationship? Why did you do this?

   b. What did you find when you tested this factor using the NetLogo model? Does YYY have an impact on the number of animals? How do you know?

2. What did it feel like to use this approach as a method to assist you to understand ecology?

   a. Tell me about some positive aspects of the NetLogo model to support your learning.

   b. Tell me about some negative aspects of the NetLogo model to support your learning.
Post-Interview

1. List all impacts which negatively impact a particular ecosystem?

2. Using as many of the terms as you can, construct a concept map about the adverse impact on animals in an area: Terms: ecosystem, predator, prey, herbivore, carnivore, plants, hunting, weather, drought, fire, birth rate, death rate, human impact, natural causes, habitat destruction, energy, introduced species.
   - Blank cards are provided if you want to use them to add any other terms that you feel can make sense. You don’t have to use all of the terms or all or any of the blank cards
   - Please label the connections
   - Two direction arrows can be used

3. Confidence in science: self-assessment of abilities in learning and understanding science
   a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?
   b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?
   c. Do you think you will be more or less successful than other students in your study of the Science Concepts unit? Why?

If they don’t think they will be successful:
   - What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?
4. Perceptions about ICT modes of presentation of information

a. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate your perceptions of how easy it would be for you to learn science if the information was presented as:

i. Text

ii. Pictures with title only

iii. Graphs showing relationships between two factors

iv. Virtual Learning Environment (VLE) like Omosa

v. A graphical model which you can change and monitor the impact of changes on other factors like (NetLogo).

b. Do you think that you will learn more about ecology, using “Omosa” VLE and NetLogo model?? Why or why not?

5. If someone asked you “What do scientists do?” what would you tell them?

6. How do scientists go about understanding what causes animals to become extinct?

7. Which environment do you feel you learnt more about ecology and the factors that affect animal population; Omosa VE or the NetLogo model? Why?
Appendix E: Interviews Transcripts

First Group (G1) Pre-Test Interview

1. Background information

a. Why did you agree to participate in this study?

Aimee: I don’t want to fail in science, and this is might help.

Tina: I just wanted to help because I heard that people just looking for people to survey and I just want to help and I did hear that it will help you in science so it did push me forward.

b. Why did you choose primary teaching as a career?

Tina: We, I guess our experience in school was enjoyable so we want to just keep going follow our teachers.

Aimee: I like working with little kids better than older kids. I spent four years in a class with all teenagers as the only girl in an all teenage boys classroom I don’t think I can handle this as teacher.

c. Why did you choose not to study a science subject in Years 11 & 12?

Tina: I did chose it, I chose biology in year 11 but I end up dropping it because it wasn’t interesting to me anymore, but I decided to choose senior science in year 12 and I really enjoyed that because it can make sure of everything and I had supportive teacher so it was a lot better.

Aimee: I like science, it is interesting but I felt dumb so I didn’t, everybody else seems to know more than I did.

2. Confidence in science: self-assessment of abilities in learning and understanding science
a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?

_Tina_: probably a 7 because I do have a good understanding, but there is something that I still don’t understand so I don’t know everything in science, I probably know like the basics and I understand the theory of it but not the stuff behind it.

_Aimee_: like a 3, I don’t know it makes sense to an extent and it is fine when I am having, where I have someone there to explain it to me but if I am just looking at the textbook or whatever at home it is just doesn’t make any sense when I am just looking at it.

b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?

_Tina_: Probably 5, because I don’t know everything to science so if a student asked me like why is the sun yellow I would not know how to answer that because I wouldn’t know how to, and you know how children ask any things so I wouldn’t know how to answer it.

_Aimee_: less than a 3 because I was a lot more confident before I started the course and realised that it is a lot more science than I thought was. I don’t remember much of science from primary school I didn’t think that there was that much science in it.

c. Do you think you will be more or less successful than other students in your study of the Science Concepts unit? Why?

If they don’t think they will be successful:
• What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

   Tina: Probably average because I only did one science in year 12 compared to other people they did possibly 3 sciences so they have a great advantage so sometimes when I mean the class that we took about factors I did learn that and I already have an understating of it but most of the stuff like %90 of the stuff is all new to me.
   Probably looking back at the notes and looking to a text book to see to support it, because text books they are theory based and they focus a lot into it. Whereas in the lectures they telling you stuff but they do not really going into depth about it.
   Aimee: probably below average I would say because I am extremely, you know, a perfectionists, I study heaps and I do all the work and all of that but I am not sure how I am actually going to go with it.

3. Can you define extinction and give an example of something which has become extinct?

   [Image: When a whole species dies out. (e.g. dinosaurs, mammoths, sabre tooth tigers)]

4. Why do you think the organism you described became extinct?

   Meteorite

5. List all impacts which negatively impact a particular ecosystem?
6. Using as many of the terms as you can, construct a concept map about the adverse impact on animals in an area: Terms: ecosystem, predator, prey, herbivore, carnivore, plants, hunting, weather, drought, fire, birth rate, death rate, human impact, natural causes, habitat destruction, energy, introduced species.

- Blank cards are provided if you want to use them to add any other terms that you feel can make sense. You don’t have to use all of the terms or all or any of the blank cards
- Please label the connections
- Two direction arrows can be used

7. Perceptions about ICT modes of presentation of information

a. Did your teachers use computer games to support students’ learning?

How?

* Tina: My teacher did it was like an online quiz thing with the smart board, we had the majority of it of multiple choice and then we work on that and whatever we got wrong she will explain why we were wrong  that is the only computer thing we did in science.

* Aimee: The only computer thing we did computer gamy thing we did to help any of my subject was Mathletics. I don’t think I did anything else.

b. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate you
perceptions of how easy it would be for you to learn science if the information was presented as:

i. Text

*Tina: Text only no pictures? Probably 7 if it is lengthy because too much information at once is hard to understand without the aid of pictures.*

*Aimee: if it is text on a computer screen probably like 1, I don’t learn a lot from like just text on computer screens I have to have it printed off and draw all over it or something, I can’t deal with just having straight text on a screen where I can’t I mean if I could sit there and you know draw what I am doing then I would be able to do it probably a bit better maybe like a 3 but if I am just sitting there staring at the computer screen with just text I can’t learn that way, I don’t.*

ii. Pictures with title only

*Tina: I think it is really depends on like what subject like what kind of thing you are focusing on. So if it was like a picture of meteorite hitting earth and killing off the things I guess I would understand it but I do need background knowledge about the certain things. I think probably 6, still depends on what it was, so if it was a picture about how rain drops form or why is it only one drop when it drips I will not understand that because all just be drips there is no text to support it.*
Aimee: If it is just picture it probably still pretty low then yah, I don’t know my brain works weirdly. Some people probably do it. 1 or 2. I probably.

iii. Graphs showing relationships between two factors

Aimee: probably 4 maybe just because it is easier for me to do it visually, I mean pictures are great but if they don’t... one single picture doesn’t really show much if I got a graph at least I can compare it and start to get my head around how it looks in comparison to each other because, I don’t know. It is probably it would be easier if I had information along with it but if I could just see the graph at least my head would be able to go ok, so visually this is how this works and then it compares to this yah probably easier.

Tina: I think mine would be probably still a 6 because like if you have say you are comparing death rate between females and males or just be like you know %50 and say 60 I would not understand it because I would not know what the influences behind it, since it is just a graph so if it was a really complicated graph may be I will understand it but it will still be bit confusing because there is so much happening at once.

iv. Virtual world simulations that you could explore (game-like environment)

Tina: that is probably good probably like 8 or something because you get to see it but you are seeking the information to why
something happening so it would be better than the other stuff to learn.

Aimee: Yeah probably so much higher like 7 maybe, because .... I don’t know I think that I will learn better looking at... stop and looking at moving and all of that I can’t it is easier for me rather than staring at something so I think that if I had a game or something rather than something solid and stable I would be able to get it more, my brain would be able to make links better, I don’t know if this makes sense.

v. A graphical model in which you can make changes and monitor the impact of changes on other factors. (interactive environment)

Tina: probably could be 8.

Aimee: if it has information along with it probably 8 I would say. I don’t know, it is like I said the relationships good to see and if it got information along with it I think I could get a lot more, if I could see the changes and see what affects it and then have the information to back it up.

c. Do you think that you will learn more about ecology, using virtual world simulations (game-like environments) and graphical representation? Why or why not?

Tina: yes, because in ecosystems it is all about changes in the world and animals and it is not like animals are influenced by anything so if you are able to see in the virtual world why something is changing and how affects them it would be easier to understand.
Aimee: yeah you can see the impacts easier and you don’t have to, it makes it easy to learn as it is almost out there to learn it, you don’t have to actually go and hunt down single species and then test it over 50 thousand years to try and work out what impacts it, so it is quicker.

8. If someone asked you “What do scientists do?” what would you tell them?

Science?

Aimee: science? Laughing.

Tina: I guess I guess they do experiments to help the world ... they will find you solutions to help, as well as testing things doing different, doing, like testing different circumstances to ... you know, make the place a bit better..

9. How do scientists go about understanding what causes animals to become extinct?

Tina: I think they count how many in the world first and then they list it as in dangers if it falls below and put tags on them unless they are already extinct. I think they just follow and track what it does and check the health once in a while and see if it is depreciating and if it is they will follow, you know, what did it do compared to something else that has health that still high. Aimee: and compare to the subject and examine the environment and these stuff and then stuff that is happen around it not just the animal itself because like if you know if it is like keeps going about its daily life and keeps eating this food and drinking this water but it might but it might be the water from the stream from some town down the road who is putting chemicals in it or whatever and it is killing off the animal so you need to look more than just the single species and you need to look around what is happening to other species does this make sense?.

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First Group (G1) Omosa Short-Interview

1. What do you remember about the virtual world “Omosa”?

   Aimee: they are all hunt to gather .... . They had the weird cheetah things with the wolf dog face things. There was a drought going on, there was 7 to 10 year rainfall pattern things ..... There is less yernt than there should be, possibly because they are over hunting but also because the drought is impacting it and that causes there to be less nutrients in the grasses that they are eating which means there is less of them anywhere.

2. The challenge you were set was to identify the possible factors which might cause the animal population on Omosa to decline. How confident are you that you identified all the factors?

   Aimee: I am not sure we identified all of them, we identified some of them.

   Tina: There is two major ones but we didn’t know what the third one could be.

   Aimee: I think it is more than this, lots of different impacts on them, what we found is not just, I mean the major one is the drought but it is not just you know, the people over hunting, it is also the weather and the environment and the farming practices of the people which doesn’t really seems like it has anything to do with it but it clearly does , so we might have discovered some of them but we are not necessarily know all of them because you need a lot more time to work on it and stuff to be able to work out all the different factors, does this make sense?.

3. Which, if any factor, is the most important in causing the decrease in the animal population in Omosa? Why?

   Aimee and Tina: The most significant? the drought. Yeah the drought.
Aimee: the drought because it impacts all the other factors as well, I mean if there is less food to eat then there will be less for the people to eat which means they will requiring more meat which means they will over hunt but it also means that there will not be as much water which means then they will you know they will go searching for food and something like that and it will impact on the breeding cycles and the food of the yerent which means they can’t breed as much so it just kind of impacts everything.

4. What did it feel like to use this approach as a method to assist you to understand ecology?
   a. Tell me about some positive aspects of the VLE “Omosa” in supporting your learning.

   Tina: I guess you can go around and ask, you could see the environment, so you could see what the animals were doing.

   Aimee: Yeah it was good to be able to see it visually, it is kind of like room escape, did you get that feeling?.

   Tina: I never played it.

   Aimee: I used to play it when I was a kid, it was so much like that, it is scary. Yeah it was good to be able to see it and to be able to understand that different factors influence it and it is not—you are not going to necessarily get all your information from one source because you can go around, and you can find out directly from the people, you can find out from researchers in the area.

   
   b. Tell me about some negative aspects of the VLE “Omosa” or about things that could have been improved or changed to support your learning.

   Tina: I found it dull.
Aimee: I think it would take a long time, well, I mean it is very helpful having the visuals and everything but it seems like if you were studying it, as you know, as studying for an exam or something. For learning about the concepts and understanding the influences it is really good, but I think it would be a bit difficult to practice for exams or something like that just because of the time it would take, because it is so, you do need to travel, in these things you need to travel from one place to another; you need to ask a certain amount of questions and look for certain things, which is very life like and good in that sense but it could be also kind of difficult if you are trying to learn a concept quickly or get an overview of an idea.

First Group (G1) Omosa NetLogo Short-Interview

1. The challenge you were set was to identify the possible factors, which might cause the animal population on Omosa to decline. You decided to that YYY was important.

   a. What did you do using NetLogo to test this relationship? Why did you do this?

       Yeah we used different, we changed the levels and we tested it out to see the outcome.

   b. What did you find when you tested this factor using the NetLogo model? Does YYY have an impact on the number of animals? How do you know?

       Aimee: I noted it usually it does, it always does pretty much so like they are all have impacts on each other when you changes one thing changes everything else.

       R: How do you know?

       Tina: Because you look at the graph.
Aimee: yeah you could see it.

2. What did it feel like to use this approach as a method to assist you to understand ecology?
   a. Tell me about some positive aspects of the NetLogo model to support your learning.

Aimee: It was really good, I liked it. It is visually was good to be able to see the relationship, the only problem was it didn’t give us many facts for you know stuff it was very much finding out through learning ourselves and through doing it, which is good and helpful for me. But I don’t know if it will be very applicable in the exam contexts, it is good for general knowledge.

Tina: Yeah I liked it, I liked it how we had the graph, you can pin point to different spots to see several levels, the only thing is … I don’t know, they don’t really have anything negative yeah I liked it, I found it interesting

b. Tell me about some negative aspects of the NetLogo model to support your learning.

Aimee: Just the fact that even though like you could see the graphs and stuff, I don’t know whether they would actually accept that as an answer. If they actually accept that as an answer in the exam like as this goes up and this goes down, I don’t know, it is just different; it lets you describe in your own words which is good when you are learning it but not necessarily so good because you don’t know if you are on the right track, well you kind of can see if you are on the right track but I mean trying to explain it
to someone else could be a bit, when trying to explain it in an exam context, like if you are explaining it to someone else just talking to them that would be fine and it would be a lot easier to explain it to them going off. this is the grass level, go up, then the yernt can go up as well because they have more food, but if you try to write it down in an exam this doesn’t sound good.

First Group (G1) Post-Test Interview

1. List all impacts which negatively impact a particular ecosystem?

   - environmental humans diseases
   - natural disasters habitat destruction
   - changes in weather/temp. import/introducing different animals/species
   - Food sources

2. Using as many of the terms as you can, construct a concept map about the adverse impact on animals in an area: Terms: ecosystem, predator, prey, herbivore, carnivore, plants, hunting, weather, drought, fire, birth rate, death rate, human impact, natural causes, habitat destruction, energy, introduced species.

   - Blank cards are provided if you want to use them to add any other terms that you feel can make sense. You don’t have to use all of the terms or all or any of the blank cards

   - Please label the connections

   - Two direction arrows can be used
3. **Confidence in science: self-assessment of abilities in learning and understanding science**

a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?

   *Aimee: In general?*

   *Tina: I think it is the same thing as last time like around 7 because there is still somethings that we don’t understand, but there is somethings that we do*

   *Aimee: In this one I would probably... I think I started off like a 2 for all of them, in general or in all science I might have risen to 3, in this I might have risen to a 5. This bit I understand, everything else still no.*

   *R: in this particular ecology subject?*

   *Aimee: 5 yeah about.*

   *Tina: probably... I don’t know a 7, because I know ecology is not just only based on this there is still other factors that we need to consider that I don’t know and I don’t understand it.*

   *R: about this subject did you understand?*

   *Tina: only the stuff we did? Yeah I understood it, 8.*

   *Aimee: 5 because I got it now but I don’t know if I could explain it to everybody.*

b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?

   *Tina: this is kind of just like, like we get it from our perspective but if students asked something that we don’t know we wouldn’t know how to answer it, so probably still an 8 or 7.*
Aimee: I don’t know, like a 5, because as I said if a student asked me any
difficult question.

c. Do you think you will be more or less successful than other students in
your study of the Science Concepts unit? Why?
If they don’t think they will be successful:

- What do you think you will need to do, so that you will be able to learn
to teach science in a primary school? Why?

Tina: I guess more, a little bit more because during the graph thing we
can actually see differences and we would be given like an example of
it so we will be able to use it, yeah, which is it a bit better.
Aimee: In this bit probably little bit more, but in general worse.

R: What do you think you will need to do, so that you will be able to
learn to teach science in a primary school? Why?
Aimee: I don’t know, probably I have to study more and actually
understand it.

R: What do you think can help you to understand science more?
Aimee: I don’t know, probably stuff like this in everything. Not
necessarily all of it because I don’t deal very well with a lot of virtual
stuff, I don’t really like drawing and stuff but drawing the graphs helps
because I got it into my head while if I just looked at it I wouldn’t
understood it at all. Like I took it from the drawing at that point and I
got it because I could do that and because I could draw the arrows
and stuff like that I got it, if I was sat there and looked at it and had to
interpret the results from looking I wouldn’t be able to do it.
Tina: yeah.
Perceptions about ICT modes of presentation of information

a. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate your perceptions of how easy it would be for you to learn science if the information was presented as:

i. Text

Aimee: just text? 2, 1 somewhere around there, because if it is just text then I probably will not do it as well because I need physical or visual something that I can see I don’t like just, I am fine doing that just like English or just reading stories or something while when if it facts and trying to memorize facts I don’t do that well.

Tina: Yeah probably a 7 because you don’t want something too meaty, it is too much information to remember, but if there is like a combination of pictures as well as well as like practical we go out see to like prove that the theories are the same then that would be better but if it is just text it is not that great.

ii. Pictures with title only

Aimee: probably like a 1 because I mean even though I don’t learn particularly well from facts I still would at least like have be able to, I don’t know, but just the picture I don’t think I will be able to get the full understand of what they are trying to tell me, I wouldn’t understand what the whole point of the picture was, if it would be like a picture of like you know after a bomb blows up oh that is cool thanks I don’t know what that means at all.
Tina: probably like a 4 because if it is just a picture we wouldn’t really know what they are talking about like say they are talking about I don’t know.

R: if it is a picture of an ecosystem?

Tina: no, I will not understand it, because you are not able to connect the text with picture so you are not make meaning of it so if it is just a picture then you will not get it like if it is a picture of a tree you will not be able to understand that it is growing up or whatever happened to it yeah because you need some text to go with it.

iii. Graphs showing relationships between two factors

Aimee: 4 or 5 because I can see it visually draw over it draw something to do with it and understand better but you know I get to see the relationship and I can see how it works together and fits together and all of that which makes more sense in my head.

Tina: probably a 6 because it is a bit better because I used to not like graphs but using that graph and actually seeing it, it helped a bit but then again if it is only two factors it is not going to give you a very good results because you need to test it few times with other different contributing factors as well yeah.

iv. Virtual Learning Environment (VLE) like Omosa

Tina: 5, I don’t know, I didn’t really liked it.

Aimee: 3,4 because I will not be able to concentrate very long, I mean like I can do it for a bit but I think I would be like ok I don’t
really know what is going on now or I don’t really get how this relates to the science in a bit of it, it is kind of, I mean it is kind of cool to do it and then I can see that would be good for the younger kids specially because they learn without realizing they are learning but I think how you get frustrated with it quite easily. But it was good for short period.

It is probably better than the text alone for me because I can still see what is going on and I could like visualize and you know walk around and be like ahh ok they are over here and this is one here and that impacts that because that is there and I be able to see it but probably bit less than graphs because it is not as an easy way to get the information I don’t know if that makes sense, like you actually have to make your character go around and it takes a long time, while by that time you can get to something else it could be a bit complicated because you had to go through a bit different steps to get there and you kind of not really got it as clear picture as you originally did so the graphs are little bit clearer.

Tina: I think mine more than like a 5 I think I still prefer graphs because like she said if you are going around looking stuff after a while you are not sure what you’re supposed to do, and with the game sometimes like whatever you do it kind of impacts what you think like in a way like if it was a game like this if you go ask one person something and then you go back and you ask something if there is two different ideas it is could easily you get confused.
v. A graphical model which you can change and monitor the impact of changes on other factors like (NetLogo).

Aimee: 5 because I can see the impacts and I can see the relationships and I can see how they work in visual work and it makes it easier.

Tina: probably an 8 because I can actually see the changes and what is contributing to it.

b. Do you think that you will learn more about ecology, using “Omosa” VLE and NetLogo model?? Why or why not?

Tina: the second one because you see the differences and stuff.

Aimee: Yeah and it is an easier way of getting the information and it is, I don’t know, I think if your kids really really like video games it would be really really helpful using the past one because you feel like you are doing something fun but actually learning a lot and it is a good way of learning the information and processing it but I think I found the second one better because it showed the relationships and it showed me how they interacted but because I kind of get frustrated in video games it is a bit more relevant to me the second one.

5. If someone asked you “What do scientists do?” what would you tell them?

Aimee: they look at the relationships, they look at the relationships between things and then what impacts what, I mean you can say that about chemistry and physics as well like it is about ecology at the moment but you know you can say that they you know analyse how hydrogen works with oxygen to make water so the relationships between these two things let say you know. Related to ecology: relationships between
things like, you know, the impacts on each other and the animals then people and animals and other animals, animals and plants and stuff, say like the relationships and the impacts of those.

Tina: In ecology they just look at like animals and plants and they see what affects it and then they can improve it and then they try to keep the levels stable.

6. How do scientists go about understanding what causes animals to become extinct?

Aimee: They look at what is impacted them and then they look at how it impacted them and to what extinct and what factors had changed to make them going to extinct.

Tina: They test animals in specific habitat and see which one is the healthiest and which one is seems to becoming weaker and then they will test more stuff.

7. Which environment do you feel you learnt more about ecology and the factors that affect animal population; Omosa VE or the NetLogo model? Why?

Tina: The second, because you are able to see differences and you are able to change the levels, in the first one you only just asking questions and you are only getting predictions from the different people rather than actual facts.

Aimee: I think in the end I learnt more about the actual factors and stuff in the second one but the first one helped me understand the whole concept like I mean that what explained to me what the yernts were and all of that and it also helped me see, I don’t know, I think I learnt easier in the second one but I still learnt a lot from the first one, because I found that, I ... you know it took consideration of different points of view of the people who actually lived there and the meteorology people and all of that and so
demonstrated a different approach to it in the second; so I think I probably learnt more factual stuff from the second one but the first one definitely did teach me a lot.

Second Group (G2) Pre-Test Interview

1. Background information

a. Why did you agree to participate in this study?

   K and A: I thought it would be helpful and beneficial in the long run for our learning as well. And because I have always did not really perform well in science compared to other subjects in high school, and I also play lots of video games so I thought this would help.

b. Why did you choose primary teaching as a career?

   A: There is a few reasons, one reason that we both share quite strongly, was our principal when we were in high school was a big actives’ for public schools and females in principals in higher roles so that was one thing that we both.

   K: But manly for me it was my nephew, so he is 4 at the moment. And since my brother and his x wife separated I am taking up a bigger role in being prep eternal and nurturing but also being quite strict as well so I have been the main one really helping him learn and reading books to him and counting so that reward from him learning and experiencing that with him really inspired me to do primary school teaching.

c. Why did you choose not to study a science subject in Years 11 & 12?

   A: Something I was kind of more in to creative arts and English and that was like my strong point. Science I was naturally good at but it was
something that I did not want to pursue growing up I guess so I did not see it as a benefit for my long term goals (professional career).

K: For me I never performed well in it so I was never encouraged I guess to continue studying it, but I always preferred maths over science, I guess there is a whole theory like if you are good at music you are generally good at maths because of the whole numbers and patterns with science I thought there was so many variables and so many theories and I like structure and formulas so I preferred maths over science.

A: And also my aunty is really smart at science and we don’t want to be compared to her she is the dean of chemistry at Melbourne university.

2. Confidence in science: self-assessment of abilities in learning and understanding science

a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?

K: mine would be 3, I guess…. If you explained the processes to me I would understand it but I think naturally I never could relate to it in a real world context because I thought that you need to be so smart to learn science I am figuring out now it is not the case but that is probably why I don’t think I am not that good because I have always thought of it to be for really smarty-pants people to be scientific.

A: I would say probably a 4, I think like remembering analogies and things like that and like by my looking at science now there is a lot of things that I knew but I don’t hold information well if I am just told it where as if I just do something like an experiment I can see logic and I can put everything together myself and do it, so I am kind of like an experiential
learner where I need to be shown things and do thing and I have to be involved in the process so for me science I look at it a lot like I look at mathematic and algebra so with algebra like if someone’s gonna show me everything and I am not gonna remember it but if I actively involved in making an experiment and getting hypothesis and all of this I feel more like I understand it and I can do it.

b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?

A: I am pretty confident I probably say like an 8 or 9, like I said like I think primary school kids learn the same way that I do, so I am not gonna sit there and teach them how to do equations and formulas and the things that I don’t understand but I am gonna be able to make them participate and be involved in the process of learning and finding things out for themselves so I will be probably learning with them.

K: At this point I would say a 7 just because I am not confident with myself and I think once I finished my 4 years I will gain that confidence and understanding in science, but at the present moment I don’t feel that confident with my own learning of science so I would say a 7.

c. Do you think you will be more or less successful than other students in your study of the Science Concepts unit? Why?

If they don’t think they will be successful:

- What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?
K: Less successful because it is been 9 years since I have been in school and about 11 since I actually studied science so since going to the lecture a lot of students putting up their hand and answering questions and using words that I have not heard in a decade so they have more familiarity with science and science terminology where I have not seen anything over a decade.

A: I am the same like I have not seen or thought about science in at least 10 years but on the same token everything I learn in a lecture or in a tutorial I know, like something in my mind that triggers and I already know the answers, and it is just a matter of refreshing myself, so I am actually more swayed toward being above the median.

3. **Can you define extinction and give an example of something which has become extinct?**

   Tasmanian Devil

   The process of elimination + the idea of survival of the fittest. Animals/humans adapting to overcoming adversity, + prove themselves by remaining alive/continuing to evolve.

4. **Why do you think the organism you described became extinct?**

   Due to the destruction of natural habitat, enemies + human interaction, excessive hunting, introduction of new species.
5. List all impacts which negatively impact a particular ecosystem?

- Pollution
- Extreme weather
- Industrialisation
- Deforestation
- Overpopulation (humans + animals)
- Global warming
- Direct changes in environment
- Introduction of new species

6. Using as many of the provided terms as you can, construct a concept map about the adverse impact on animals in an area:

Terms: ecosystem, predator, prey, herbivore, carnivore, plants, hunting, weather, drought, fire, birth rate, death rate, human impact, natural causes, habitat destruction, energy, introduced species.

- Blank cards are provided if you want to use them to add any other terms that you feel can make sense. You don’t have to use all of the terms or all or any of the blank cards.
- Please label the connections.
- Two direction arrows can be used.

7. Perceptions about ICT modes of presentation of information

a. Did your teachers use computer games to support students’ learning?

How?

A: We did like typing game in primary school,

K: yeah there were computers in primary and in secondary there were no computers readably available to us,

A: but in primary school like there was defiantly a use of computer like because we were learning about computers and how computers become part of everyday life, so we obviously learn how to type, and we had all of these like computer games where you do the typing and you have to reflect
on what is on the screen and you do different games based on typing. Computers otherwise was not a huge thing in our primary school education it was more just you learn how to type, whereas these days I would say every kid already knows how to type.

b. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate you perceptions of how easy it would be for you to learn science if the information was presented as:

i. Text

A: so instead of reading a book you read it on a computer, it would be the same as a book for me, like I consider reading from computer the same as reading your book. I think it is the same 9.

K: I would say about 9.

ii. Pictures with title only

A: same, 9.

K: I don’t want to say 10 because that is too definite, so I would say 9 as well because like pictures defiantly help my understanding more than text.

iii. Graphs showing relationships between two factors

K: a 9 again.

A: a 9, I really don’t see a lot of difference between text and computers now whereas in primary school I would but now I would use it probably more than I would use a text... It depends.
iv. Virtual world simulations that you could explore (game-like environment)

*K:* Then I would do 10 because you are actively involved in it so it is defiantly more than an image more than a text. So if what you are asking is do I learn better by words by pictures or by interactively involved so with words it is probably about 5 or 6, with images it is about 7 or 8 and by being interactively involved would be about 8 to 9, I don’t wanna say 10 because I can never guarantee but I would say defiantly interactive games it would be more beneficial for my learning and I would retain it yeah because I am actively doing something with it.

*A:* I am probably about the same pictures may be the same as text like I will gather information from a picture but sometimes it is better for me if just read it, I am not gonna retain the information but if I am actively doing it is gonna be like a 9 ... text maybe 7, picture 7, interactive stuff 9.

v. A graphical model in which you can make changes and monitor the impact of changes on other factors. (interactive environment)

*K:* 10 or 9, I wanna say 10 but 9.

*A:* yeah 9.

c. Do you think that you will learn more about ecology, using virtual world simulations (game-like environments) and graphical representation? Why or why not?
K: yes.

A: yes because I am participating and learning through the participation and I will retain the information because I actually done it myself.

K: and when you are talking about controlling you can then use your own, like you can change things and see the effect of it so.

A: from the exercises you gave us like I can already still remember my text that I wrote, I scan till remember these pictures but if I was actively I guess we kind of did this in an active way I feel like I would retain more from that.

8. If someone asked you “What do scientists do?” what would you tell them?

A: a lot, I mean just from my aunty like she has a lot so she is actively involved is research and trying to get grants for the university and teaching and being a mentor and replying to many emails a day, doing admin,...

K: I guess you could break scientist stuff into like a theorist or like a teaching someone with education just studying research or scientist doing experiments so there is a lot, if you had to give one sentence for the scientists someone actively investigating the world, how the world works and theorizing experimenting and observing.

A: and also coming up with new ideas and then innovation—getting rid of the old ideas so it is an ever-changing discipline.

K: You have to be creative to be a scientist

9. How do scientists go about understanding what causes animals to become extinct?

A: well, I mean with the scientists it is always testing hypotheses so I guess in a sense you would be testing everything and then when you have a new idea implementing the idea and if it is successful.
K: If you are talking about a particular species I would imagine that they studied the species and their environment to see and observe exactly what happening and what could be the effects.

A: I think of scientist like that testing ideas rather than just observing, they do observe but I think the ultimate goal is to test and challenge.

**Second Group (G2) Omosa Short-Interview**

1. What do you remember about the virtual world “Omosa”?

   **K:** Like a desert type environment, and the cats chasing the deer that is what they were and the villagers dancing around the fire and it is island shape and the people that I talked to in all the areas.

2. The challenge you were set was to identify the possible factors which might cause the animal population on Omosa to decline. How confident are you that you identified all the factors?

   8

3. Which, if any factor, is the most important in causing the decrease in the animal population in Omosa? Why?

   **K:** It would be between the human impact or the drought, probably the drought because which it is like the rain fall and then the deer did not have enough farm nutrients to keep reproduction so I would say the drought.

4. What did it feel like to use this approach as a method to assist you to understand ecology?
a. Tell me about some positive aspects of the VLE “Omosa” in supporting your learning.

*K:* Had lots of fun, it was good to be in like that character’s shoes and exploring it and seeing everything, so it gave me better understanding of the setting and saying it for myself. That was good.

b. Tell me about some negative aspects of the VLE “Omosa” or about things that could have been improved or changed to support your learning.

*A:* I guess I would like clarification; maybe like having questions come up in the game and then you explore to find these questions so you have like a good direction.

**Second Group (G2) Omosa NetLogo Short-Interview**

1. The challenge you were set was to identify the possible factors, which might cause the animal population on Omosa to decline. You decided to that YYY was important.

   a. What did you do using NetLogo to test this relationship? Why did you do this?

   *We formed an independent and dependent variable so we set our own hypotheses and then chose something that we could control to ultimately to see if our ideas were true or not.*

   *We did it multiple times to show a varied number of results and we don’t want to rely on one result because it could change each time and we did extreme circumstances verse mild or not so much of the thing that could make an impact.*
b. What did you find when you tested this factor using the NetLogo model?

Does YYY have an impact on the number of animals? How do you know?

*K: human Impact.

A: yeah, I would say human impact as well.

*K: because with drought we did the 20 to 60 scale and there was no extinction of animals still.

A: and they adapted.

*K: and nature still could balance whereas humans were so excessive.

A: yeah and humans found that they could hunt so quickly and kill of the whole species that there was no chance for reproduction or for them to be saved.

2. What did it feel like to use this approach as a method to assist you to understand ecology?

a. Tell me about some positive aspects of the NetLogo model to support your learning.

*K: I liked it when we tried to predict what happened and then we tested it and we could see what was happening and we were happy, we weren’t happy like when we went wrong. Ohhh we did not realise that because it makes you think of different possibilities and understand in different ways that you did not before. I like actually seeing more of what happens, and seeing the graph like you predict something and then you see it happening and then you can reevaluate and test another theory and actually see it.

A and K: one thing we did not realize from the beginning that there were numbers on the screen showing the actual numbers of populations when
you press to clear, realistically we should spent more time on playing with
the program. The numbers on screen was how many were at the time so
like that there was just a different way for reading it rather than just
looking at a picture. We were just drawing the picture and then we saw
like yrents I left and like oh damn we didn’t realize that there was actual
number but now that we did I mean I still like looking at the graph. I like
looking at the graph but maybe it is a good way for other people to learn
rather than just looking at a graph like this, looking at the numbers and
we could’ve used that in our evidence so when we wrote it down in the
book instead of just relying on a drawing we should have wrote it down
also on numbers as facts instead of just graphs.

b. Tell me about some negative aspects of the NetLogo model to support
your learning.

A: No, because it challenges your ideas and perceptions and I don’t think
that is a negative thing that is something to go from.

K: No I don’t think there is anything negative.

Second Group (G2) Post-Test Interview

1. List all impacts which negatively impact a particular ecosystem?

| HUMAN IMPACT - hunting, destruction of ecosystems |
| ENVIRONMENT - drought, natural causes + disasters, food supply |
| PREDATORS + introduction of new species |

2. Using as many of the terms as you can, construct a concept map about the
adverse impact on animals in an area: Terms: ecosystem, predator, prey, herbivore,
carnivore, plants, hunting, weather, drought, fire, birth rate, death rate, human impact, natural causes, habitat destruction, energy, introduced species.

- Blank cards are provided if you want to use them to add any other terms that you feel can make sense. You don’t have to use all of the terms or all or any of the blank cards
- Please label the connections
- Two direction arrows can be used

3. **Confidence in science: self-assessment of abilities in learning and understanding science**

   a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?

   _K: In science 5 but in this field I would say 8 or 9._

   _A: In this kind of field may be 7 like I have had a lot of general knowledge and things I understand of how things connect but it is more just my general knowledge I don’t have facts._

   b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?

   _K: 8 because I can see how things interconnect and relate to each other and make sense and if I can take that from the things that we just did I think that I can relay that to people as well and make them see how everything connects to._

   _A: I think but because this is type like a general knowledge type thing I feel that I would be 8 because I can show them through those materials_
you given us, like showing them the world then relay that onto them as well and show them how things in actual world.

c. Do you think you will be more or less successful than other students in your study of the Science Concepts unit? Why?

If they don’t think they will be successful:

- What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

  A: I think in this concept I will probably be more successful because I have a better understanding of how the world works and its interrelation with other ideas, I think maybe other students I am giving that based on my age just being growing up and learning may be that is my advantage over other students

  K: I would say average because I haven’t done this in 10 years so I feel like that other students specially students who just came from year 12 have more recent knowledge and things that they are not struggling to remember so I don’t even know what is taught in the curriculum so this could be all basic stuff I am not sure any more

  R: What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

  A: Design interactions and like tests and interactive things that I can do that make children see and understand rather than just relaying them information so as long as I have the tools that I need I think that is how I make the child understand, if I ask them to do a board like this that is a good way because that is them getting their ideas out of thinking about how things connect and using a game is a good way
because that is how they playing something but also learning and I think that is what I need to know is the tools rather than a lot of the information.

K: I feel the same because you need to show them and ask them questions and then you show them and then break it down for them to understand defiantly visual help would help them I feel you know or them experimenting as well would be helpful for their learning because they are actually partaking in it or even in that virtual world as well doing something like that would give them a better understanding because they don’t have the back knowledge that we do so they have to experience.

A: yeah experience rather than learn from a text book or me telling them something.

4. Perceptions about ICT modes of presentation of information

a. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate you perceptions of how easy it would be for you to learn science if the information was presented as:

i. Text

A: as text I would be a 6.

K: the same, I would be 6 because it will be just static , I think I will retain some of it but there is no way I retain all of it, if I wasn’t involved .

ii. Pictures with title only
A: maybe 7 because it is a little bit more in-depth it is a little bit more of me seeing and remembering but I still am not gonna retain all the information.

iii. Graphs showing relationships between two factors

K: probably still a 7 it stills a picture to me.

A: 7.5 or 8 , I think I learn more from interring the different variables into the computer and seeing it reflect in real time rather than just looking at a graph like me actually deciding the parameters this help me grasp the concept of how things interrelate.

iv. Virtual Learning Environment (VLE) like Omosa

A: 9 or 9.5

K: 9, I am too scared to say 10

v. A graphical model which you can change and monitor the impact of changes on other factors like (NetLogo).

K: 9, that was fun

A: yeah

b. Do you think that you will learn more about ecology, using “Omosa” VLE and NetLogo model?? Why or why not?

Yes.
5. If someone asked you “What do scientists do?” what would you tell them?

A: Testing hypothesis and constantly reinventing a concepts and ideas about things that we think we already know.

K: challenging, perception and observing and think of new ideas and also being highly intelligent and experimenting making like theories.

6. How do scientists go about understanding what causes animals to become extinct?

K and A: Observations and experiments, yeah observation is probably the biggest one they can’t really control drought or anything that we did in Omosa but by observation they can document and maybe create like one of those mathematical equations and graphs; as well as prediction, tagging of animals to catch more events to collect data that provide them with the information

7. Which environment do you feel you learnt more about ecology and the factors that affect animal population; Omosa VE or the NetLogo model? Why?

A and K: NetLogo, because I could actually see the overview; you have the data to reflect and you are also using all the controls and stuff, but a child might like the VLE more because it is more of an environmental world that the child is playing a game in—the child may not understand the graph—but also with the game if you don’t have a clear set of like definitions or values within it, then it can be up to the person’s interpretation, and how they wanna draw information from it. It will be two different experiences for two different people so if you had a graph you are sticking with the numbers so if that could cooperated to the virtual world that would have more integrity.

If you had like a side bar or side panel or something that looked up the world and show the decrease and increase in population that might help because they knew there
is a new experienced as a whole new level but you still got that like real time in fluctuation in population and decrease so you still have that information so it can’t be interpreted differently, but then again the child may not look at that information they might be just concerned with running around the world.

Third Group (G3) Pre-Test Interview

1. **Background information**
   
   a. Why did you agree to participate in this study?

   *L: I haven’t studied science in a really long time so I was interested to find out what it was. It is been about four years since I have done any form of science, so that is why I decided.*

   *M: I just did it because I thought it would help out.*

   b. Why did you choose primary teaching as a career?

   *L: I always do like working with kids and I did a lot of work experience but I particularly wanted to go to special education.*

   *M: Yes I just I like teaching kids because I like how kids have that energy and they are much more innocent rather than like the high school students, because I like when you teach someone and they have that light bulb moment when they are suddenly clicks and it is interesting to try and have to describe things in different ways for them to be able to get to that kind of stage, and then yeah I always preferred kids to like high school students because you don’t have as much back chat and all the teens anxious issues.*
c. Why did you choose not to study a science subject in Years 11 & 12?

L: *Science just never really clicked with me* I like maths but I don’t know you were only allowed 6 subject and science just wasn’t an option to me and science like I think it is interesting but it is from the junior school it is just never really like clicked with me.

M: *I have done a lot of science, I have a background in science* because I did that in the degree I was doing before but I did not finish with science I always found it interesting and it is kind of family background because my parents are both doctors so I saw that kind of grow up in this kind of learning hows and things as well.

2. **Confidence in science: self-assessment of abilities in learning and understanding science**

a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?

L: *About 2 because I really don’t know much other than like what is in my media world I don’t really understand like what the hows and things and I like to but it just haven’t really done it.*

M: *Mine is more of an 8 probably because I have kind of studied it so I done more.*

b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?

L: *I think I am pretty determined to learn, the course we are doing right now is quite simple so it is perfect for me and yeah I think I’ll do a good job. If this still from 1 to 10 then hopefully a 9.*
c. Do you think you will be more or less successful than other students in your study of the Science Concepts unit? Why?

If they don’t think they will be successful:

- What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

  L: I think I can be possibly be a little bit less successful but when it comes to actually teaching the content then I think I would be the same as others.

  Because my background knowledge is not that good, because at this point in time if a child had a follow up question I will have difficulty answering that but by the end of it I would hopefully.

  R: What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

  L: Research like when people talking about things in class and I don’t know what it is but not really sure why it happened just general research could of really helped me.

  M: I probably say more just because I have got the background like kind of I done it earlier so it is kind of, I am kind of learning how to teach it to kids whereas other people have to learn what they teach and then how to teach it whereas I have kind of got the background of it already.

3. Can you define extinction and give an example of something which has become extinct?
4. Why do you think the organism you described became extinct?

   Couldn't survive in the changed environment
   (possible extraterrestrial)

5. List all impacts which negatively impact a particular ecosystem?

   human impact
   weather (extreme out of normal)
   disease
   overpopulation or a certain species (plants or animals)

6. Using as many of the provided terms as you can, construct a concept map about
   the adverse impact on animals in an area: Terms: ecosystem, predator, prey,
   herbivore, carnivore, plants, hunting, weather, drought, fire, birth rate, death rate,
   human impact, natural causes, habitat destruction, energy, introduced species.

   • Blank cards are provided if you want to use them to add any other terms that you
     feel can make sense. You don’t have to use all of the terms or all or any of the
     blank cards

   • Please label the connections

   • Two direction arrows can be used

7. Perceptions about ICT modes of presentation of information

   a. Did your teachers use computer games to support students’ learning?

   How?
L and M: We have a computer lab like once a week ....; actually it was like very occasionally. Maths games like time tables, like a whole website of different like educational games.

b. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate your perceptions of how easy it would be for you to learn science if the information was presented as:

i. Text

M: probably like a 2 or 3 I would say, because I am a visual learner without diagrams I have trouble learning.

L: I would say 4 because the information still there but it is not engaging.

ii. Pictures with title only

L: 3 hopefully.

M: I would say probably around 3.

L: it depends on the picture it could be like an awesome diagram that completely explains everything but if maybe that diagram was presented before or after the text where we can come back to it while you are during the text it would be a lot more effective.

iii. Graphs showing relationships between two factors

L: like I said it depends on what kind of graph but it will only show you certain differences or certain facts about each factor I would say M: I would say probably about 3 or 4.
iv. Virtual world simulations that you could explore (game-like environment)

L: I think that is very effective I would say maybe an 8.

M: yeah I would say like an 8 as well because with the simulation usually they kind of have you do something so they explain it and then have you do something and then because it is a game kind of tells you we rate you it is kind of giving you feedback on what you are doing whereas with those other techniques you don’t really get any feedback.

L: You can just look at it and no one would know the difference. This is more motivation it is actually engaging the information and take it in because you know you gonna be like not tested on that but you gonna get scores.

M: you gonna try to win kind of thing.

v. A graphical model in which you can make changes and monitor the impact of changes on other factors. (interactive environment)

M: Yeah that would be helpful, so it would be like an 8, because you should be able to see the direct impacts, you are going to be able to see like what the correlation, the relationship between the beginning thing for whatever you are changing and then the effect that it has.
c. Do you think that you will learn more about ecology, using virtual world simulations (game-like environments) and graphical representation? Why or why not?

_L_: I think it is a good way to start a lesson to engage (I said engage about 10 times sorry) but like to make the children interested in the content before they start going to like further details because sometimes the simulations might only have a limit amount of information so get that prior knowledge first then learn the rest of the content.

8. If someone asked you “What do scientists do?” what would you tell them?

_L_: they do science.

_M_: They find out like how things work and they do all the tests and they do experiments to find out that.

9. How do scientists go about understanding what causes animals to become extinct?

_M_: They do research, they have to look at what animals need when they were alive or what similar animals need when they are alive and then maybe how that wasn’t provided to see like maybe that’s why they went extinct, if something that they needed to stay alive was taken away; so looking at the environment at the time that they wouldn’t have been alive.

_L_: I think it would be hard not to have the view stated by prior research though because sometimes that might be false or not correct that might make them go the whole new tangent, I think they need to be careful about what they have regardless fact not just the theory.
Third Group (G3) Omosa Short-Interview

1. What do you remember about the virtual world “Omosa”?
   
   L: dry place, fire stick farming, lots of people, different views.
   
   M: changing practice kind of led to decline in one species.

2. The challenge you were set was to identify the possible factors which might cause the animal population on Omosa to decline. How confident are you that you identified all the factors?

   L: we didn’t go to the weather station, so maybe we missed something there.

   M: but we heard from the other guy that the drought as well, which was pretty much one of the weather station task.

   M: we are pretty confident.

3. Which, if any factor, is the most important in causing the decrease in the animal population in Omosa? Why?

   M: I would say the fire stick farming because it both clears it out first so they don’t have immediate supplies because they are the food for the yrent and then it also stops the kind of the regrowth of the grass because then it is more suitable habitat for basically the seeds of the fire dominant grasses to grow so kind of stops both the immediate and the future kind of food for the animal.

   L: I think it is also like a combination.

   M: it is a combination.

   L: if not full the drought then there will be more like, less the drought more living plants, and maybe more other kinds of life that they might have had before, they might not have to do the burning off because the plants are so dry they will prevent the fires.

   M: It is not just one thing.
L: and then Omosans could live off these plants and the yrents left from hunting much.

4. What did it feel like to use this approach as a method to assist you to understand ecology?
   a. Tell me about some positive aspects of the VLE “Omosa” in supporting your learning.

   L: It is good, it is fun because it is like going somewhere and actually talking (not actually talking to people), but it is close to little conversation with them—say reading from the text, you can choose which questions you want to ask based on your understanding. I thought was very helpful.

   b. Tell me about some negative aspects of the VLE “Omosa” or about things that could have been improved or changed to support your learning.

   M: I think it is not negative so much as just, I think it would take a little bit of getting used to it, like if you are using it for kids as well; people do it in different ways so you have to account for that time period because it is exploring and wherein some people will kind of go just for just the basics where some people like to be more thorough.

   L: and I think this is kind of walk around.

Third Group (G3) Omosa NetLogo Short-Interview

1. The challenge you were set was to identify the possible factors, which might cause the animal population on Omosa to decline. You decided to that YYY was important.
   a. What did you do using NetLogo to test this relationship? Why did you do this?
M: we changed the levels for the independent variables like so we changed what we thought would affect something, we changed that level, we put it up basically then we looked at how much it changed.

R: Why did you do this?

M: we changed the levels to see what effect it would have, so if it is more severe like if drought is more severe then would the population go up or down? So basically to see what would happen.

b. What did you find when you tested this factor using the NetLogo model? Does YYY have an impact on the number of animals? How do you know?

L: yes, because we have seen a significant change in the population numbers, like there were ... we did have the other factors going in the same time so we could see that had direct impact on the animal population.

2. What did it feel like to use this approach as a method to assist you to understand ecology?

a. Tell me about some positive aspects of the NetLogo model to support your learning.

L: I enjoyed it, I like seeing the graph and then like I can see how it moves in a correspondence with the image and also seeing the exact numbers of the population so you can see. So I think it is really good, really clear precise visual information.

M: similar because I am more like a visual leaner I like seeing like I saw the graph and the numbers.
b. Tell me about some negative aspects of the NetLogo model to support your learning.

*M:* Not particular, I mean it is just with the activity because you have to kind of make like you don’t kind of get feedback as to whether you are doing this correct; do you know what I mean?, like it is kind of like why do you think this is happening and at the same time you can’t really say if that is right so you are kind of speculating in a way if you are not sure.

*L:* I think it is also really good to see the graphs in better details so when they compressed over longer periods of time when there is like little squiggles altogether you can’t really see what was going on there. I mean you can guess but I just thinking it is good to see the full scale but other than that ok.

**Third Group (G3) Post-Test Interview**

1. **List all impacts which negatively impact a particular ecosystem?**

   ![Concept Map]

2. **Using as many of the terms as you can, construct a concept map about the adverse impact on animals in an area:** Terms: ecosystem, predator, prey, herbivore, carnivore, plants, hunting, weather, drought, fire, birth rate, death rate, human impact, natural causes, habitat destruction, energy, introduced species.
• Blank cards are provided if you want to use them to add any other terms that you feel can make sense. You don’t have to use all of the terms or all or any of the blank cards

• Please label the connections

• Two direction arrows can be used

3. **Confidence in science: self-assessment of abilities in learning and understanding science**

a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?

   *L: in science.*

   *In this like particular part of ecology in animals and population I guess 7; like what we did today like a higher number like 8 or something because what we just did was easy like common knowledge like things that you could just make sense without prior knowledge of terminology or anything like that, you just could work it out.*

   *R: do you think this method helped you?*

   *L: yes definitely that is like showed me exactly what was happening instead of saying like just flatly like if drought occurred then what would happen that I guess this was reaffirming I guess.*

   *M: yeah I am pretty confident with science so like an 8, I mean I have kind of had an experience in this, this is just more experience so kind of show me the relationship.*

b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?
L: I still the same as last week, I will say10, because I am not really teaching for 4 years and I think maybe with my side of having to relearn science at that age I have actually to remember and then actually be able to remember the difficulties that I had when I was learning science, I can use that to teach and help children that is one positive aspect to knowing nothing.

M: I am like pretty confident as well that I will be able to teach it.

c. Do you think you will be more or less successful than other students in your study of the Science Concepts unit? Why?

If they don’t think they will be successful:

• What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

L: less successful because I have trouble in I think really simple things, like in the lecture I get lost sometimes so I have to just do a lot more work.

R: What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

L: I don’t know I think I just need to like talk it out with someone, like I have some friends who do science so I am just kind of make him baby sit me for a little bit just tell me what I missed, yeah I don’t know because like in the lecture the information still there but I think with like close communications it is easier for me to really take the knowledge in.

M: probably more just because like I said I have the background in science and I kind of already like ... (L) has to learn the terminology
4. Perceptions about ICT modes of presentation of information

a. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate you perceptions of how easy it would be for you to learn science if the information was presented as:

i. Text

L: Just text? 3 or 4.

M: yeah same 3 or 4.

ii. Pictures with title only

L and M: same, it is like 3 or 4 because you need the writing as well.

iii. Graphs showing relationships between two factors

L: I think graphs are obviously helpful.

M: graphs are somehow helpful but I would still put it like as a 5 or a 6 because then even they show the relationship we are not quite sure why so you still need that kind of text you need like a combination.

L: it is 6.

iv. Virtual Learning Environment (VLE) like Omosa

L: yeah I liked that it is interactive.
M: I will give it like an 8, because like I said the thing to improve it is kind of ... because you are doing it, like it is fun and it is interactively you get to see the relationships but the only thing like this is personally like my learning style like I like to know that I am in the right track like that I am doing the right thing and there isn’t that feedback that you know that what you are doing is right.

L: what you are learning and what you think you are learning is right, like you getting a little tick on it I will give it probably an 8 as well.

v. A graphical model which you can change and monitor the impact of changes on other factors like (NetLogo).

M: same

L: yeah I liked it.

b. Do you think that you will learn more about ecology, using “Omosa” VLE and NetLogo model?? Why or why not?

L: yeah I will learn more, if you use them as well as what you did learning in lectures and in tutorial things then I suppose to learn them yeah that will be helpful but if you would only using them to learn science then that may not be enough because as other like all what you might be learning you may not be remembering you rather going to your working memory instead of long term memory I think there is other factors to consider

M: yeah I think I would learn more but you need to use it like with something else not just by itself
5. If someone asked you “What do scientists do?” what would you tell them?

M: They investigate the hows and whys of just general things, about things in the world around us, just how things work and why they work.

6. How do scientists go about understanding what causes animals to become extinct?

M: Tracing populations, and like so you have to trace populations and I suppose that they have to hypothesise like factors that would influence and then also trace that; so say if it is drought then you trace the population in correlation with drought being present or not

L: They also work on like prior theories as well; I mean I don’t know if there are prior theories for Omosa but they might already know.

L: they also work like prior theories as well, I mean I don’t know if there is a prior theories in Omosa but they might already know.....they do experiments.

7. Which environment do you feel you learnt more about ecology and the factors that affect animal population; Omosa VE or the NetLogo model? Why?

L: I liked the NetLogo better; I liked it because it is more straightforward. I think children might find interactively going talking to people but I think I prefer the NetLogo.

M: I preferred NetLogo because you could see the relationships, which is kind of what we were being asked about more; whereas, over there it is kind of like you had to talk to different people and you are kind of getting fed information rather than saying it to for yourself.
L: I think the fact that we saw Omosa before this was helpful as well because we already knew about like what a yernt was like if I just like saw that straight away that would be like what is this and what is that, why, why, or like no idea about where Omosa was, what kind of habitat was in because it was good to see exactly what it looked like.

Fourth Group (G4) Pre-Test Interview

1. Background information

   a. Why did you agree to participate in this study?

      Y: we were just asked to so we thought that this might help.

      M: I agreed because it is sort of like related to what I want to do anyway just like primary teaching and science would be involved.

   b. Why did you choose primary teaching as a career?

      Y: because I was told when I was little I liked acting as a teacher marking and yeah seeing some students from my high school they couldn’t really read that well so I want to make a difference.

      M: I really want to help kids to have like self-confident and self believes and to know that they can like contribute to the world and society when they have that like positivity I guess.

   c. Why did you choose not to study a science subject in Years 11 & 12?

      Y: just didn’t really understand science, it wasn’t really in my interest.

      M: in high school like the science I was taught in junior years it seemed really like removed from, like me and like everything that I was sort of
interested in it didn’t really seemed like that engaging to me, so I didn’t like choose it.

2. **Confidence in science: self-assessment of abilities in learning and understanding science**
   
a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?
   
   *Y: Probably 5, like if I had to learn it I could, you know, read text books and stuff but to contain that information for a period of time just won’t work.*
   
   *M: yeah probably 6 because I think like I could understand it, I don’t know, may be just like my motivations are like not as high.*
   
b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?
   
   *Y: maybe 7 or 8 because the content that they learn is easier than like high school and senior science.*
   
   *M: Like now would probably be maybe like 6 or 7 but I think like at the end it might increase probably be like a 10, because I still sort of like we are relearning science like concepts for myself.*
   
c. Do you think you will be more or less successful than other students in your study of the Science Concepts unit? Why?
   
   If they don’t think they will be successful:
   
   - What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?
Y: Because I think there are gonna be those people that are gonna be really good at science and then there are people that are gonna be like alright and then there is gonna be people that don’t really like science at all so I don’t know whom I am comparing to. I guess teaching it is different from learning the content because sciences are a bit more practical in primary school like you do all these experiments and stuff so I think I should be on pile of most students.

R: What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

Y: I don’t know maybe .like as the course go on I will pick it up like in the workshops that Armstrong does.

M: I think more because I know like I didn’t do it in year 11 and 12 and I really want to work as hard as I can in science concept to make sure I have got like all that down and like understood and I want to like give like a 100 per cent effort to it because I haven’t really done that s in science before so I want to do now.

R: What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

M: I don’t know, I think it is just about like motivation so I just need like professors and stuff to keep explaining like why it is important and then I like, do a lot of work I guess.

3. Can you define extinction and give an example of something which has become extinct?
4. Why do you think the organism you described became extinct?

From excessive hunting

5. List all impacts which negatively impact a particular ecosystem?

- Need for food resources: humans and predators
- Loss of habitat
- Natural disasters

6. Using as many of the terms as you can, construct a concept map about the adverse impact on animals in an area: Terms: ecosystem, predator, prey, herbivore, carnivore, plants, hunting, weather, drought, fire, birth rate, death rate, human impact, natural causes, habitat destruction, energy, introduced species.

- Blank cards are provided if you want to use them to add any other terms that you feel can make sense. You don’t have to use all of the terms or all or any of the blank cards
- Please label the connections
- Two direction arrows can be used

7. Perceptions about ICT modes of presentation of information
a. Did your teachers use computer games to support students’ learning?

How?

*M: Yes, mostly like for maths, Mathletics.*

*Y: yeah maths mostly, not for science.*

b. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate your perceptions of how easy it would be for you to learn science if the information was presented as:

i. Text

*Y: maybe if there is a bit of diagrams, if it is just text it would be a bit more difficult to not be able to see anything, probably 6 or 7.*

*M: yeah, if there is like a lot of text it would be very hard to understand it all, if it is like sort of in like short points it is easier I would say like 6 probably.*

ii. Pictures with title only

*Y: probably about the same 6 or 7 depending on how the picture is.*

*M: probably I think if it is just like have a title only probably 4 or 5.*

iii. Graphs showing relationships between two factors

*Y: 5.*

*M: I think like 8 or 9.*
iv. Virtual world simulations that you could explore (game-like environment)

Y: it is probably better that way maybe 8 or 9.

M: yeah I think 9.

v. A graphical model in which you can make changes and monitor the impact of changes on other factors. (interactive environment)

Y: 9 because you can actually like it is kind of you watch the change and stuff you don’t have to physically do that thing, you just have it in your computer, less troublesome and you will be more engaged into it.

M: I think 9 or 10, like if you watch something and you get to like see changes I think you will remember what you see.

c. Do you think that you will learn more about ecology, using virtual world simulations (game-like environments) and graphical representation? Why or why not?

Y: yeah I think so, it is a bit more engaging in like graphical because I am a visual learner so I like to see things but I still do like text to go with it but like bit more of a balance like not all text but not all graphics.

M: probably, I think because you are sort of involved in like making it all like interactive, then you are not like sitting passively in the classroom you can’t like day dream and not engage with the information it is better because you are like learning it.

8. If someone asked you “What do scientists do?” what would you tell them?
Y: Research, hypothesis

M: yeah, experiments.

9. How do scientists go about understanding what causes animals to become extinct?

Y: They go to the habitat where they lived and understand the area that they live in—the foods that they eat, and like the other species around them, and the human population.

M: yah, like the same thing like they could also sort of study species that are endangered and see what they think are in risk and becoming extinct and study what is happening and like that process.

Fourth Group (G4) Omosa Short-Interview

1. What do you remember about the virtual world “Omosa”?

Y: everything, I don’t know, like the reasons why the population of the yrent is declining

M: yeah I remember like everything the people said, all of the answers of the questions yeah like I think I remember all of them.

2. The challenge you were set was to identify the possible factors which might cause the animal population on Omosa to decline. How confident are you that you identified all the factors?

M: like pretty confident.

Y: 8 to 9 because I think maybe some of them can be elaborated a bit more.

3. Which, if any factor, is the most important in causing the decrease in the animal population in Omosa? Why?
M: I think the drought, because it affects the grass and the vegetation, there is nothing good to eat.

4. What did it feel like to use this approach as a method to assist you to understand ecology?

   a. Tell me about some positive aspects of the VLE “Omosa” in supporting your learning.

      M: I liked it because you see the environment, you could see like the colours of the grass and like the sky, and you like actually can see the physical environment and be able to move around it, so it is helpful; like a lot better than just like reading like dry grass, which like I would forgot in like 5 seconds

      Y: I like how you can ask people impressions and like we ask them if we forgot what they said.

   b. Tell me about some negative aspects of the VLE “Omosa” or about things that could have been improved or changed to support your learning.

      M: I think it is really good; I just think like you don’t know if what you are including from the information is correct, so I feel like missing something I guess.

      Y: for me it is just getting around, it is alright but like if I had to say anything negative it would have to navigate around to find people.

Fourth Group (G4) Omosa NetLogo Short-Interview

1. The challenge you were set was to identify the possible factors, which might cause the animal population on Omosa to decline. You decided to that YYY was important.
a. What did you do using NetLogo to test this relationship? Why did you do this?

*M: We changed the levels to see the impacts more clearly, because it is like if we keep it at low severity then we will not be able to see the major impact.

b. What did you find when you tested this factor using the NetLogo model? Does YYY have an impact on the number of animals? How do you know?

*Y: Both the factors had an impact on the decline, the first test that we did, we didn’t see that much human impact like for the hunting one for 30 there wasn’t much human impact then when it is 60 you can see the major impact that tells like no more yrents.

*How do you know?

*Y: from looking at the graphs.

2. What did it feel like to use this approach as a method to assist you to understand ecology?

   a. Tell me about some positive aspects of the NetLogo model to support your learning.

   *M: I like being able to change the independent variable and then see the result is good, see on the graph is good, you can see like sharp declines and increases something.

   b. Tell me about some negative aspects of the NetLogo model to support your learning.
Y and M: I am not sure, I can’t think of any….. it is pretty easy to use.

Fourth Group (G4) Post-Test Interview

1. List all impacts which negatively impact a particular ecosystem?

   - droughts
   - hunting & other human activities
   - logging
   - farming
   - natural disasters

2. Using as many of the terms as you can, construct a concept map about the adverse impact on animals in an area: Terms: ecosystem, predator, prey, herbivore, carnivore, plants, hunting, weather, drought, fire, birth rate, death rate, human impact, natural causes, habitat destruction, energy, introduced species.

   - Blank cards are provided if you want to use them to add any other terms that you feel can make sense. You don’t have to use all of the terms or all or any of the blank cards
   - Please label the connections
   - Two direction arrows can be used

3. Confidence in science: self-assessment of abilities in learning and understanding science

   a. On a scale of 1 (lowest) to 10 (highest), how would you rate your ability in science? Why?

      Y: 7

      M: yeah probably a 7
R: in this subject?

M: probably an 8.

Y: 8 yeah.

b. How would you rate your confidence that you will be able to learn to teach science to primary school students? Why?

Y: 8 and a half because I think I can do it but I haven’t actually done it, yeah I haven’t tried really learning science, I am not too sure if I can do it to like a 10, so at this point maybe an 8.5.

M: yeah I would say the same.

c. Do you think you will be more or less successful than other students in your study of the Science Concepts unit? Why?

If they don’t think they will be successful:

- What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

  Y: Equal, can we say equally, because I think a lot of us like are starting off with like basic knowledge of science and like barely any knowledge of science so we gonna all be like working toward the same thing.

  R: What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

  Y: lots of practice, just like maybe read from text books first and then once I get to handoff I can do like more activities that are more engaging afterwards. Practical thing are good.
M: I don’t think I will be less successful, I probably like equal, may be like a bit better because I like to because it is not something that I have lots of background and study so trying to study really hard.

What do you think you will need to do, so that you will be able to learn to teach science in a primary school? Why?

M: I think doing lots of practical activities can help because like you remember it longer.

4. Perceptions about ICT modes of presentation of information

a. Computers can be used to present and provide information in a number of different ways. On a scale of 1 (lowest) to 10 (highest), rate you perceptions of how easy it would be for you to learn science if the information was presented as:

i. Text

Y: 7

M: yeah I think a 6, because it is boring, it is just like it is hard you have to sort of construct like the images of it in your head it is hard to understand it of just reading it.

Y: the missing 3 to gets to 10 is because of I can’t visualize it like I can’t read it and like maybe remember the information for like short period of time.

ii. Pictures with title only

M: Probably like 5, like quite low because it is just a picture and you may not understand what it saying without words.
Y: I will go for like 5 or 6 as well because if you just learn from the picture you may not taking the science concept behind it.

iii. Graphs showing relationships between two factors

M: be like an 8 because in graph you sort of you can understand like the impacts and sort of like the relationship between things which is good.

Y: 6 or 7, I don’t like graphs.

iv. Virtual Learning Environment (VLE) like Omosa

Y: 8 because maybe because that is more like not a factual one it is kind of like made of, so like it may not reflect the real world.

M: I think a 9 because you can see everything and you can like investigate it yourself and ask the people questions and get all the information you need.

v. A graphical model which you can change and monitor the impact of changes on other factors like (NetLogo).

Y: yeah 9 because it is easy to see it is all laid out for you they draw the graphs and they also give you the numbers for that and you can kind of guess, they give you the impacts of all the... it is easy to relate when everything is just in front of you in one page.

M: I would say like a 7 because it is not as fun as the simulation one, it is easy to remember like when you actually can see like animals and like the world other than like the lines on a graph.
b. Do you think that you will learn more about ecology, using “Omosa” VLE and NetLogo model?? Why or why not?

_Y: NetLogo because I like visuals but like not for long, just enough to give me the picture, but like Omosa it is a bit too much work for me like you have to go through everything you collected whereas compared to NetLogo everything is there._

_M: I will say Omosa because I think it is more like you are sort of immersed and like be in ecology world, so it is sort of excited because all the concepts are there you can investigate the effects yourself so it is sort of satisfying to work it out and stuff._

5. If someone asked you “What do scientists do?” what would you tell them?

_M: investigate things._

_Y: They search, establish hypotheses and research it for any field._

6. How do scientists go about understanding what causes animals to become extinct?

_Y: make a hypothesis and then like independent and dependent variables and then test it over a period of time._

7. Which environment do you feel you learnt more about ecology and the factors that affect animal population; Omosa VE or the NetLogo model? Why?

_Y: the first one, Omosa, yeah because they actually give you paragraph information rather than the graphs, you have to make the connections yourself._

_M: yeah I would say Omosa probably the same reason because I think there is more information._
Appendix F: Participants’ Concept Maps

G1 pre concept map

G1 post concept map
G3 pre concept map

G3 post concept map
G4 pre concept map

G4 post concept map
Appendix G: Coding under all engagement categories in the two environments

**Table A1**
The frequency of contributions for all dyads during **Omosa the immersive session** (collaborative engagement, flow of engagement, and technical engagement categories):

<table>
<thead>
<tr>
<th>Omosa</th>
<th>Collaboration engagement</th>
<th>Flow of engagement / Non-Verbal</th>
<th>Flow of engagement / Verbal</th>
<th>Technical engagement / Negative</th>
<th>Technical engagement / Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>44</td>
<td>19</td>
<td>16</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>G2</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>G3</td>
<td>21</td>
<td>26</td>
<td>16</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>G4</td>
<td>12</td>
<td>15</td>
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</tr>
</tbody>
</table>

**Table A2**
The frequency of contributions for all dyads during **Omosa the immersive session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories):

<table>
<thead>
<tr>
<th>Omosa</th>
<th>Goal based explanation</th>
<th>Checking Understanding</th>
<th>Monitoring-Negative</th>
<th>Monitoring-Positive</th>
<th>Noticing Coherence</th>
<th>Paraphrasing</th>
<th>Principle based explanation</th>
</tr>
</thead>
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<td>28</td>
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<tr>
<td>G2</td>
<td>17</td>
<td>11</td>
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<td>24</td>
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**Table A3**
The frequency of contributions for all dyads during **Omosa NetLogo the modelling session** (collaborative engagement, flow of engagement, and technical engagement categories):

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</tr>
</thead>
<tbody>
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<tr>
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<td>0</td>
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**Table A4**
The frequency of contributions for all dyads during **Omosa NetLogo the modelling session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories):

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<th>Omosa NetLogo</th>
<th>Goal based explanation</th>
<th>Checking Understanding</th>
<th>Monitoring-Negative</th>
<th>Monitoring-Positive</th>
<th>Noticing Coherence</th>
<th>Paraphrasing</th>
<th>Principle based explanation</th>
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<td>18</td>
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</tbody>
</table>
### Table A5
The frequency of contributions for the first dyad (G1) during *Omosa the immersive session* (collaborative engagement, flow of engagement, and technical engagement categories):

<table>
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<th>Collaboration engagement</th>
<th>Flow of engagement / Non-Verbal</th>
<th>Flow of engagement / Verbal</th>
<th>Technical engagement / Negative</th>
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<tbody>
<tr>
<td>both</td>
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<td>Aimee</td>
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<tr>
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### Table A6
The frequency of contributions for the second dyad (G2) during *Omosa the immersive session* (collaborative engagement, flow of engagement, and technical engagement categories):

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<th></th>
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</tr>
<tr>
<td>Kristy</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alice</td>
<td>3</td>
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### Table A7
The frequency of contributions for the third dyad (G3) during *Omosa the immersive session* (collaborative engagement, flow of engagement, and technical engagement categories):

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<th>Collaboration engagement</th>
<th>Flow of engagement / Non-Verbal</th>
<th>Flow of engagement / Verbal</th>
<th>Technical engagement / Negative</th>
<th>Technical engagement / Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>both</td>
<td>21</td>
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<td>16</td>
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<td>1</td>
</tr>
<tr>
<td>Mia</td>
<td>12</td>
<td>15</td>
<td>7</td>
<td>0</td>
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</tr>
<tr>
<td>Lina</td>
<td>9</td>
<td>11</td>
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### Table A8
The frequency of contributions for the fourth dyad (G4) during *Omosa the immersive session* (collaborative engagement, flow of engagement, and technical engagement categories):

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</tr>
<tr>
<td>Elisa</td>
<td>8</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mary</td>
<td>4</td>
<td>5</td>
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<td>0</td>
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Table A9
The frequency of contributions for the first dyad (G1) during **Omosa the immersive session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories):

<table>
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<tr>
<th></th>
<th>Goal based explanation</th>
<th>Checking Understanding</th>
<th>Monitoring-Negative</th>
<th>Monitoring-Positive</th>
<th>Noticing Coherence</th>
<th>Paraphrasing</th>
<th>Principle based explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>both</td>
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<td>7</td>
<td>11</td>
<td>24</td>
<td>15</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>Aimee</td>
<td>22</td>
<td>6</td>
<td>7</td>
<td>12</td>
<td>11</td>
<td>23</td>
<td>19</td>
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<td>Tina</td>
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<td>4</td>
<td>12</td>
<td>4</td>
<td>12</td>
<td>9</td>
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</table>

Table A10
The frequency of contributions for the second dyad (G2) during **Omosa the immersive session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories):

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<th>Checking Understanding</th>
<th>Monitoring-Negative</th>
<th>Monitoring-Positive</th>
<th>Noticing Coherence</th>
<th>Paraphrasing</th>
<th>Principle based explanation</th>
</tr>
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<tbody>
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<td>both</td>
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<td>11</td>
<td>0</td>
<td>9</td>
<td>8</td>
<td>47</td>
<td>24</td>
</tr>
<tr>
<td>Kristy</td>
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<td>7</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>30</td>
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</table>

Table A11
The frequency of contributions for the third dyad (G3) during **Omosa the immersive session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories):

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<tr>
<th></th>
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<th>Checking Understanding</th>
<th>Monitoring-Negative</th>
<th>Monitoring-Positive</th>
<th>Noticing Coherence</th>
<th>Paraphrasing</th>
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<td>6</td>
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<td>16</td>
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<td>26</td>
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<tr>
<td>Mia</td>
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<td>5</td>
<td>7</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>Lina</td>
<td>14</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>8</td>
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Table A12
The frequency of contributions for the fourth dyad (G4) during **Omosa the immersive session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories):

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<th>Goal based explanation</th>
<th>Checking Understanding</th>
<th>Monitoring-Negative</th>
<th>Monitoring-Positive</th>
<th>Noticing Coherence</th>
<th>Paraphrasing</th>
<th>Principle based explanation</th>
</tr>
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<td>6</td>
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<td>32</td>
<td>17</td>
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<td>Elisa</td>
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<td>0</td>
<td>2</td>
<td>1</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Mary</td>
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<td>4</td>
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<td>10</td>
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</tbody>
</table>
### Table A13
The frequency of contributions for the first dyad (G1) during Omosa NetLogo the modelling session (collaborative engagement, flow of engagement, and technical engagement categories):

<table>
<thead>
<tr>
<th>G1</th>
<th>Collaboration engagement</th>
<th>Flow of engagement / Non-Verbal</th>
<th>Flow of engagement / Verbal</th>
<th>Technical engagement / Negative</th>
<th>Technical engagement / Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>both</td>
<td>50</td>
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<td>10</td>
<td>5</td>
<td>2</td>
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<tr>
<td>Aimee</td>
<td>32</td>
<td>11</td>
<td>8</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Tina</td>
<td>18</td>
<td>3</td>
<td>2</td>
<td>5</td>
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</table>

### Table A14
The frequency of contributions for the second dyad (G2) during Omosa NetLogo the modelling session (collaborative engagement, flow of engagement, and technical engagement categories):

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</thead>
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<td>0</td>
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<tr>
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### Table A15
The frequency of contributions for the third dyad (G3) during Omosa NetLogo the modelling session (collaborative engagement, flow of engagement, and technical engagement categories):

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<th>Technical engagement / Negative</th>
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</tr>
</thead>
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<td>9</td>
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</tr>
<tr>
<td>Mia</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Lina</td>
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### Table A16
The frequency of contributions for the fourth dyad (G4) during Omosa NetLogo the modelling session (collaborative engagement, flow of engagement, and technical engagement categories):

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</tr>
</thead>
<tbody>
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</tr>
<tr>
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<td>2</td>
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</tr>
<tr>
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</table>
Table A17
The frequency of contributions for the first dyad (G1) during **Omosa NetLogo the modelling session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories):

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<th>Goal based explanation</th>
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<th>Monitoring-Negative</th>
<th>Monitoring-Positive</th>
<th>Noticing Coherence</th>
<th>Paraphrasing</th>
<th>Principle based explanation</th>
</tr>
</thead>
<tbody>
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<td>both</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aimee</td>
<td>77</td>
<td>29</td>
<td>13</td>
<td>24</td>
<td>7</td>
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Table A18
The frequency of contributions for the second dyad (G2) during **Omosa NetLogo the modelling session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories)

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<th>Monitoring-Positive</th>
<th>Noticing Coherence</th>
<th>Paraphrasing</th>
<th>Principle based explanation</th>
</tr>
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<tbody>
<tr>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kristy</td>
<td>59</td>
<td>11</td>
<td>7</td>
<td>31</td>
<td>17</td>
<td>91</td>
<td>74</td>
</tr>
<tr>
<td>Alice</td>
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<td>2</td>
<td>21</td>
<td>13</td>
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</table>

Table A19
The frequency of contributions for the third dyad (G3) during **Omosa NetLogo the modelling session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories)

<table>
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<th>Goal based explanation</th>
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<th>Monitoring-Negative</th>
<th>Monitoring-Positive</th>
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</thead>
<tbody>
<tr>
<td>both</td>
<td></td>
<td></td>
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<tr>
<td>Mia</td>
<td>52</td>
<td>22</td>
<td>9</td>
<td>37</td>
<td>27</td>
<td>58</td>
<td>58</td>
</tr>
<tr>
<td>Lina</td>
<td>30</td>
<td>14</td>
<td>2</td>
<td>18</td>
<td>16</td>
<td>32</td>
<td>34</td>
</tr>
</tbody>
</table>

Table A20
The frequency of contributions for the fourth dyad (G4) during **Omosa NetLogo the modelling session** (goal based explanations, paraphrasing, principle based explanation, checking understanding, monitoring-negative, monitoring-positive and noticing coherence categories)

<table>
<thead>
<tr>
<th>G4</th>
<th>Goal based explanation</th>
<th>Checking Understanding</th>
<th>Monitoring-Negative</th>
<th>Monitoring-Positive</th>
<th>Noticing Coherence</th>
<th>Paraphrasing</th>
<th>Principle based explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>both</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elisa</td>
<td>28</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>31</td>
<td>18</td>
</tr>
<tr>
<td>Mary</td>
<td>18</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>19</td>
<td>10</td>
</tr>
</tbody>
</table>

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Appendix H: Participants Omosa Guidebooks

First Group (G1) Omosa Guidebook

*Phase one guidebook to accompany the VLE "Omosa"

*Student name:*
Letter from the Chief Scientist, IEIA

Dear Scientist,

Welcome to planet Omosa. My name is Dr. Sarah Newton and I am the Chief Scientist at the IEIA (Interplanetary Environmental Investigation Agency) in charge of environmental affairs affecting terrestrial type worlds. Recently, planet Omosa has been showing signs of ecosystem change. The indigenous people who live there have reported that the populations of certain species of animals, including those that are an important food source in their society, are declining.

The Omosans have agreed to allow scientists to come and study the situation. We think you can help our investigators and the people of Omosa in understanding their ecological crisis. During your trip, you will learn a lot about planet Omosa. The inhabitants know that you are coming and they are looking forward to talking with you.

The IEIA team and I are excited to be working with you in trying to solve these problems. Your main job is to conduct investigations into possible reasons for the animal population decline using your scientific knowledge and inquiry skills. I know you will do your very best job in helping to solve the mysteries of Omosa.

Sincerely,

Sarah Newton

Chief Scientist, Interplanetary Environmental Investigation Agency
Orientation
At the beginning you need to learn the basic skills of moving around Omosa. Here are the main areas and icons of the Omosa VW.

Navigation
You may navigate through Omosa using these keys:
- Arrow keys: use the arrow keys to move forward, backward, left, and right.
- Q key: use Q key to pan 360 degrees. Top view (bird eye view).
- Shift key + arrow keys: hold down shift plus arrow key to increase the speed
- Click the on screen map in the top left-hand corner of the Omosa screen to quickly travel around the island, such as the weather station, the research station, the hunting grounds, and the village.

When you click on the map, you will see an image like the one below.

- Click on the backpack icon and see what, if any, objects you have collected.
- Try moving around Omosa.
  - Can you talk to a character? How do you know if they can talk to you?
You will use observations to investigate Omosa ecosystem and investigate the relationships between the ecosystem components to answer the questions.

1. Do an initial exploration on planet Omosa. Make some brief notes below about things you observe as you explore.

   - Lypoa - (hunter) - hunts Yent for their meat
   - Omoseye - (overhunting) - hunted in reserves & sacred spaces
   - Yent - drought, few foraging, not reproducing enough

2. Can you think of the predator-prey based on your observation? Draw a food chain, which includes this predator-prey relationship. Identify the predator and the prey and what the arrows mean?

   - Omosa People (predator)
   - Yent (prey) (herbivores)
   - Grass & plants

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology? Why?

3 - 5

Faceless express
Root based reality
3. In certain areas on Omosa, there are patches of burnt out areas of bush alternating with clumps of dry grass (see images below). Think about:

![Image of burnt out areas of bush and clumps of dry grass]

a. Why this pattern is occurring?

Because of the burnoffs, where the plants are built up, some grassed areas burn more effectively. A dry fires promote some of the plants. The grass then becomes dry.

b. What it might mean for the survival of the animals.

The burn will leave its health deteriorated as there won’t be enough grass (drought) and it is not nutritious.

4. What do you think are three factors, which might be causing the decline of the animals on Omosa?

1. Drought
2. Overhunting by Amosa people
3. Lower breeding rates
5. As you know, the Chief Scientist would like to get information about what is impacting the predator-prey ecosystem on Omosa. Use the table below to summarise and organize your findings.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>The hunter Lyina. She’s usually in the village unless she is off on a hunting expedition. What does she say about the population of the animal?</td>
</tr>
<tr>
<td></td>
<td>It is declining.</td>
</tr>
<tr>
<td>b.</td>
<td>The wise old village man Omeweye. He’s usually in the village at a table holding consultations with villagers to resolve disputes. What does Omeweye say about Omosoan hunting practices? hunted on the reserves and sacred places.</td>
</tr>
<tr>
<td>c.</td>
<td>The climate scientist Zafirah. She is located in the weather station (click on the weather station in the map). What do you learn from her about the weather patterns on Omosa?</td>
</tr>
<tr>
<td></td>
<td>Wet and dry season; major changes in a drought 7-10 years and non-repeated events, severe and using emergency responses.</td>
</tr>
<tr>
<td>d.</td>
<td>The ecologist Charlie. He is located in the IEIA Research Lab (see the map for help). What does Charlie think about the declining animal populations?</td>
</tr>
<tr>
<td></td>
<td>Drought, fire farming and the breeding cycle all play a part in the population levels.</td>
</tr>
<tr>
<td>e.</td>
<td>Research Lab data book.</td>
</tr>
<tr>
<td>f.</td>
<td>Weather Station data book.</td>
</tr>
</tbody>
</table>

**Nov - March = generally heaviest rainfall**

Lots of change in rainfall (some months are as low as 1 mm)

---

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology?

5 - 7 (a bit better)
6. Based on your exploration of Omosa and the data you have collected, what would you put into the report to the chief scientist about what has caused the decline in the population of animals on Omosa?

Outline the points you would include in the space below. Provide any evidence you have to support each of your points.

- Major impact being because of the drought (arid), which means fewer
  and drier, less nutrients for them to eat and drink.
- Overhunting by the people, they don't stop wait for the breeding cycle: (Marine?
  Fire farming to worse become there's a drought now and it makes a huge impact.)
Second Group (G2) Omosa Guidebook

*Phase one guidebook to accompany the VLE “Omosa”*

*Student name:*

Page 1 of 7
Letter from the Chief Scientist, IEIA

Dear Scientist,

Welcome to planet Omosa. My name is Dr. Sarah Newton and I am the Chief Scientist at the IEIA (Interplanetary Environmental Investigation Agency) in charge of environmental affairs affecting terrestrial type worlds. Recently, planet Omosa has been showing signs of ecosystem change. The indigenous people who live there have reported that the populations of certain species of animals, including those that are an important food source in their society, are declining.

The Omosians have agreed to allow scientists to come and study the situation. We think you can help our investigators and the people of Omosa in understanding their ecological crisis. During your trip, you will learn a lot about planet Omosa. The inhabitants know that you are coming and they are looking forward to talking with you.

The IEIA team and I are excited to be working with you in trying to solve these problems. Your main job is to conduct investigations into possible reasons for the animal population decline using your scientific knowledge and inquiry skills. I know you will do your very best job in helping to solve the mysteries of Omosa.

Sincerely,

Sarah Newton

Chief Scientist, Interplanetary Environmental Investigation Agency
Orientation

At the beginning you need to learn the basic skills of moving around Omosa. Here are the main areas and icons of the Omosa VW.

Navigation

You may navigate through Omosa using these keys:

- Arrow keys: use the arrow keys to move forward, backward, left, and right.
- Q key: use Q key to pan 360 degrees. Top view (bird eye view) ????
- Shift key + arrow keys: hold down shift plus arrow key to increase the speed
- Click the on screen map in the top left-hand corner of the Omosa screen to quickly travel around the island, such as the weather station, the research station, the hunting grounds, and the village.

When you click on the map, you will see an image like the one below.

- Click on the backpack icon and see what, if any, objects you have collected.
- Try moving around Omosa.
  - Can you talk to a character? How do you know if they can talk to you?
You will use observations to investigate Omosa ecosystem and investigate the relationships between the ecosystem components to answer the questions.

1. Do an initial exploration on planet Omosa. Make some brief notes below about things you observe as you explore.

   Sunshine + clouds: Almost barren land. Lots of sand, not much grass. Omosa is an island. Water on island is low. Animals roaming free - deer, cats, species, etc. Reminds us of Africa.

2. Can you think of the predator-prey based on your observation? Draw a food chain, which includes this predator-prey relationship. Identify the predator and the prey and what the arrows mean?

   - Humans = predators
   - Cats = predators / prey
   - Deer = prey

   ![Food Chain Diagram]

   On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology? Why?

   5 - We can understand the basics of what we see in Omosa, but we still have a lot to observe and learn.
3. In certain areas on Omosa, there are patches of burnt out areas of bush alternating with clumps of dry grass (see images below). Think about:

a. Why this pattern is occurring?

Possibility of fire + human interaction (not nutritious)  
with land → Fire stick farming  
Increase in pollen in fire loving plants  
Which results in more 
also: drought

b. What it might mean for the survival of the animals.

Dry grassy will not feed deer which leads to extinction then cats can’t feed: possibility of wiping out food chain.

4. What do you think are three factors, which might be causing the decline of the animals on Omosa?

1. Human impact (fire stick farming)
2. Drought (less rainfall)
3. Lack of variety of food.
5. As you know, the Chief Scientist would like to get information about what is impacting the predator-prey ecosystem on Omosa. Use the table below to summarise and organize your findings.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>The hunter Lyina. She’s usually in the village unless she is off on a hunting expedition. What does she say about the population of the animal?</td>
</tr>
<tr>
<td></td>
<td>TOO DRY + GRASS IS NOT GOOD – NOT RELATED TO HUMAN IMPACT</td>
</tr>
<tr>
<td>b.</td>
<td>The wise old village man Omeweye. He’s usually in the village at a table holding consultations with villagers to resolve disputes. What does Omeweye say about Omosan hunting practices?</td>
</tr>
<tr>
<td></td>
<td>GENERATIONS LOST ‘OLD WAYS’, LOST FEAR OF INVASING SACRED PLACES, LOST RESPECT</td>
</tr>
<tr>
<td>c.</td>
<td>The climate scientist Zafirah. She is located in the weather station (click on the weather station in the map). What do you learn from her about the weather patterns on Omosa?</td>
</tr>
<tr>
<td></td>
<td>CYCLICAL PATTERN OF WET + DRY SEASONS (600) CHANGES EVERY 7-10 YRS + DROUGHT</td>
</tr>
<tr>
<td>d.</td>
<td>The ecologist Charlie. He is located in the IEIA Research Lab (see the map for help). What does Charlie think about the declining animal populations?</td>
</tr>
<tr>
<td></td>
<td>DROUGHT - SOIL IS POOR + DRY GRASS NOT NUTRITIOUS NOT SAME REPRODUCTION NUMBERS</td>
</tr>
<tr>
<td>e.</td>
<td>Research Lab data book.</td>
</tr>
<tr>
<td></td>
<td>CATS DISAPPEARING – CONSISTANT. WHEN GRASS PEAKS, YERENT DROP</td>
</tr>
<tr>
<td>f.</td>
<td>Weather Station data book.</td>
</tr>
<tr>
<td></td>
<td>CYCLICAL PATTERN - MONTHS ARE NOT CONSISTENT EACH YR BUT PATTERN CONTINUES</td>
</tr>
</tbody>
</table>

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology?
6. Based on your exploration of Omosa and the data you have collected, what would you put into the report to the chief scientist about what has caused the decline in the population of animals on Omosa?

Outline the points you would include in the space below. Provide any evidence you have to support each of your points.

A mix of drought, cyclical weather patterns, and lack of food. Deer are not reproducing in same numbers. Humans continue to have fires which does not produce nutrient-rich food. Lack of new plants means deer cannot eat.
Phase one guidebook to accompany the VLE "Omosa"
Letter from the Chief Scientist, IEIA

Dear Scientist,

Welcome to planet Omosa. My name is Dr. Sarah Newton and I am the Chief Scientist at the IEIA (Interplanetary Environmental Investigation Agency) in charge of environmental affairs affecting terrestrial type worlds. Recently, planet Omosa has been showing signs of ecosystem change. The indigenous people who live there have reported that the populations of certain species of animals, including those that are an important food source in their society, are declining.

The Omosans have agreed to allow scientists to come and study the situation. We think you can help our investigators and the people of Omosa in understanding their ecological crisis. During your trip, you will learn a lot about planet Omosa. The inhabitants know that you are coming and they are looking forward to talking with you.

The IEIA team and I are excited to be working with you in trying to solve these problems. Your main job is to conduct investigations into possible reasons for the animal population decline using your scientific knowledge and inquiry skills. I know you will do your very best job in helping to solve the mysteries of Omosa.

Sincerely,

Sarah Newton

Chief Scientist, Interplanetary Environmental Investigation Agency
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- Q key: use Q key to pan 360 degrees.
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When you click on the map, you will see an image like the one below.

- Click on the backpack icon and see what, if any, objects you have collected.
- Try moving around Omosa.
  - Can you talk to a character? How do you know if they can talk to you?
You will use observations to investigate Omosa ecosystem and investigate the relationships between the ecosystem components to answer the questions.

1. Do an initial exploration on planet Omosa. Make some brief notes below about things you observe as you explore.
   - Location: grassland, lots of entelephes, dry, hot, humidity, vultures
   - Village: social environment, huts, dry
   - Modern: lab, modern
   - Weather: sunny, equipment amongst the people, inhabitants

2. Can you think of the predator-prey based on your observation? Draw a food chain which includes this predator-prey relationship. Identify the predator and the prey and what the arrows mean?

   ![Food Chain Diagram]

   On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology? Why?
   - Rate: 5
   - Reason: need more information

   If your confidence is 5 or more then:
   What features of Omosa do you think will help you in responding to the chief scientist?
   - Talking to the people, and reading the books

   If your confidence is less than 5 then:
   What do you think you need to do to improve your confidence?
   - More information

   [Signature]

   [Date]
3. In certain areas on Omosa, there are patches of burnt out areas of bush alternating with clumps of dry grass (see images below). Think about:

![Image of burnt and dry grass areas]

a. Why this pattern is occurring?

   Caused by firestick farming

b. What it might mean for the survival of the animals.

   Less food for the Yearat → More deaths of Yearat (dying out)

   Less food for Toolu & People

4. What do you think are three factors, which might be causing the decline of the animals on Omosa?

   Over Hunting

   1. Less food – grass available because cleared for firestick farming

   2. Less food – type of grass growing is drier (more suited to firestick farming but not to animal’s taste)

   3. Less food – type of grass growing is drier (more suited to firestick farming but not to animal’s taste)

   Also Drought
5. As you know, the Chief Scientist would like to get information about what is impacting the predator-prey ecosystem on Omosa. Use the table below to summarise and organize your findings.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| a. | The hunter Lyina. She’s usually in the village unless she is off on a hunting expedition. What does she say about the population of the animals?  
  Yeasnt are dying out |
| b. | The wise old village man Omeweye. He’s usually in the village at a table holding consultations with villagers to resolve disputes. What does Omeweye say about Omosan hunting practices?  
  They would hunt only in certain places before but now they hunt everywhere |
| c. | The climate scientist Zafirn. She is located in the weather station (click on the weather station in the map). What do you learn from her about the weather patterns on Omosa?  
  Cause by change in vegetation from fire stick farming + drought, Yeasnt aren't reproducing at same rate as before |
| d. | The ecologist Charlie. He is located in the IEIA Research Lab (see the map for help). What does Charlie think about the declining animal populations?  
  Tree ring width decreased over time |
| e. | Research Lab data book.  
  Tree ring width decreased over time |
| f. | Weather Station data book. |

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology? Why?

4

L= 4  M= 9

Page 6 of 7
If you feel better (your confidence has increased or stayed) please write down what have you done in Omosa has made you more confident.

Talking to more people - gives more knowledge

If your confidence has decreased, what else do you think you need to know/do to improve your confidence?

6. Based on your exploration of Omosa and the data you have collected what would you put into the report to the chief scientist about what has caused the decline in the population of animals on Omosa?

Outline the points you would include in the space below. Provide any evidence you have to support each of your points.

Fire stick farming - caused area to be cleared of grass (food for yeewat) + new fire tolerant flowering plants more dominant (not good food)

Drought

Outsourcing - not respecting reserve (sacred place)

Hard for yeewat to survive & stress has causes less young to be born

Knowledge from reading data books + talking to village people & scientists
Fourth Group (G4) Omosa Guidebook

Phase one guidebook to accompany the VLE "Omosa"

Student name:
Letter from the Chief Scientist, IEIA

Dear Scientist,

Welcome to planet Omosa. My name is Dr. Sarah Newton and I am the Chief Scientist at the IEIA (Interplanetary Environmental Investigation Agency) in charge of environmental affairs affecting terrestrial type worlds. Recently, planet Omosa has been showing signs of ecosystem change. The indigenous people who live there have reported that the populations of certain species of animals, including those that are an important food source in their society, are declining.

The Omosans have agreed to allow scientists to come and study the situation. We think you can help our investigators and the people of Omosa in understanding their ecological crisis. During your trip, you will learn a lot about planet Omosa. The inhabitants know that you are coming and they are looking forward to talking with you.

The IEIA team and I are excited to be working with you in trying to solve these problems. Your main job is to conduct investigations into possible reasons for the animal population decline using your scientific knowledge and inquiry skills. I know you will do your very best job in helping to solve the mysteries of Omosa.

Sincerely,

Sarah Newton

Chief Scientist, Interplanetary Environmental Investigation Agency
**Orientation**

At the beginning you need to learn the basic skills of moving around Omosa. Here are the main areas and icons of the Omosa VW.

**Navigation**

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- Arrow keys: use the arrow keys to move forward, backward, left, and right.
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- Click the on screen map in the top left-hand corner of the Omosa screen to quickly travel around the island, such as the weather station, the research station, the hunting grounds, and the village.

When you click on the map, you will see an image like the one below.

- Click on the backpack icon and see what, if any, objects you have collected.
- Try moving around Omosa.
  - Can you talk to a character? How do you know if they can talk to you?
You will use observations to investigate Omosa ecosystem and investigate the relationships between the ecosystem components to answer the questions.

1. Do an initial exploration on planet Omosa. Make some brief notes below about things you observe as you explore.
   * Most people that are hunted
   * The land is quite dry and very few plants

2. Can you think of the predator-prey based on your observation? Draw a food chain which includes this predator-prey relationship. Identify the predator and the prey and what the arrows mean?

   [Diagram of food chain: Predator - Toxoa → Prey - Yemt → Toxoa → Villagers for meat / Yemt → Plants]

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology? Why?

If your confidence is 5 or more then:

What features of Omosa do you think will help you in responding to the chief scientist?

If your confidence is less than 5 then:

What do you think you need to do to improve your confidence?

* Some way of confirmation of being right or wrong
* Asking more questions
3. In certain areas on Omosa, there are patches of burnt out areas of bush alternating with clumps of dry grass (see images below). Think about:

![Image of burnt and dry vegetation]

a. Why this pattern is occurring:

- Constant drought and fires can cause this decreased density of other deposits from firestick farming.
- Without steady rains, grasses go brown and dry.

b. What it might mean for the survival of the animals:

- Less chance of survival because their only food source has become less nutritious.
- Their survival may need to depend more on what the villagers can provide for them.

4. What do you think are three factors, which might be causing the decline of the animals on Omosa?

1. Hunting - by humans & Toon
2. Drought - and climate affects food source
3. Decline in birth rate
5. As you know, the Chief Scientist would like to get information about what is impacting the predator-prey ecosystem on Omosa. Use the table below to summarise and organize your findings.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. The hunter Lyina. She’s usually in the village unless she is off on a hunting expedition. What does she say about the population of the animals?</td>
<td>The people started to hunt anywhere.</td>
</tr>
<tr>
<td>b. The wise old village man Omeweyc. He’s usually in the village at a table holding consultations with villagers to resolve disputes. What does Omeweyc say about Omosan hunting practices?</td>
<td>Restricted hunting area. But then people started to hunt anywhere.</td>
</tr>
<tr>
<td>c. The climate scientist Zafirah. She is located in the weather station (click on the weather station in the map). What do you learn from her about the weather patterns on Omosa?</td>
<td>Dry seasons unpredictable. Currently in a drought.</td>
</tr>
<tr>
<td>d. The ecologist Charlie. He is located in the IEIA Research Lab (see the map for help). What does Charlie think about the declining animal populations?</td>
<td>Increasing desert and arid zones, increased fire-stick farming, droughts affected the soil &amp; quarry.</td>
</tr>
<tr>
<td>e. Research Lab data book.</td>
<td>When fire is less, grass does burn, so yam is eating it. Hence more abundance of yam during that time. When there are more humans, the animals decrease.</td>
</tr>
<tr>
<td>f. Weather Station data book.</td>
<td>Dry season hard to predict. No particular pattern. Either lots of rainfall or very little.</td>
</tr>
</tbody>
</table>

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology? Why? 6-7 because this activity allowed us to gather and analyse the information together.
If you feel better (your confidence has increased or stayed) please write down what have you done in Omose has made you more confident.

- Asking more questions and putting the answers together, working out trends and patterns.
- Repeatedly asked the same questions and became more familiar with it.

If your confidence has decreased, what else do you think you need to know/do to improve your confidence?

________________________________________________________________________________________

________________________________________________________________________________________

6. Based on your exploration of Omose and the data you have collected what would you put into the report to the chief scientist about what has caused the decline in the population of animals on Omose?

Outline the points you would include in the space below. Provide any evidence you have to support each of your points.

The drought caused by the lack of rain and unpredictable weather. In addition, the fire-stick farming affected the quality of the grass, causing it to go burnt. The changing hunting practice of the villagers, where they have become less restricted to where they can hunt.

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________
Appendix I: Participants Omosa NetLogo Guidebooks

First Group (G1) Omosa NetLogo Guidebook

*Phase two guidebook to accompany the Omosa NetLogo model*

*Student name:*
Introducing computational experiments using NetLogo

Many areas of modern science use computer models to run experiments—sometimes called computational experiments or simulations. These computer experiments are usually based on data scientists have collected from observations. Scientists can use such a model to carry out virtual experiments by changing an independent variable and taking measurements of the dependent variable in the computational experiment. Each time the scientist runs a virtual experiment, the mathematic model in the computer program can calculate changes in the relative numbers of animals and plants. This means that scientists can use a mathematic model to test their ideas about the factors impacting an ecosystem.

You will use a powerful computer modeling program called NetLogo to run computational experiments about Omosa. Below you will find a screenshot of the NetLogo model for Omosa world.

To run a simulation, you go through the following procedure:
1. Press the SETUP button.
2. Press the GO button to begin the simulation.
3. Look at the monitors to see the current population sizes.
4. Look at the POPULATIONS plot to watch the populations fluctuate over time.

To stop and start the simulation click the GO button.
1. Run the simulation twice (1. The pilot simulation and 2. The experimental simulation) with the default settings listed in the previous steps. Stop the run in different stages (by clicking the GO button):

a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The pilot simulation</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td>2. The experimental simulation</td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
</tbody>
</table>

b. Describe the most common pattern for the various populations you have observed

Tennis population: slowly increase, frequently increase in number, then decrease to a level below that of the other populations.

2. Population: __________

__________________________________________

c. Explain why this pattern is occurring.

Tennis rate: the speed is on the up, numbers increase, the sport becomes more popular.

2. Population: __________

__________________________________________

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology?

- G  
- H  
- E  
- M  

390
In the model, there are sliders to set and adjust (see picture below) the three initial population parameters of interest:

- Initial number of Yernts
- Initial numbers of Toorus
- Initial numbers of Omosan people

There are also on-off switches (see picture below) that allow you to manipulate the independent variables:

- Drought
- Fire-stick farming
- Hunting

In the next phase you will have an opportunity to test two of these independent variables.

2. After reviewing reports from research teams on Omosa, the Chief Scientist has decided that there are several experiments that could be done in order to find out more about the possible causes of the decline of the population of animals. One possibility is that the decline in the population has a natural cause – the ongoing drought. Another possibility is that one of the Omosans’ practices such as fire stick farming or the over hunting are causing the decline in the population of animals.

In the next stage in this study you will test some of these possibilities using the NetLogo model.
Study 1: Testing how drought impacts on the population of animals.

In this study you will examine how a long period of drought might impact on the population of animals.

Before running the experiment think about why the drought might cause a decrease in the population of animals.

- Not enough 
  - water
  - food

Scientists test their ideas by writing testable questions. Please specify the design for your experiment by filling in the table below. Some parts have already been completed for you.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research question.</td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td>Does the level of drought impact</td>
<td></td>
</tr>
<tr>
<td>the population of the animals?</td>
<td></td>
</tr>
<tr>
<td>2. Your hypothesis.</td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
<tr>
<td>if there is an increase in the level of</td>
<td>if there is ________</td>
</tr>
<tr>
<td>drought, then the population will decrease</td>
<td>then ________</td>
</tr>
<tr>
<td>because there is less available food + water</td>
<td>because ________</td>
</tr>
<tr>
<td>3. Independent variable.</td>
<td>The independent variable is an “if”—it is what may cause the change.</td>
</tr>
<tr>
<td>drought severity level</td>
<td></td>
</tr>
<tr>
<td>4. Dependent variable.</td>
<td>The dependent variable is the “then”—it is the thing that you measure.</td>
</tr>
<tr>
<td>population</td>
<td></td>
</tr>
</tbody>
</table>
- Turn the **drought** switch “On”, set the **drought severity level** to 20 or 30 and run the model two times

- Conduct two runs using the same settings

  a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Run 1</strong></td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
</tr>
<tr>
<td><strong>Run 2</strong></td>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
<td><img src="image6.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

b. What do you notice about the pattern of on the graph and the relative numbers of Yerrt, Toorus, and the amount of grass for each of these runs of the model?

As the severity increases, the populations particularly *Grasses + yeast* decrease rapidly, while you get increases on *Grasses* the yeast increase briefly afterward.
c. Is this what you expected? Why or why not?

- Yes - it makes sense that if there is less food available, there will be lower survival rates.

Now increase the severity of the drought to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yerms, Toorns, and the amount of grass?

- Decrease dramatically

b. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td>Run 2</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

C. What has changed in the pattern and why might this occur?

- Population dropped much more dramatically and continued lower.
What would you report to the chief scientist? Is the drought contributing to the decline in the population of the animals? What evidence do you have to support your answer?

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding the factors impacting the population of animal in an ecosystem?

You can now examine the impact the Omosans might be having on the size of the animal populations. You need to choose one of the following possibilities:

**Study 2:** Is it likely to be the fire-stick farming that is causing the decline in the population of the animals?

**Study 3:** Is it likely to be the hunting practices of the Omosans that are causing the decline in the animal population?

You can use the work you did for Study 1 as a guide to assist you answer the questions.

- Go to the next page if you decide to do Study 2 (fire-stick farming)
- Go to page 12 if you decide to do Study 3 (hunting practices)
**Study 2:** In this study you will examine the impact of **fire stick farming** on the population of the animals.

Remember to turn the drought off and turn on the fire stick farming.

Please specify the design for your experiment by filling in the table below.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research question.</td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td>Does the <strong>fire stick farming</strong> impact the population of the animals?</td>
<td></td>
</tr>
</tbody>
</table>
| 2. Your hypothesis.               | The hypothesis is what you think will happen and why, in this general format:
| if there is an increase in the percent-burned-grass | 
| then _____________________________ | then _____________________________ because _____________________________ |
| because __________________________ | |
| 3. Independent variable.          | The independent variable is an "if"—it is what causes the change. |
| _____________________________     | |
| 4. Dependent variable.            | The dependent variable is the "then"—it is the thing that you measure. |
| _____________________________     | |
- Turn the **fire stick farming** switch "On", set the **percent-burned-grass** to 30 and run the model.
- Conduct two runs using the same settings.
  - a. Draw the graph for three different stages in each run.

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- b. What do you notice about the pattern of the graph and the relative numbers of Yernt, Toorus, and the amount of grass for each of these runs of the model?
  
  - c. Is this what you expected? Why or why not?
  
  -
Now change the level of percent-burned-grass to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

b. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c. What has changed in the pattern and why might this occur?

What would you report to the chief scientist? Is the fire stick farming contributing to the decline in the population of the animals? What evidence do you have to support your answer?

Go to page 15
Study 3: In this study you will examine the impact of the Omosans' hunting practices on the population of animals. The Omosans don't change their hunting practices but the size of the Omsan population determines how many animals are killed in each hunt.

Remember to turn the drought and the fire stick farming switches to off.

Please specify the design for your experiment by filling in the table below.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Research question.</td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td>Do the hunting practices impact the population of the animals?</td>
<td></td>
</tr>
<tr>
<td>2. Your hypothesis.</td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
<tr>
<td>if there is an increase in the Omosans then there will be a decrease in your? because they will need to hunt more.</td>
<td>if there is then because</td>
</tr>
<tr>
<td>3. Independent variable.</td>
<td>The independent variable is an &quot;if&quot;—it is what causes the change.</td>
</tr>
<tr>
<td>population of Omosans</td>
<td></td>
</tr>
<tr>
<td>4. Dependent variable.</td>
<td>The dependent variable is the &quot;then&quot;—it is the thing that you measure.</td>
</tr>
<tr>
<td>population of year</td>
<td></td>
</tr>
</tbody>
</table>
- Turn the omosan switch “On”, set the initial-number-omosans to 20 or 30, and run the model.
- Conduct two runs using the same settings
  a. Draw the graph for three different stages in each run.

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. What do you notice about the pattern on the graph and the relative numbers of Yermi, Toorus, and the amount of grass for each of these runs of the model?

The model suggests that the prey population, actually measured, did not impact negatively.

Nothing just mainly impacted by grass levels.

c. Is this what you expected? Why or why not?

Not expected more omosan to increase hunting in this year.
Now change the level of **initial-number-Omosans** to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

Yernts to decrease
Toorus remains about the same
Grass increases a little

b. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
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<tbody>
<tr>
<td>Run 1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Run 2</td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(c) What has changed in the pattern and why might this occur?

Grass increases dramatically due to yernts being too many
Toorus died out as there was no grass to eat
Yernts & Toorus all dead

What would you report to the chief scientist? Are the Omosan hunting activities contributing to the decline in the population of the animals? What evidence do you have to support your answer?

Yes - as yernts increase (200 to 600)
You can generally expect there to be a decrease of yernts population which negatively impacts the toorus while the grass increases on there's nothing eating it.
Are there any other tests you would like to make before you create your report for the Chief Scientist? Why?

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding the factors impacting the population of animal in an ecosystem?

What would put into the report to the chief scientist about what has caused the decline in the population of animals on Omosa?
Phase two guidebook to accompany the Omosa NetLogo model
Introducing computational experiments using NetLogo

Many areas of modern science use computer models to run experiments—sometimes called computational experiments or simulations. These computer experiments are usually based on data scientists have collected from observations. Scientists can use such a model to carry out virtual experiments by changing an independent variable and taking measurements of the dependent variable in the computational experiment. Each time the scientist runs a virtual experiment, the mathematic model in the computer program can calculate changes in the relative numbers of animals and plants. This means that scientists can use a mathematic model to test their ideas about the factors impacting an ecosystem.

You will use a powerful computer modeling program called NetLogo to run computational experiments about Omosa. Below you will find a screenshot of the NetLogo model for Omosa world.

To run a simulation, you go through the following procedure:
1. Press the SETUP button.
2. Press the GO button to begin the simulation.
3. Look at the monitors to see the current population sizes.
4. Look at the POPULATIONS plot to watch the populations fluctuate over time.

To stop and start the simulation click the GO button.
1. Run the simulation twice (1. The pilot simulation and 2. The experimental simulation) with the default settings listed in the previous steps. Stop the run in different stages (by clicking the GO button):

a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The pilot simulation</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td>2. The experimental simulation</td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
</tbody>
</table>

b. Describe the most common pattern for the various populations you have observed

- **Tooth** - steady increase
- **Grass + yeasts** correlate - when grass increases - it affects the decrease of yeasts

---

c. Explain why this pattern is occurring.

- Yeasts die from lack of food / grass
- Then grass grows and yeasts return to eat it again

---

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology?

8 - Adi
7 - Kate

We can see the patterns + direct relation.
In the model, there are sliders to set and adjust (see picture below) the three initial population parameters of interest:

- Initial number of Yernts
- Initial numbers of Toorus
- Initial numbers of Omosan people

There are also on-off switches (see picture below) that allow you to manipulate the independent variables:

- Drought
- Fire-stick farming
- Hunting

In the next phase you will have an opportunity to test two of these independent variables.

2. After reviewing reports from research teams on Omosa, the Chief Scientist has decided that there are several experiments that could be done in order to find out more about the possible causes of the decline of the population of animals. One possibility is that the decline in the population has a natural cause – the ongoing drought. Another possibility is that one of the Omosans’ practices such as fire stick farming or the over hunting are causing the decline in the population of animals.

In the next stage in this study you will test some of these possibilities using the NetLogo model.
**Study 1**: Testing how drought impacts on the population of animals.

In this study you will examine how a long period of **drought** might impact on the population of animals.

Before running the experiment think about why the drought might cause a decrease in the population of animals.

- Lack of food + water
- Adjusting to different environment
- Poor soil to reproduce plants + food
- Death of other species

Scientists test their ideas by writing testable questions. Please specify the design for your experiment by filling in the table below. Some parts have already been completed for you.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Research question.</strong>&lt;br&gt;Does the level of drought impact the population of the animals?</td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td><strong>2. Your hypothesis.</strong>&lt;br&gt;if there is an increase in the level of drought, then <strong>yerns will decrease in pop</strong>, because <strong>grass is not being reproduced</strong>.</td>
<td>The hypothesis is what you think will happen and why, in this general format: if there is ________, then ________, because ________.</td>
</tr>
<tr>
<td><strong>3. Independent variable.</strong>&lt;br&gt;drought severity level</td>
<td>The independent variable is an “if”—it is what may cause the change.</td>
</tr>
<tr>
<td><strong>4. Dependent variable.</strong>&lt;br&gt;decrease in yerns</td>
<td>The dependent variable is the “then”—it is the thing that you measure.</td>
</tr>
</tbody>
</table>
- Turn the **drought** switch "On", set the **drought severity level** to 20 or 30 and run the model two times
- Conduct two runs using the same settings
  a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td>Run 2</td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
</tbody>
</table>

b. What do you notice about the pattern of on the graph and the relative numbers of Yern, Toorus, and the amount of grass for each of those runs of the model?

---

**Toorus remains stable in growth.** Yern increase as grass decreases but a spike suggests they re-discover grass as a food source, and may have found another food source elsewhere which allowed for the grass to grow.
c. Is this what you expected? Why or why not?

No, we thought that yernts and grass would directly correlate, but animal adapts to environment.

Now increase the severity of the drought to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

Grass may not reproduce due to severity.
Yernts may not reproduce due to lack of food + new conditions.
Toorus may also decrease.

b. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 2</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y</td>
</tr>
</tbody>
</table>

c. What has changed in the pattern and why might this occur?

Drought is so severe that there is no time for a gradual shift in numbers. Grass supply is so low that starvation becomes a direct effect.
What would you report to the chief scientist? Is the drought contributing to the decline in the population of the animals? What evidence do you have to support your answer?

From Exp. 1 to 2, the yeast levels dramatically dropped as a direct cause of the severity of the drought which suggests a lack of feed. Our evidence is based on 2 experiments which altered the severity of the drought from 20 to 60.

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding the factors impacting the population of animal in an ecosystem?

8 - We can see what has happened and make sense of our understanding.

You can now examine the impact the Omosans might be having on the size of the animal populations. You need to choose one of the following possibilities:

**Study 2:** Is it likely to be the fire-stick farming that is causing the decline in the population of the animals?

**Study 3:** Is it likely to be the hunting practices of the Omosans that are causing the decline in the animal population?

You can use the work you did for Study 1 as a guide to assist you answer the questions.

- Go to the next page if you decide to do Study 2 (fire-stick farming)
- Go to page 12 if you decide to do Study 3 (hunting practices)
Study 2: In this study you will examine the impact of **fire stick farming** on the population of the animals.

Remember to turn the **drought off** and turn **on the fire stick farming**.

Please specify the design for your experiment by filling in the table below.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
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</thead>
<tbody>
<tr>
<td>1. Research question.</td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td>Does the <strong>fire stick farming</strong> impact the population of the animals?</td>
<td></td>
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<tr>
<td>2. Your hypothesis.</td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
<tr>
<td>if there is an increase in the percent-burned-grass</td>
<td></td>
</tr>
<tr>
<td>then</td>
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</tr>
<tr>
<td>because</td>
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<tr>
<td>4. Dependent variable.</td>
<td>The dependent variable is the &quot;then&quot;—it is the thing that you measure.</td>
</tr>
</tbody>
</table>
- Turn the **fire stick farming** switch "On", set the **percent-burned-grass** to 30 and run the model
- Conduct two runs using the same settings
  a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Run 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. What do you notice about the pattern of the graph and the relative numbers of Yern, Toorus, and the amount of grass for each of these runs of the model?

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b. What do you notice about the pattern of the graph and the relative numbers of Yern, Toorus, and the amount of grass for each of these runs of the model?
Now change the level of **percent-burned-grass** to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

b. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
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<td>Run 1</td>
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</tr>
<tr>
<td>Run 2</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

c. What has changed in the pattern and why might this occur?

What would you report to the chief scientist? Is the **fire stick farming** contributing to the decline in the population of the animals? What evidence do you have to support your answer?

Go to page 15
Study 3: In this study you will examine the impact of the **Omosans’ hunting** practices on the population of animals. The Omosans don’t change their hunting practices but the size of the Omosan population determines how many animals are killed in each hunt.

Remember to turn the drought and the fire stick farming switches to off.

Please specify the design for your experiment by filling in the table below.

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<td>Do the hunting practices impact the population of the animals?</td>
<td></td>
</tr>
<tr>
<td>2. Your hypothesis.</td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
<tr>
<td>if there is an increase in the Omosans then <strong>yernts + troons</strong> will decrease because <strong>omosans are hunting for food</strong></td>
<td>If there is:</td>
</tr>
<tr>
<td></td>
<td>then</td>
</tr>
<tr>
<td></td>
<td>because</td>
</tr>
<tr>
<td>3. Independent variable.</td>
<td>The independent variable is an “if”—it is what causes the change.</td>
</tr>
<tr>
<td><strong>Pop. of omosans</strong></td>
<td></td>
</tr>
<tr>
<td>4. Dependent variable.</td>
<td>The dependent variable is the “then”—it is the thing that you measure.</td>
</tr>
<tr>
<td><strong>Place</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Pop. of yernts + troons</strong></td>
<td></td>
</tr>
</tbody>
</table>

12
Turn the omosan switch “On”, set the initial-number-omosans to 20 or 30 and run the model.

Conduct two runs using the same settings

a. Draw the graph for three different stages in each run

b. What do you notice about the pattern on the graph and the relative numbers of Yerits, Toorus, and the amount of grass for each of these runs of the model?

- Osomans remain stable.
- Toorus remain steady with gradual decline in 2 when Toorus decline, grass increases dramatically from normal.
- Yerits initially decrease but grass↑ allows for mass reproduction
- Osomans hunt to almost extinction  reproduction

C. Is this what you expected? Why or why not?

No - expected both animals to drop completely due to hunting from Osomans.
Yerits can survive as long as right environment + food.
Now change the level of \textbf{initial-number-Omosans} to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

- Toorus to become extinct
- Yernts struggle to repopulate quickly enough so decline in population - less spikes.

b. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="graph1.png" alt="" /></td>
<td><img src="graph2.png" alt="" /></td>
<td><img src="graph3.png" alt="" /></td>
</tr>
</tbody>
</table>

c. What has changed in the pattern and why might this occur?

- Yernts cannot repopulate quickly enough so became extinct in Stage 2 which also meant a decrease in Toorus but not total extinction.
- Grass prospers from no yearnts to consume.

What would you report to the chief scientist? Are the Omosan hunting activities contributing to the decline in the population of the animals? What evidence do you have to support your answer?

Yes. Hunting directly affected the extinction. Declines of Toorus + Yernts due to excessive killing + not allowing time for the animals to reproduce + conserve their species. There needs to be a balance between nature + the Omosans.
Are there any other tests you would like to make before you create your report for the Chief Scientist? Why?

- Run the same tests at least 3 times for more accurate results

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding the factors impacting the population of animal in an ecosystem?

9 - Our predictions matched expectations + understanding.

What would put into the report to the chief scientist about what has caused the decline in the population of animals on Omosa?

Everything impacts. We need to educate the Omosans on balancing + reproduction. Possibly introduce new techniques to effectively farm + hunt. Also effects of draught + how to adapt.
Third Group (G3) Omosa NetLogo Guidebook

*Phase two guidebook to accompany the Omosa NetLogo model*

*Student name:*

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Introducing computational experiments using NetLogo

Many areas of modern science use computer models to run experiments—sometimes called computational experiments or simulations. These computer experiments are usually based on data scientists have collected from observations. Scientists can use such a model to carry out virtual experiments by changing an independent variable and taking measurements of the dependent variable in the computational experiment. Each time the scientist runs a virtual experiment, the mathematic model in the computer program can calculate changes in the relative numbers of animals and plants. This means that scientists can use a mathematic model to test their ideas about the factors impacting an ecosystem.

You will use a powerful computer modeling program called NetLogo to run computational experiments about Omosa. Below you will find a screenshot of the NetLogo model for Omosa world.

To run a simulation, you go through the following procedure:
1. Press the SETUP button.
2. Press the GO button to begin the simulation.
3. Look at the monitors to see the current population sizes
4. Look at the POPULATIONS plot to watch the populations fluctuate over time

To stop and start the simulation click the GO button
1. Run the simulation twice (1. The pilot simulation and 2. The experimental simulation) with the default settings listed in the previous steps. Stop the run in different stages (by clicking the GO button):

   a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
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<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The pilot simulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. The experimental simulation</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

b. Describe the most common pattern for the various populations you have observed:
   - When there is more yeasts, there is less grass.
   - If less yeasts, there is more grass.
   - Torus Yeasts are pretty constant.
   - No osmosensors.

c. Explain why this pattern is occurring.

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology?

\[ L - 3 \quad M - 9 \]
In the model, there are sliders to set and adjust (see picture below) the three initial population parameters of interest:

- Initial number of Yernts
- Initial numbers of Toorus
- Initial numbers of Omosan people

There are also on-off switches (see picture below) that allow you to manipulate the independent variables:

- Drought
- Fire-stick farming
- Hunting

In the next phase you will have an opportunity to test two of these independent variables.

2. After reviewing reports from research teams on Omosa, the Chief Scientist has decided that there are several experiments that could be done in order to find out more about the possible causes of the decline of the population of animals. One possibility is that the decline in the population has a natural cause – the ongoing drought. Another possibility is that one of the Omosans’ practices such as fire stick farming or the over hunting are causing the decline in the population of animals.

In the next stage in this study you will test some of these possibilities using the NetLogo model.
**Study 1:** Testing how drought impacts on the population of animals.

In this study you will examine how a long period of **drought** might impact on the population of animals.

Before running the experiment think about why the drought might cause a decrease in the population of animals.

1. **Less or minimal grass**
2. **Less food for years**
3. **Thus, less food for years.**

Scientists test their ideas by writing testable questions. Please specify the design for your experiment by filling in the table below. Some parts have already been completed for you.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
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<tbody>
<tr>
<td><strong>1. Research question.</strong></td>
<td>The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.</td>
</tr>
<tr>
<td>Does the level of <strong>drought</strong> impact the population of the animals?</td>
<td></td>
</tr>
<tr>
<td><strong>2. Your hypothesis.</strong> if there is an increase in the level of drought, then there will be <strong>a decrease in animal populations</strong> because <strong>less water for plants means no food</strong> for <strong>years</strong> of then <strong>years.</strong></td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
<tr>
<td>if there is ______________________ then ______________________ because ______________________</td>
<td></td>
</tr>
<tr>
<td><strong>3. Independent variable.</strong></td>
<td>The independent variable is an &quot;it&quot;—it is what may cause the change.</td>
</tr>
<tr>
<td>drought severity level</td>
<td></td>
</tr>
<tr>
<td><strong>4. Dependent variable.</strong></td>
<td>The dependent variable is the &quot;then&quot;—it is the thing that you measure.</td>
</tr>
<tr>
<td>animal population</td>
<td></td>
</tr>
</tbody>
</table>
• Turn the **drought** switch “On”, set the **drought severity level** to 20 or 30 and run the model two times.

• Conduct two runs using the same settings.
  
  a. Draw the graph for three different stages in each run.

<table>
<thead>
<tr>
<th></th>
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<th>Stage 2</th>
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</thead>
<tbody>
<tr>
<td>Run 1</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td>Run 2</td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
</tbody>
</table>

b. What do you notice about the pattern of on the graph and the relative numbers of Yerr, Toorus, and the amount of grass for each of these runs of the model?

- Both levels of grass and yeasts went down.
- Or rose pretty much at similar rates at similar times.
- Toorus was pretty stable.
c. Is this what you expected? Why or why not?
   Yes - when food source goes down, levels of yeast go down

Now increase the severity of the drought to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?
   Grass of Yernts will go down.
   Drought is very severe so maybe Toorus will be unaffected.

b. Draw the graph for three different stages in each run

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</table>

c. What has changed in the pattern and why might this occur?
   Grass and yeast levels are lower than at 30% drought. Toorus are unaffected.
What would you report to the chief scientist? Is the drought contributing to the decline in the population of the animals? What evidence do you have to support your answer?

Yes, mean population has dropped because of drought and less food available.

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding the factors impacting the population of animal in an ecosystem?

If your confidence is 5 or more then:
What features of NetLogo do you think will help you in responding to the chief scientist?

- graph
- slider: change of effect on animal population
- image: (visual aid)

If your confidence is less than 5 then:
What do you think you need to do in NetLogo to improve your confidence?

- nothing

You can now examine the impact the Omosans might be having on the size of the animal populations. You need to choose one of the following possibilities:

Study 2: Is it likely to be the fire-stick farming that is causing the decline in the population of the animals?

Study 3: Is it likely to be the hunting practices of the Omosans that are causing the decline in the animal population?

You can use the work you did for Study 1 as a guide to assist you answer the questions.

- Go to the next page if you decide to do Study 2 (fire-stick farming)
- Go to page 12 if you decide to do Study 3 (hunting practices)
Study 2: In this study you will examine the impact of **fire stick farming** on the population of the animals.

Remember to turn the **drought off** and turn on the **fire stick farming**.

Please specify the design for your experiment by filling in the table below.

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</tr>
<tr>
<td>Does the <strong>fire stick farming</strong> impact the population of the animals?</td>
<td></td>
</tr>
<tr>
<td><strong>2.</strong> Your hypothesis.</td>
<td>The hypothesis is what you think will happen and why, in this general format:</td>
</tr>
<tr>
<td>if there is an increase in the percent-burned-grass</td>
<td></td>
</tr>
<tr>
<td>then there will be a decrease in the population of animals</td>
<td></td>
</tr>
<tr>
<td>because <strong>less food source (grass)</strong> for your...</td>
<td></td>
</tr>
<tr>
<td><strong>3.</strong> Independent variable.</td>
<td>The independent variable is an “if”—it is what causes the change.</td>
</tr>
<tr>
<td><strong>fire stick farming</strong></td>
<td></td>
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<tr>
<td><strong>4.</strong> Dependent variable.</td>
<td>The dependent variable is the “then”—it is the thing that you measure.</td>
</tr>
<tr>
<td><strong>animal population</strong></td>
<td></td>
</tr>
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</table>
- Turn the **fire stick farming** switch "On", set the **percent-burned-grass** to 30 and run the model.
- Conduct two runs using the same settings
  a. Draw the graph for three different stages in each run

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<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
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<tr>
<td>Run 2</td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
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</tbody>
</table>

b. What do you notice about the pattern of the graph and the relative numbers of Yernt, Toorus, and the amount of grass for each of these runs of the model?

   When there are more **Yernt**, there is less [Diagram]
   
   A demand for grass, so there is less [Diagram]

   [Diagram]

   [Diagram]

c. Is this what you expected? Why or why not?

   Yes, when the Yernt are around, they eat the grass

   [Diagram]

   [Diagram]
Now change the level of *percent-burned-grass* to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yerms, Toorus, and the amount of grass?

There will be a decline in grass & therefore a decline in population.

b. Draw the graph for three different stages in each run

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<td>Run 2</td>
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</tbody>
</table>

c. What has changed in the pattern and why might this occur?

Toorus are affected because the yerm beans get very low.

What would you report to the chief scientist? Is the *fire stick farming* contributing to the decline in the population of the animals? What evidence do you have to support your answer?

We are not sure why when the yerm population number started rising again, the toorus get better.

Go to page 15
Study 3: In this study you will examine the impact of the Omosans' hunting practices on the population of animals. The Omosans don’t change their hunting practices but the size of the Omosan population determines how many animals are killed in each hunt.

Remember to turn the drought and the fire stick farming switches to off.

Please specify the design for your experiment by filling in the table below.

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<td>If there is, then</td>
</tr>
<tr>
<td>__________________________________</td>
<td>____________________________</td>
</tr>
<tr>
<td>because _________________________</td>
<td>because ___________________</td>
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</table>
- Turn the \textbf{omosan} switch “On”, set the \textbf{initial-number-omosans} to 20 or 30 and run the model.

- Conduct two runs using the same settings
  a. Draw the graph for three different stages in each run

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</tbody>
</table>

b. What do you notice about the pattern on the graph and the relative numbers of Yernt, Toorus, and the amount of grass for each of these runs of the model?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

c. Is this what you expected? Why or why not?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Now change the level of **initial-number-Omosans** to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

b. Draw the graph for three different stages in each run.

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run 2</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

c. What has changed in the pattern and why might this occur?

What would you report to the chief scientist? Are the Omosan hunting activities contributing to the decline in the population of the animals? What evidence do you have to support your answer?
Are there any other tests you would like to make before you create your report for the Chief Scientist? Why?

We simulated with the settings for population of a mosasaur. When we increased the population level to a high level, both the young & females became extinct.

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding the factors impacting the population of animal in an ecosystem?

L - 8
M - 9

If you feel better (your confidence has increased or stayed) please write down what have you done in NetLogo has made you more confident.

Playing around with the settings was interesting & engaging.

If your confidence has decreased, what else do you think you need to know/do in NetLogo to improve your confidence?
What would you put into the report to the chief scientist about what has caused the decline in the population of animals on Omota?

1. Drought & the shift of farming were both significant in the decline of animal population.
2. Drought is seemingly more harmful.
Fourth Group (G4) Omosa NetLogo Guidebook

Phase two guidebook to accompany the Omosa NetLogo model

Student name: [redacted]
Introducing computational experiments using NetLogo

Many areas of modern science use computer models to run experiments—sometimes called computational experiments or simulations. These computer experiments are usually based on data scientists have collected from observations. Scientists can use such a model to carry out virtual experiments by changing an independent variable and taking measurements of the dependent variable in the computational experiment. Each time the scientist run a virtual experiment, the mathematic model in the computer program can calculate changes in the relative numbers of animals and plants. This means that scientists can use a mathematic model to test their ideas about the factors impacting an ecosystem.

You will use a powerful computer modeling program called NetLogo to run computational experiments about Omosa. Below you will find a screenshot of the NetLogo model for Omosa world.

To run a simulation, you go through the following procedure:
1. Press the SETUP button.
2. Press the GO button to begin the simulation.
3. Look at the monitors to see the current population sizes.
4. Look at the POPULATIONS plot to watch the populations fluctuate over time.

To stop and start the simulation click the GO button.
1. Run the simulation twice (1. The pilot simulation and 2. The experimental simulation) with the default settings listed in the previous steps. Stop the run in different stages (by clicking the GO button):
   a. Draw the graph for three different stages in each run

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1. The pilot simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Graph" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. The experimental simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5" alt="Graph" /></td>
</tr>
</tbody>
</table>

b. Describe the most common pattern for the various populations you have observed
   - There is a steady increase in foxes.
   - When there is a high population of yeasts, there is less population of grass. Higher population of grass when lower population of yeasts.

c. Explain why this pattern is occurring.
   - When there is a high population of yeasts, they consume more grass, hence the lower population.

On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding ecology?

Middle - 5 or 6

Yu Ying - 8
In the model, there are sliders to set and adjust (see picture below) the three initial population parameters of interest:

- Initial number of Yernts
- Initial numbers of Toorus
- Initial numbers of Omosan people

There are also on-off switches (see picture below) that allow you to manipulate the independent variables:

- Drought
- Fire-stick farming
- Hunting

In the next phase you will have an opportunity to test two of these independent variables.

2. After reviewing reports from research teams on Omosa, the Chief Scientist has decided that there are several experiments that could be done in order to find out more about the possible causes of the decline of the population of animals. One possibility is that the decline in the population has a natural cause – the ongoing drought. Another possibility is that one of the Omosans’ practices such as fire stick farming or the over hunting are causing the decline in the population of animals.

In the next stage in this study you will test some of these possibilities using the NetLogo model.
**Study 1:** Testing how drought impacts on the population of animals.

In this study you will examine how a long period of **drought** might impact on the population of animals.

Before running the experiment think about why the drought might cause a decrease in the population of animals.

---

**The drought effects the availability of food.**

and water for the
generations which affects the food web.

---

---

Scientists test their ideas by writing testable questions. Please specify the design for your experiment by filling in the table below. Some parts have already been completed for you.

<table>
<thead>
<tr>
<th>Write your experiment design here</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| 1. **Research question.**

Does the level of **drought** impact the population of the animals?

The research question is more specific about the aim of your experiment. Basically, you conduct an experiment to answer this question.

| 2. **Your hypothesis.**

If there is an increase in the level of drought, then ________

**Population of animals**

because of ______

**Food and water.**

The hypothesis is what you think will happen and why, in this general format:

if there is ________

then ________

because ________

| 3. **Independent variable.**

**Drought severity level**

The independent variable is an "if"—it is what may cause the change.

| 4. **Dependent variable.**

**Animal population**

The dependent variable is the "then"—it is the thing that you measure.
- Turn the **drought** switch "On", set the **drought severity level** to 20 or 30 and run the model two times
- Conduct two runs using the same settings
  a. Draw the graph for three different stages in each run

<table>
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<tr>
<td>Stage 1</td>
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<td><img src="image3.png" alt="Graph" /></td>
</tr>
<tr>
<td>Stage 2</td>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
<td><img src="image6.png" alt="Graph" /></td>
</tr>
<tr>
<td>Stage 3</td>
<td><img src="image7.png" alt="Graph" /></td>
<td><img src="image8.png" alt="Graph" /></td>
<td><img src="image9.png" alt="Graph" /></td>
</tr>
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</table>

b. What do you notice about the pattern of on the graph and the relative numbers of Yakita, Tooru, and the amount of grass for each of these runs of the model?

*Yakita* population increasing at a very slow rate.
*Grass* and *yakita* fluctuate between the population of *grass* and *yakita*. More *yakita* means less *grass*.
And that grass less *yakita* mean more grass is available.
c. Is this what you expected? Why or why not?

No, we expected it to be part of a steady decline in the population of the animals and grass, rather than the constant fluctuation in population.

Now increase the severity of the drought to 60 by moving the slider.

a. What do you expect to happen to the relative number of Yernts, Toorus, and the amount of grass?

There will be a sharp decline in the number of grass, leading to a sharper decline in the population of Yernts and a slower increase in the population of Toorus, or even no increase.

b. Draw the graph for three different stages in each run

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</tbody>
</table>

c. What has changed in the pattern and why might this occur?

The number of Toorus has decreased over time. There is less fluctuation in the population of Yernts and grass. The severity level of the drought has caused this.
On a scale of 1 (lowest) to 10 (highest), how would you rate your confidence in understanding the factors impacting the population of animal in an ecosystem?

If your confidence is 5 or more then:
What features of NetLogo do you think will help you in responding to the chief scientist?

If your confidence is less than 5 then:
What do you think you need to do in NetLogo to improve your confidence?

You can now examine the impact the Omosans might be having on the size of the animal populations. You need to choose one of the following possibilities:

Study 2: Is it likely to be the fire-stick farming that is causing the decline in the population of the animals?
Study 3: Is it likely to be the hunting practices of the Omosans that are causing the decline in the animal population?

You can use the work you did for Study 1 as a guide to assist you answer the questions.

- Go to the next page if you decide to do Study 2 (fire-stick farming)
- Go to page 12 if you decide to do Study 3 (hunting practices)