Using Remote Access Laboratories to Enhance Queensland Pre-service Primary Teachers' Self-efficacy for Teaching Technologies Education

A Thesis submitted by

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Abstract

Education for Science, Technology, Engineering and Mathematics (STEM) is acknowledged as a priority around the world. However, many primary teachers are inadequately prepared for teaching the Australian Curriculum: Technologies because of their limited exposure in their own schooling and teacher preparation. Remote Access Laboratories (RAL) offer hands-on and remote experiments to students and teachers in schools, especially those in remote locations. They also have potential for influencing teachers' capacity and capability to teach the Technologies curriculum.

Bandura's self-efficacy theory was the theoretical framework for this research, which explored the use of Remote Access Laboratories (RAL) as a vehicle to influence Queensland pre-service teachers' (PSTs) self-efficacy to teach the Australian Curriculum: Technologies. Mixed methods were used to investigate how engagement with the Remote Access Laboratories for fun, innovation and education (RALfie) project influenced teachers' self-efficacy for teaching the Technologies curriculum. The Science Teaching Efficacy Belief Instrument-B (STEBI-B) used to measure pre-service teachers' self-efficacy to teach science was modified to create the Technology Teaching Efficacy Belief Instrument (T-TEBI) to measure pre-service teachers' self-efficacy to teach technologies. The Positive and Negative Affect Schedule (PANAS) was used to measure pre-service teachers' emotional status. Using pre-test and post-test survey data, the research investigated changes in pre-service teachers' self-efficacy as measured before and after engagement with RAL. Interviews, PSTs' comments and reflections were used to investigate factors affecting their self-efficacy in greater depth.

The pre-test results of T-TEBI and PANAS (N=119) demonstrated the reliability of the instruments. Comparison of the pre-test and post-test results of T-TEBI and PANAS (N=41) showed that there was no significant difference between PSTs who engaged with the RALfie experience and PSTs who did not engage with the RALfie experience. Subsequently, the individual results for pre-test and post-test comparison were examined to identify interview participants for further analysis using qualitative data to further understand the quantitative data. The themes that emerged from the pilot study and the main study were very similar. A case study approach was used to explore the changes of self-efficacy associated with the RALfie experience for individuals.

The qualitative data from this research revealed that PSTs' self-efficacy can be affected by their engagement with successful experience, vicarious experience, verbal persuasion and emotional status in the context of working with RALfie. This study showed that hands-on events were more powerful than remote experiences. Hands-on experiments were concrete and better suited to PSTs who were at a beginning level of robotics. This study also showed that the lack of background knowledge of technology in PSTs' schooling can cause anxiety, and technical issues occurring while using RALfie can result in frustration.

Keywords: Self-efficacy, STEM education, Remote Access Laboratories

Thesis Certification

This thesis is entirely the work of 吴婷（Ting Wu）except where otherwise acknowledged. The work is original and has not previously been submitted for any other award, except where acknowledged.

Student and supervisors’ signatures of endorsement are held at USQ.

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Dedication

I dedicate this thesis to my beloved husband 郝荣杰 and my beloved niece 赖子宁.

Abbreviations

PA	Positive Affect
PSTs	Pre-Service Teachers
NA	Negative Affect
RAL	Remote Access Laboratories
RALfie	Remote Access Laboratories for fun, innovation and education
STEM	Science, Technology, Engineering and Mathematics
USQ	University of Southern Queensland
T-TEBI	Technology Teaching Self-efficacy Beliefs Instrument

Author's Publications

Kist, A, Maiti, A, Maxwell, A., Orwin, L., Wu, T., Albion, P., & Brutenshaw, R. (2016) Hosting and Sharing Your Own Remote Experiments with RALfie – an Open Ended Experiment Design Experience *International Journal of Online Engineering (iJOE), 12*(4), 40. doi: 10.3991/ijoe.v12i04.51

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Table of Contents

Chapter 1: Contents

List of Figures

List of Tables

Chapter 1: Introduction

This study focused on primary pre-service teachers' (PSTs) self-efficacy for teaching the Australian Curriculum: Technologies. The chapter begins with the rationale for the importance of technology, followed by discussion of the importance of Science, Technology, Engineering, and Mathematics (STEM) and STEM education. It then discusses the Australian Curriculum: Technologies and its relationship to STEM education. Primary teachers' preparation for teaching STEM subjects is contextualized in relation to the Remote Access Laboratories for fun, innovation and education (RALfie) project at the University of Southern Queensland (USQ). This chapter concludes with discussion of the significance and structure of this research.

1.1 Background

There are five areas of background related to this research. They are the role of technology in society, the consequent significance of STEM subjects, challenges of STEM education, the Australian Curriculum: Technologies, and the research context of Remote Access Laboratories.

1.1.1 Technology

Human beings respond to the world by inventing new technologies to solve problems. China invented paper and printing to store and spread knowledge in ancient times. Traditional technologies were most often related to tangible goods such as food, clothing and shelter whereas modern technologies are more related to intangible products such as information.

Digital technology has changed the way we learn. Digital technology has offered flexibility of time and place. It is convenient to revisit teaching resources and learn using more visual forms (Henderson, Selwyn, & Aston, 2015). Digital technology extended the possibilities of distance learning and subsequently reshaped teaching and learning even for students studying on campus (Ng, 2012). At the University of

Southern Queensland (USQ), for example, over 70% of students study via online courses. Therefore, it is important to learn how to use digital technologies.

Modern citizens need to be equipped with digital skills to understand the government policy. The new media helps citizens to understand social phenomena and make decisions for the future of a country. The affordability of digital technologies has enhanced the decentralization of decision making. (Webster, 2014). Individuals need to be educated to understand the consequences of their application of knowledge so that they can make wise decisions. It is the individuals who matter most in making use of technologies for good or bad purposes. Australian citizens need to be digitally enabled to make information-intensive decisions (Roden, 2014). Digital skills are important for citizens to enjoy a modern life in the digital era.

However, there are challenges to educating students to learn digital technologies in schools. Technology anxiety may be caused among teachers by the rapidly changed digital technology and insufficient exposure of technology learning in their own education (Chiu & Churchill, 2016). Teachers who demonstrate technology anxiety avoid integrating technology into their teaching. Individuals should overcome technology anxiety. People need to learn and use new technologies and even create new technologies. Therefore, it is important to learn digital skills and build up digital confidence in the digital age.

1.1.2 STEM Subjects

It is now commonplace in public discussion to refer to the STEM subjects, meaning science, technology, engineering and mathematics, as a cluster of related areas of knowledge (Park, 2015) rather than to technology alone. The significance of STEM has been highlighted by various researchers and policy makers (Van Aalderen - Smeets, Walma van der Molen, & Asma, 2012). It is argued that STEM contributes dramatically to development of new knowledge and technologies which benefit national prosperity and social welfare (Office of the Chief Scientist, 2013). However, although science, technology, engineering and mathematics are interrelated and integrated they are different subjects (Park, 2015), each with its own body of knowledge.

Science helps human beings to understand the universe as well as humanity's relationship to nature. Science developed areas such as physics, chemistry and biology which enabled human beings to find new solutions (Bohm & Peat, 2000). The scientific approach and experimental techniques help human beings to test hypotheses, explore and discover the unknown world which appears to have a substantial impact on the relationship between humans and nature. The power of scientific knowledge evoked strong beliefs to find the truth of the world and to question the foundations upon which the truth rested. Many believe that science has enabled humans to draw on new paradigms which included not only a system of theories and principles but also the infrastructure of ideas which are transmitted from generation to generation (Bohm & Peat, 2000).

Technology is important to modern life in the developed world. Some suggest that technology is the medium of social life in modern society. Technologies have changed the way people live in the world. People use smart phones and tablets for study, work and social life. In agriculture, computer monitoring systems help farmers to be more precise and less wasteful which improves efficiency and productivity (Rehman, Jingdong, Khatoon, & Hussain, 2016). Technology has a great impact on peoples' lives.

Engineering helps human beings to solve problems, often by making things. Engineering has been developed based on scientific and technological principles (De Weck, Roos, & Magee, 2011). Engineering covers multiple areas in daily life and has been developed into different engineering subjects such as civil engineering, electronic engineering, bioengineering, software engineering and so on. Engineering has impact on every aspect of human lives by designing, building and operating new systems (De Weck et al., 2011). Engineering has a substantial impact on sustainability and innovation in the world.

Mathematics is very important in the history of human civilization. In the construction of the Pyramids, Egyptians introduced various mathematical concepts, such as the cotangent of an angle to maintain a uniform slope for the faces, which laid a great foundation for the construction of the Pyramids in Egypt (Boyer & Merzbach, 2011). In the Mesopotamian Valley, the empire used measurement which was the keynote of algebraic geometry to build a system of canals to irrigate the land and control floods. In Egypt and Mesopotamia, the elements of arithmetic and geometry contributed to solving the problems associated with pyramids and inheritance of land. In the modern civilization, mathematics is a crucial skill for technological change and scientific development. Mathematics is a key to economic prosperity. Mathematics contributes to daily life and also to engineering, psychology, science, statistics and social science. Many believe that mathematics has contributed to both early and modern human civilization.

Each individual subject of STEM is important to national development. However, it is argued that STEM is a holistic concept and emerging perspective rather than merely the sum of separate component (English & King, 2015).

1.1.3 STEM Education

Leading authors who research in the STEM area argue that the STEM concept emphasises cooperation and collaboration across science, technology, engineering and mathematics. STEM pedagogy enables students to build connections with the real world. STEM concepts are addressed through the exploration of the real-world applications of principles.

The STEM concept emphasises the interdisciplinary collaboration and interdisciplinary approach rooted in STEM pedagogy (Bell, 2016). STEM pedagogy enables students to become more aware of real-world connections. Aproject-based learning approach focuses on learning to do something with knowledge acquired. The aim of problem-based learning in STEM is to motivate and engage more students to learn STEM and become STEM literate.

STEM concepts are addressed through STEM education which moves from the acquisition of facts to the exploration of the practical application of principles and theories (Bell, 2016). STEM educators seek to create purposeful learning environments and real-world connections. The STEM concept facilitates students to understand learning contexts and become motivated toward STEM learning. It helps students to become better problem-solvers, demonstrate more positive attitudes in STEM learning, and also improve their learning results.

STEM education is attracting increased international interest (Drew, 2015; Royal Academy of Engineering, 2016). STEM learning and teaching was considered as an integration of the underlying STEM disciplines. Educating a more scientifically literate community is one of the core targets of STEM education (English & King, 2015). Although educational institutions in many countries have argued the importance of STEM education in schools, the nature of STEM teaching experiences and how these subjects are integrated within the curriculum are still open to debate (English & King, 2015).

Research has found that incorporating aspects of engineering in the STEM curriculum can enhance STEM learning, especially for primary school students (English & King, 2015). Problem-based learning follows the key components of engineering design (Capraro et al., 2016). Engineering experiences include making and building things which develop children's understanding of the important role of engineering in shaping and developing societies. Engineering can provide a real world context. Students can draw on maths and science principles to solve problems, which enhances motivation and performance for STEM learning.

Students' high dropout in STEM learning has been identified in the Australia workforce. Australia's lack of STEM graduates entering the workplace is caused by a decline in STEM study at the tertiary level. Fewer tertiary students choose to study STEM as a career path because there is a high dropout rate from STEM subjects in high school (Freeman, 2013). The reason for the decline in STEM interest in high school has been attributed to an inadequate amount of time spent on STEM teaching in primary schools (Office of the Chief Scientist, 2013). Thus the shortfall of STEM graduates entering the workforce is attributed to their low engagement and low performance in STEM learning at primary school. Therefore, it is important to provide experiences to maintain students' STEM interest in primary school.

One response strategy is to embrace an expanded engagement with STEM skills at primary school level when children first encounter these areas (Education and Training:The Australian Industry Group, 2013). It is important to promote the STEM pipeline through K-12 education. In order to foster STEM learning, it is of significance for primary teachers to deliver motivating and engaging STEM lessons to engage students to learn STEM. Primary school teachers need to be able to incorporate different technologies and be confident to teach STEM. Therefore, teachers need to be exposed to different modes of technologies and to build up their capability to teach STEM.

Research shows that pre-service science teachers' positive science experiences during their childhood are an important contributor to their decision to pursue an advanced level of STEM learning (Westerlund, Radcliffe, Smith, Lemke, & West, 2011). Research shows that young adults made their career choice, which was rooted in earlier learning experience in childhood (van Tuijl & van der Molen, 2015). Many pre-service primary teachers described how good science teachers in their past were an important factor which influenced their interest in teaching science (Westerlund et al., 2011). Good science teachers provided positive science learning experiences which were helpful to maintain their long-term interest in learning science. To build up the pipeline of science teachers, it is important to teach children science in a motivational and engaging way when they first encounter science. Negative experience of STEM learning at school results in negative attitudes towards STEM in later life (Cormick, 2014). Thus, STEM learning in primary schools is of great importance to attract more students and teachers to the STEM field.

In order to promote STEM education, the adoption of robotics is being increased dramatically as an educational tool. Robotics in schools has mainly been used to stimulate learning STEM concepts. Robotics allows learning through designing, building and operating robots (Zhou, Yuen, Popescu, Guillen, & Davis, 2015). It leads to the acquisition of principles and knowledge in electrical, mechanical and computer engineering, skills which are in high demand in the industrial workforce. Robotics promotes problem-solving, system-oriented thinking, team work and independent study skills (Zhou et al., 2015). LEGO Mindstorms is probably the best known product which allows students to have a hands-on experience with robotics while maintaining concurrent focus on their academic learning (Zhou et al., 2015). Using robotics appears to be an effective method for delivering STEM content in the classroom to engage students in STEM learning.

STEM-oriented teacher professional development is important for teachers to develop their professional knowledge to be able to engage students in STEM learning. Research has showed that teacher professional development can benefit students' performance (Capraro et al., 2016). There is a great need to provide professional development about how to teach technologies in the classroom. There are many professional development opportunities for STEM integration which are engineering oriented (English & King, 2015; Wang & Nam, 2015), and science and mathematics oriented (Charlesworth, 2015). However, how to prepare teachers to teach technology for STEM integration is a gap because few researchers have explored this issue.

1.1.4 Australian Curriculum: Technologies

The Australian Curriculum was released to ensure all students benefit from learning traditional, contemporary and emerging technologies that shape the world (Falkner & Vivian, 2015). It comprises two distinct but related subjects: Design and Technologies, and Digital Technologies (Australian Curriculum Assessment and Reporting Authority, 2015). The Australian Curriculum: Technologies provides opportunities for students from Foundation (F) to Year 10 to explore their design thinking, algorithmic thinking and coding skills. For example, in Years 3-6, students need to be introduced to a visual programming language, such as MIT's Scratch (Falkner & Vivian, 2015). In order to enhance STEM competitiveness, the Australian Curriculum: Technologies provides a significant opportunity for children to develop and master their skills to design and create new technology to create a preferred future.

However, to ensure the successful implementation of the Australian Curriculum: Technologies, high-quality learning resources are core components (Falkner & Vivian, 2015). High quality resources are important to engage students in meaningful ways to build up their capabilities to solve problems and a clear pathway for STEM capacity from primary school (Zagami, 2015). Therefore, it is important to provide a variety of high-quality resources to engage students in learning technologies.

The capacity of teachers, especially primary school teachers, plays a fundamental role in the successful implementation of the Australian Curriculum: Technologies (Zagami, 2015). Primary school teachers are lacking experience of learning Technologies based on their own school learning experiences. Many primary school teachers are unfamiliar with the concepts of computational thinking and design thinking and consequently anxious about teaching Technologies (Albion et al., 2016). The successful introduction of the Australian Curriculum: Technologies requires a significant effort to prepare primary teachers to be capable of delivering high quality teaching in their classrooms. Therefore, it is urgent to build up primary school teachers' capacity to be able to teach Technologies in an engaging way through provision of high quality professional learning opportunities.

1.1.5 Research Context– RALfie

There is substantial experience over recent decades with Remote Access Laboratory (RAL) use in universities to provide students with more flexible access to learning through experiments, especially in electrical and computer control engineering disciplines (Lowe, Newcombe, & Stumpers, 2012; Maiti, Maxwell, & Kist, 2013). More recently they have been found effective in secondary schools (Lowe, Newcombe, & Stumpers, 2013) and may also offer benefits for primary schools by enabling sharing of equipment that is expensive to acquire and maintain and by assisting teachers. To date there has been little research on RAL in teacher education (Kist, Maxwell, & Gibbings, 2012), which suggests a gap to be further explored in this study.

The RALfie Project represents a new approach to RAL. Where most RAL systems offer remote access to experiments at a central location such as a university campus, RALfie is designed to support peer-to-peer (P2P) sharing of experiments. It was aimed at creating a learning environment and the associated technical systems to allow children aged 11 to 17 years to create low cost RAL, using tools such as cameras, sensors, LEGO Mindstorms EV3, and other robotics, and share them with other learners online (Maxwell et al., 2013). The RALfie project was originally designed for students and was extended for pre-service and in-service teachers to prepare them to teach technology in classrooms.

RALfie is technology which addresses key skills related to computational thinking and associated concepts, such as design thinking and systems thinking. Computational thinking is a key idea in the new Australian Curriculum: Technologies (Australian Curriculum Assessment and Reporting Authority, 2013a). It is believed that computational thinking will empower children to change the future of the world (Catlin & Woollard, 2014).

There are two types of participants in RALfie activities: makers and users (Maxwell et al., 2013). RALfie allows students and teachers to create and access STEM experiments face to face or remotely via an online system. The unique feature of the RALfie project was that it provided not only for users but also for makers of experiments other than the host organization. RALfie provided a hands-on experience which allowed makers to build and create their own hands-on experiments and share them in the RALfie online community. Depending upon their location, PSTs in this study could access both maker and user activities.

1.2 Overarching Research Problem

The aim of this research was to investigate the effect of working with RALfie on PSTs' self-efficacy for teaching technologies. There have been many research studies and programs for science teacher education (Bellocchi et al., 2014; Luehmann, 2016). However, there were few research studies about preparing primary school teachers to teach technology. The Australian Curriculum: Technologies has been newly released (Australian Curriculum Assessment and Reporting Authority, 2013a). It is important to prepare primary school teachers to build up their capacity and capabilities to teach the Australian Curriculum: Technologies. Children will benefit from motivating and engaging lessons about technology. It is crucial to establish a positive attitude of learning technology when they first encounter STEM areas. Additionally, RAL has been widely used in engineering, nursing and farming areas. But there have been few research studies using RAL in teacher education (Bowtell et al., 2012). This research is important. This study will use RAL to enhance pre-service primary teachers' self-efficacy for teaching technologies education. The specific research questions will be elaborated in Chapter 2.

1.3 Significance of this Research

1.3.1 Theoretical Significance

This study investigated the effects of hands-on and remote experiences with RAL on PSTs' self-efficacy to teach the Technologies Curriculum. Teachers' attitudes and beliefs about their capability to teach technology have a great impact on students' attitudes and achievements in learning. It is important to explore PSTs' self-efficacy to teach Technologies (Albion et al., 2016). This study also built a theoretical framework based on Bandura's self-efficacy theory, Vygotsky's social constructivism and Piaget's learning stages theory. The framework broadened understanding of self-efficacy theory by building links to scaffolding and learning stages theory. The framework also highlighted the importance of hands-on learning in technologies.

1.3.2 Methodological Significance

Both quantitative data and qualitative data were collected and a mixed method was used to study self-efficacy. In the past, predominantly quantitative research methods have been used for study of self-efficacy. Quantitative data was used to identify the 'unusual' participants and qualitative data was used to elaborate reasons for changes in self-efficacy. It was important to understand the value of PSTs' self-efficacy through their voice as agents of change.

The Technology Teaching Efficacy Belief Instrument (T-TEBI) was developed by adapting the Science Teaching Efficacy Belief Instrument (STEBI) (Enochs & Riggs, 1990). T-TEBI was used to measure PSTs' technology teaching efficacy beliefs. The pre-test and post-test T-TEBI results were examined for the differences in their self-efficacy before and after engaging with the RAL experiments. The Positive and Negative Affect Scale (PANAS) was used to measure experiences of positive and negative affect (Ebesutani, Kim, & Young, 2014). The pre-test and post-test PANAS results were used to measure differences between their emotional status before and after the treatment as emotional status was one source of self-efficacy (Bandura, 1997). The combination of T-TEBI and PANAS used different methods to identify the differences in self-efficacy before and after the treatment with RAL experiments.

1.3.3 Practical Significance

This research allowed PSTs to access hands-on and remote RAL experiments and empowered them to learn about RAL as a new technology. PSTs used LEGO, computers, and cameras to build their own experiments and hook them to the RAL system to allow remote control. The hands-on experiments allowed them to interact with their peers and professional engineers.

This research provided opportunities for PSTs to be engaged and motivated to learn material relevant to teaching the Technologies Curriculum. The RALfie project provides ready-made experiments for PSTs to use. Ready-made experiences save preparation time and evoke positive responses from teachers to teach science (Albion & Spence, 2013b). Ready-made RAL experiments and successful learning experiences with RAL have the potential to positively impact teachers' self-efficacy to teach Technologies.

1.3.4 Personal Significance

My personal STEM learning experience was full of ups and downs. When my maths teacher was capable of delivering motivating and engaging lessons, my maths performance was very good. My maths teacher in Year 6 was not good at delivering maths concepts in an engaging way. Her teaching style was more like 'a sage on the stage'. Students had to do a maths test in a competitive way every day. She did not respect students who did poorly in maths tests. Even though I could achieve good results sometimes, I did not like her teaching style and gradually the subject that she taught. From Year 8 to Year 9, my maths teacher had difficulties to answer students' questions in class. From Year 10 to 12, I avoided learning Maths, Physics and Chemistry which began a bad cycle. From my personal experience of learning STEM, I know that students not only respond to the subject but also the teacher, who he or she is in the classroom.

My two years teaching practice in Sydney local schools helped to identify teacher engagement as my research focus for my Master of Education (Honours) degree. If teachers are positive and engaged, it is more likely that students are motivated and engaged to learn. If teachers are negative and diffident, students will soon sense the negativity and adopt negative attitudes which will impede students' engagement and their learning outcomes. Students can sense teachers' anxiety and fear which teachers want to hide. Therefore, teachers' confidence has a great impact on students' attitudes towards learning (Bursal & Paznokas, 2006). It is one of the reasons why I chose to investigate teachers' preparation for my PhD study.

When I first started my PhD, I was overwhelmed by the complex science and technology experiments that RALfie involved. I changed the focus of my research. My supervisor never doubted about my capacity to complete my PhD. At different stages of my research, my supervisors encouraged me to try different approaches to tackle research problems which interested me. I experienced some success which was helpful to build up my confidence and capacity to conduct my PhD. Bandura's self-efficacy theory was a torch which guided me through my intellectual journey.

1.4 Structure of this Research

This thesis is divided into six chapters, which are organized as follows:

Chapter 1 Introduction

This chapter introduced the background of the thesis. It introduced the significance of technology, STEM and STEM education. It then introduced the Australian Curriculum: Technologies. The research was limited to the context of the RALfie project at a university in Queensland, Australia. The significance of this research was outlined as well.

Chapter 2 Literature Review

This chapter reviews the relevant literature in three parts. Part one reviews contexts of this study. Part two reviews Bandura's self-efficacy theory which is the main theory for this study. Part three reviews Piaget's learning stages theory, Vygotsky's social constructivism theory and Motivation and Engagement theory. Drawing on the four theories, this researcher builds the theoretical framework. The research gaps are identified based on the theoretical framework. Research questions are raised to address the research gaps.

Chapter 3 Methodology

This chapter introduces the methodology of this research. It outlines the research paradigm which was pragmatism. It talks about the mixed methods, data collection and analysis, ethics, validity and reliability.

Chapter 4 Pilot Data Analysis

This chapter focuses on pilot data analysis. It introduces the RALfie experiences. It outlines data collection and analysis, discussion, lessons learnt from pilot data analysis, and summary.

Chapter 5 Major Data Analysis

This chapter focuses on the major data analysis. It introduces the RALfie experiences. It outlines major data collection and analysis, discussion, and summary.

Chapter 6 Conclusion

This chapter concludes this thesis. It answers the research questions and outlines contributions. It reports limitations and recommendations and finally draws a conclusion to this research.

Chapter 2: Literature Review

This chapter contains three parts. Part one reviews the relevant literature on the context of this study. It begins with the significance of STEM education and then considers issues related to STEM education in Australia. The Australian Curriculum: Technologies is discussed as a national response to the challenges of STEM education. Remote Access Laboratories are reviewed for their potential to contribute to STEM education. Part two reviews literature about Bandura's self-efficacy theory, which is the main theory for this study. Part three reviews Piaget's learning stages theory, Vygotsky's social constructivism, and the Motivation and Engagement (MeE) Framework. Drawing on these theories, a theoretical framework is developed to serve as a basis for exploring the issues around teacher preparation. The chapter then addresses the research gaps and raises research questions.

2.1 Context of This Research

2.1.1 The Significance of STEM Education

STEM education has a great impact on innovation and new technology-based enterprises (Marginson, Tytler, Freeman, & Roberts, 2013). In order to stimulate creativity, productivity and economic growth, it is essential to enhance STEM education in Australia. Hence, STEM education is very important for Australia to participate in the global digital economy (Office of the Chief Scientist, 2013). A technology-based economy requires citizens to be engaged in mainstream STEM education.

Besides the economic reasons, there are political reasons to develop STEM education. To improve the quality of STEM teachers in the workforce has been increasingly prioritized by policymakers and politicians (Goldhaber, Krieg, Theobald, & Brown, 2014). President Obama launched a series of recommendations regarding taking actions to ensure that the United States of America is a leader in STEM education with the reason that STEM education plays a critical role to enable the U.S.A. to be a leader of the global market in the digital landscape. The most important factor in ensuring excellence in STEM education is excellent STEM teachers (Holdren, Lander, & Varmus, 2010). To improve the quality of STEM education is a priority because it will enhance national competitiveness.

Australian prosperity is greatly shaped by STEM education (Office of the Chief Scientist, 2013). STEM education contributes to the pipeline for a STEM workforce which will stimulate innovation and productivity for economic growth. STEM is a crucial and critical element that Australian education must be committed to develop and sustain for the prosperity of the nation (Office of the Chief Scientist, 2013). STEM is a key way to improve Australia's productivity and competitiveness in the digital future.

2.1.2 STEM Education Challenges in Australia

There are several issues impeding the success of Australian STEM education. They include the STEM divide by students' gender (Gonski et al., 2011) based on the stereotype that girls are less successful than boys in STEM learning. Women are under-represented in STEM fields (Marginson et al., 2013; Ping et al., 2011; Stout, Dasgupta, Hunsinger, & McManus, 2011; Wallace & Sheldon, 2014). Even though such stereotypes are diminishing, there is a link between girls' STEM performance and girls' stereotype endorsement (Beilock, Gunderson, Ramirez, & Levine, 2010). Girls with low STEM achievement are more inclined to endorse the stereotype. Research also highlighted that first-grade and second-grade girls are more likely to endorse such traditional gender stereotypes of their female teachers (Beilock et al., 2010). Teacher training is of great importance to reduce teachers' anxiety and build up their confidence to teach STEM subjects (Van Aalderen ‐ Smeets et al., 2012). Therefore, it is important to provide teacher professional development which will be helpful to increase students' STEM performance and engage more girls toward STEM careers and to diminish the gender stereotype.

There are shortages of highly developed STEM skills in the workforce worldwide (Hausamann, 2012), including in Australia (Education and Training:The Australian Industry Group, 2013), America (Innes, Johnson, Bishop, Harvey, & Reisslein, 2012;

Knezek, Christensen, & Tyler-Wood, 2011) and Europe (Hausamann, 2012). The shortage of advanced STEM workers is a global concern. Low numbers of STEM graduates are also reflected in a shortage of qualified STEM teachers. The shortage of STEM teachers is a concern in Australia (Marginson et al., 2013). The reason for the falling numbers of STEM graduates was students' low interest in learning STEM (van Tuijl & van der Molen, 2015). Australian education systems need to employ primary and secondary teachers and specialist teachers to a total of 10,000 each year to meet the domestic requirement. It is important to maintain numbers of qualified STEM teachers in schools so that there will be enough teachers to teach STEM. It has been recommended that Australia needs to lift quality, capacity and qualifications in STEM and related disciplines (Education and Training:The Australian Industry Group, 2013). It has been identified that countries with high STEM advancement have a reliable STEM workforce whose STEM skills are valued by employers (McLaughlin, Kennedy, & Reid, 2015). Evidence shows that "Australia is falling short in educating future STEM graduates" (McLaughlin et al., 2015, p. 356), which is reflected by the shortages of STEM teachers. It is important to retain qualified STEM teachers in Australia to meet the domestic needs in schools.

The lack of teacher professional development for teaching the Australian Curriculum: Technologies is a concern. Teachers' professional development is important to support them to teach in the classroom (Marginson et al., 2013). Evidence shows that high quality professional development on STEM-oriented problem based learnings could result in increasing students' learning achievement. Low quality professional development could lead to low gains by students which could be mediated through teacher content knowledge (Capraro et al., 2016). Providing high quality professional development enhances teachers' knowledge and expertise (Miles, van Tryon, & Mensah, 2015). Science and Mathematics teacher professional development has been highlighted and investigated for a long time (Miles et al., 2015). There are some research studies that have targeted teachers' professional development for ICT integration (Blau & Shamir-Inbal, 2016) and pre-service teachers' competence for using ICT into teaching practice (Tondeur et al., 2016). However, there were few research studies targeted on teachers' professional development for teaching technology. Therefore, it is important to provide and investigate professional development opportunities to prepare teachers to be able to teach the Technologies curriculum (Freeman, 2013).

There is huge disparity in the success of STEM education based on socioeconomic status (Marginson et al., 2013) and the size and location of schools and funding systems (Gonski et al., 2011). The different funding systems between Government, Catholic and Independent schools result in unequal learning resources and learning opportunities to achieve STEM outcomes (Gonski et al., 2011). The disparities are longstanding between states and territories. The most disadvantaged cohorts are students with disabilities, low socioeconomic status, English as a second language, Indigenous background and those in remote locations (Gonski et al., 2011). There is the equivalent of up to three years' of schooling difference in STEM performance between students of the same age from different backgrounds (Freeman, 2013). It is very difficult for the most disadvantaged cohorts to have hands-on STEM experiences (Johnson et al., 2013). Therefore, it is urgent to provide equal opportunities for students with different backgrounds to achieve STEM success in education.

One of the concerns is that the digital divide increases disparity in STEM education. The digital divide refers to the gap between people who have, or have not, access to digital technologies (Henderson & Romeo, 2015). Digital divide not only includes the lack of ability to afford technology but also the lack of access to training and education which enhances digital learning. It is evidenced that the digital divide is across rural and urban areas in Australia (Erdiaw-Kwasie & Alam, 2016). The rural areas of Australia with low socioeconomic status are in a disadvantaged position because the digital divide is widening. It is hard for students and teachers in rural areas to access digital technologies. The digital divide makes it hard for everyone to achieve the requirement of the Australian Curriculum: Technologies.

In order to improve STEM teaching in primary schools, there are some initiatives which focus on "allocating more time" to STEM education (Van Aalderen‐Smeets et al., 2012, p. 159). However, merely adding more time to STEM teaching does not solve the problem for unqualified or less qualified STEM teachers in primary schools (Van Aalderen‐Smeets et al., 2012). In order to improve STEM teaching in primary schools, teachers need professional learning about how to teach STEM in an engaging way.

STEM teacher shortages have been identified as a key element of the crisis in STEM education in Australia (Freeman, 2013; Marginson et al., 2013). In order to fill STEM teaching positions, primary and secondary schools apply the following strategies: requiring teachers to teach outside their expertise; recruiting less-qualified or unqualified replacement teachers; reducing the STEM curriculum offered; reducing the length of classroom time for STEM; combining classes across year levels; combining classes across subject areas; combining classes within subject areas; sharing programs with other schools and recruiting retired teachers on short-term contracts (Marginson et al., 2013; McKenzie, Rowley, Weldon, & Murphy, 2011). Schools in remote locations, of small size with low socioeconomic status, and in Indigenous communities find it very hard to recruit teachers (Marginson et al., 2013). The STEM teacher shortage is a significant concern in Australia.

The consequences of employing such strategies to address the STEM teacher shortage are serious. Requiring teachers to work outside their area of expertise has been shown to result in anxiety (Bandura, 1997). If teachers become anxious as a result of working outside their area of expertise, their anxiety will cause student anxiety and low performance in STEM (Ping et al., 2011). Teachers who are less-qualified or unqualified to teach STEM are not capable of delivering motivating and engaging lessons to engage students to learn STEM. Employing less-qualified or unqualified teachers is against the *Australian Teacher Performance and Development Framework* (Australian Institute for Teaching and School Leadership, 2012). Removing STEM from the curriculum and reducing teaching time for STEM are against the learning requirements of Australian Curriculum (2013a, 2013b). Combining classes across year levels and subject levels will increase class size and reduce learning time for STEM subjects (Marginson et al., 2013). The consequences of using these strategies result in students' low performance and low engagement in STEM learning.

The lack of relevant professional development is another issue that causes teachers' STEM anxiety. There are insufficient professional learning programs for STEM teachers, especially primary school teachers (Freeman, 2013). Primary school teachers without specific discipline training are required to teach the primary school science and technology curriculum (Freeman, 2013). It is reaffirmed that primary school teachers are not adequately trained to teach Science in the Netherlands which resonates with the situation in Australia (Van Aalderen ‐ Smeets et al., 2012). It is important to provide professional learning programs for primary school teachers which are in line with the *Australian Professional Standards for Teachers* (2011) and the *Melbourne Declaration on Educational Goals for Young Australians* (2008). It is suggested that the crux of high quality teaching lies in how and what teachers learn (Goldsmith, Doerr, & Lewis, 2013). There is a great need for primary school teachers to access professional training about STEM. Professional learning related to STEM is helpful to build up their "confidence and capacity" (Freeman, 2013, p. 12) to teach STEM in motivating and engaging ways.

In order to meet the STEM priority, it is important to prepare pre-service teachers at all levels of schooling to teach the Australian Curriculum: Technologies (Cooke & Walker, 2016). It is important to focus on pre-service teachers with the reason that they will implement the new curriculum, they are eager to learn and to change (Idowu, 2013). Pre-service teachers' STEM perception, confidence, belief and knowledge impact on their quality of STEM teaching (Cooke & Walker, 2016). It is imperative that pre-service teacher education focus on skills, competencies, and knowledge which can prepare PSTs to become capable of teaching the Australian Curriculum Technologies.

2.1.3 Australian Curriculum: Technologies

Australia has incorporated Science and Technology in the general curriculum at all year levels since 1989 (Australian Education Council, 1989). Before that time study of technologies was limited to the vocational subjects of manual arts (woodwork and metalwork) and home economics in secondary schools. Due to a growing interest in the value of technological literacy, the national and state governments developed the national framework in 1989 to develop scientific and technological skills to stimulate students to be informed citizens in modern society (Australian Education Council, 1989). The *Melbourne Declaration on Educational Goals for Young Australians* (Ministerial Council on Education Employment Training and Youth Affairs, 2008) acknowledged major technological changes in the world which placed greater demands on further education and technological skills for jobs in the global context. However, it was another 25 years before a truly national technologies curriculum was developed (Barr et al., 2008).

In order to build a technologically literate workforce, the development of a new curriculum for technologies was undertaken in consultation with ICT industry and public stakeholders in 2013 (Australian Curriculum Assessment and Reporting Authority, 2013a; Department of Broadband Communications and the Digital Economy, 2013). There are two subjects in the new Curriculum, *Design and Technologies* and *Digital Technologies*. Both of them are presented through two strands, 'knowledge and understanding' and 'processes and production skills'. From Foundation to Year 10, *Digital Technologies* and *Design and Technologies* are mandatory subjects. The overarching idea for the entire curriculum is 'creating preferred futures'. Students identify possible and preferred futures as they progress with the Technologies Curriculum. The key ideas included are project management and thinking in technologies (systems thinking, design thinking and computational thinking).

Including Digital Technologies as a compulsory subject for Foundation to Year 10 is revolutionary and new in Australian education (Reynolds & Chambers, 2015). The Digital Technologies curriculum receives particular support and welcome by the Australian Council for Computers in Education (Zagami, 2015). Digital Technologies allow students to "use computational thinking and information system to define, design and implement digital solutions" (Australian Curriculum Assessment and Reporting Authority, 2010, p. 4). Teaching Digital Technologies will provide opportunities to engage students in learning, enhance digital skills and problem-solving skills. The Queensland government has announced that the new curriculum will be implemented in its schools from 2016 with significant new initiatives to support work with robotics and coding (DET, 2015). The NSW Board of Studies, Teaching and Educational Standards has developed new syllabuses for primary schools to focus on the Science and Technology K-6 syllabus (NSW Department of Education and Communities, 2016).

Incorporating design thinking into the curriculum allows students to engage in the process of design and apply integrated STEM knowledge to solve real-world problems (English & King, 2015). Design and Technologies allows students to use “design thinking and technologies to generate and produce designed solutions for authentic needs and opportunities” (Australian Curriculum Assessment and Reporting Authority, 2010, p. 4). Through design, students can appreciate that there are multiple ways to solve complicated problems and there are various tools which can produce a desired product (English & King, 2015).

For many in-service and pre-service teachers, many of the elements in the technologies curriculum were not experienced in their own school education and have received little attention in their post-secondary education (Zagami, 2015). They are likely to be unsure about the knowledge and skills that children are expected to learn in technologies and will lack the repertoire of teaching ideas and resources that they have accumulated for more traditional subjects (Wu et al., 2015). They will require time and support for preparation. Thus, successful implementation of the Australian Curriculum: Technologies will require the provision of relevant teaching resources and attention to relevant pre-service and in-service teacher education.

In summary, it is important to build up teachers’ capacity and capability to teach the Technologies curriculum. It is crucial that teachers are capable of delivering the new technologies curriculum to attract a large pool of students to enter STEM careers. It is also important to educate everyone to have a good understanding of technologies for participation in advanced democratic economies. Teachers need to be prepared to be confident and competent to engage students in learning the Technologies. This research will investigate using RAL to prepare PSTs to teach the Australian Curriculum: Technologies.

2.1.4 Remote Access Laboratories (RAL)

Attracting and employing teachers in remote and rural locations is a major issue (Dorman, Kennedy, & Young, 2015) because of the increased urbanisation in Australia. Queensland is the most decentralised state in Australia and it is estimated that nearly one third of school-aged children study in remote and rural communities in Queensland (Queensland Government: Department of Education, 2006). RAL provides professional development opportunities for PSTs and in-service teachers in schools where they can access resources from remote locations. At the University of Southern Queensland up to 70% of students in the 4-year Bachelor of Education are studying at least some subjects online (Albion, 2014).

The regular mainstream STEM teaching provides insufficient hands-on labs to motivate and engage students in learning STEM (Hausamann, 2012). The gifted and talented students are often unchallenged by regular STEM lessons in schools. They are less motivated or engaged by the lower cognitive level provided by regular STEM teaching. There is a need for schools to provide extracurricular science labs for talented students. In order to retain more students to learn STEM at the tertiary level, a variety of extracurricular science laboratories have been established successfully to engage primary and secondary students in STEM learning (Hausamann, 2012). However, physical classroom laboratories are very expensive and may be unavailable at many schools (Hausamann, 2012), especially those with low socioeconomic status or in disadvantaged locations (Erdiaw-Kwasie & Alam, 2016). Additionally, it is very hard to maintain physical equipment for individual schools (Lowe et al., 2012).

Remote access laboratories (RAL) have been increasingly investigated as a partial solution to the challenge of hands-on labs (Lowe, Dang, Daniel, Murray, & Lindsay, 2015). RAL are online systems using real equipment and physical devices which are operated at distance to observe a real result over the Internet (Heintz, Law, Manoli, Zacharia, & van Riesen, 2015; Sáenz, Chacón, De La Torre, Visioli, & Dormido, 2015). The aim of RAL is to accommodate a large number of students with limited resources and remove barriers such as time and space limitations (Maiti, Kist, & Maxwell, 2015). The nature of RAL provides opportunities for students to make experimental observations using real equipment. The experimental interface records full data streams which allow students to capture, study, manipulate and analyse experimental data (Lowe et al., 2013). It allows deep understanding of the experimental observation. RAL enable a large number of schools to share access to high quality facilities and offset costs. Therefore application of RAL provides an opportunity for schools to share resources to offset costs (Lindsay, Murray, & Stumpers, 2011).

There are many benefits of using RAL in engaging students in learning STEM. RAL can be carried out autonomously (Hanson et al., 2008). Students can try experiments in remote laboratories many times without being identified with their failure. Students can access RAL any time which increases learning time for them to study STEM subjects (Lindsay et al., 2011; Zubía & Alves, 2012). The flexibility of access is one of the most significant benefits (Lowe et al., 2013). They can use it repeatedly to check answers and test their hypotheses (Olive et al., 2010). RAL allows students to use it repeatedly with “round the clock accessibility” (Lindsay et al., 2011, p. 4). Importantly, technology makes students feel that they are in control because students are the locus of control at key decision-making junctures during exploration (Olive et al., 2010). Additionally, RAL provides online experiments instead of physical experiments which minimize the risks of being hurt (Lindsay et al., 2011). Equipment that involves high radiation or voltages is dangerous to access (Lowe et al., 2013). RAL offers opportunities for students’ collaboration internationally which is rather difficult using the hands-on labs (Machotka, Nedić, & Nafalski, 2011). Therefore, there are multiple advantages of using RAL in STEM teaching.

However, there are disadvantages that need to be taken into consideration when using RAL. RAL has been used and researched in undergraduate education. However, there is limited research that investigates RAL for K-12 education (Lowe et al., 2013). In tertiary education, content needs to be redesigned for RAL as courses that incorporate RAL are not reproductions of face-to-face classes in an online environment (Kist, 2012). RAL courses need to be designed carefully to scaffold the learner under the principle of constructivism. There are many studies analysing the implementation details of RAL. However, pedagogical issues are key concerns in the deployment of

RAL at universities. Teachers need professional support related to technical knowledge and online operational support to use RAL (Kist, 2012).

In order to solve pedagogical problems using RAL, a key to solving them is collaboration among academics in different faculties in universities (Kist, 2012). With different expertise drawn from across disciplines, collaboration provides an opportunity for reflection and critical thinking about the existing RAL courses. Importantly, collaborations allow specialists from different disciplines to work together to design and create new RAL activities (Kist, 2012).

2.1.4.1 RALfie

Traditional Remote Access Laboratories (RAL) system follow a client-server architecture. The universities host the RAL system and manage user access (Maiti, Kist, et al., 2015). Traditional RAL architectures play the role of service provider which add experiments from the server side. Users can only use the experiments but had little operational autonomy regarding to design of rigs. Figure 1 depicts the traditional RAL model (Maiti, Maxwell, Kist, & Orwin, 2015, p. 213).

Figure 1: Traditional RAL System

RALfie offered peer-to-peer (P2P) RAL system which enabled users to create experimental setups and share experiments with others. Users can run experiments created by others and evaluate them. RALfie featured the notion of a distributed RAL system where users have the flexibility and autonomy to join or remove any experiment. RALfie offered a significant change by distributing experiments geographically. It expanded the one-to-many approach, where one central laboratory serves many users, to many-to-many approach, with many users using multiple equipment by various providers (Maiti, Kist, et al., 2015). Individuals can be both makers and users of experiment in RALfie system. Figure 2 shows the RALfie distributed P2P system (Maiti, Kist, & Maxwell, 2014b, p. 179).

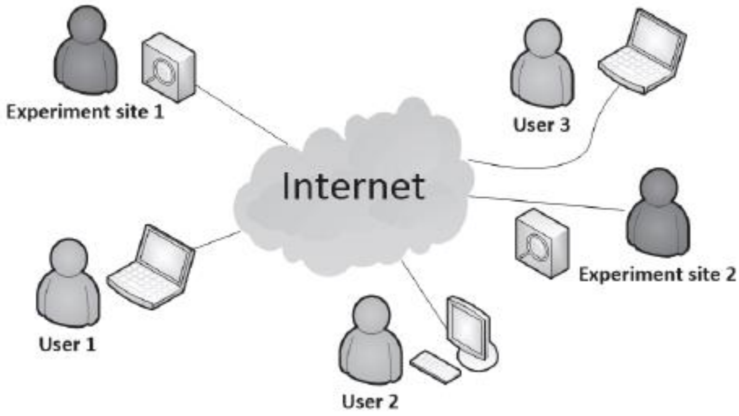

Figure 2: The RALfie P2P System

RALfie system is built using a VPN service which allows direct access between users and makers' experimental rigs. Snap! (http://snap.berkeley.edu/) is a graphical programming language which provides the basis for programming and interfacing with the rigs (Kist, Maiti, & Maxwell, 2015). Using Snap! to program LEGO Mindstorms to remote control a robot enables the makers to learn mathematical, engineering and computational ideas and conceptions. Importantly, makers learn how to work collaboratively in a group to think creatively.

2.1.4.2 Maker activity

The maker movement started in 2006 from America where a growing number of people are engaged in building, creating and tinkering things in the world such as designing their own jewellery, furniture and robots (Resnick & Rosenbaum, 2013). Makers are passionate to engage with designing things which make them more than just consumers. Makers are enthusiasts essentially (Dougherty, 2012). Makers take pride and pleasure to invent things personally. The Maker movement allows enthusiasts to gather together to share their hobbies, interests and new ideas in a community. Today's makers are interconnected within micro-communities defined by a particular hobby with the significant influence of new technologies and digital tools.

Makerspaces are increasingly being viewed as a method for engaging learners in creative, high-order thinking, problem-solving through hands-on design, construction and iteration (Johnson, Adams Becker, Estrada, & Freeman, 2015). The driving force behind makerspaces originated from the Maker movement which comprised artists, engineers, builders, tinkerers, tech enthusiasts and anyone else with a passion for making things. Many school leaders are considering adding makerspaces into the formal learning environment to encourage students and teachers to develop their ideas and explore design thinking from start to end.

RALfie offered hands-on activities. Tinkering and making are powerful ways to learn (Martinez & Stager, 2013). The tinkering approach is characterized by “a playful, experimental, iterative style of engagement, in which makers are continually reassessing their goals, exploring new paths, and imagining new possibilities” (Resnick & Rosenbaum, 2013, p. 164). A tinkering approach allows makers to try out ideas, make adjustments and experiment with new things.

Hands-on experiments are designed to motivate and engage students in STEM learning (Innes et al., 2012). Compared to didactic STEM teaching, hands-on activities in laboratories provide opportunities for students to actively apply the principles and concepts to solve problems in authentic environments. Students are more likely to view themselves as problem solvers in collaborative hands-on laboratories which are helpful in enhancing students’ engagement in learning STEM. Hands-on activities in laboratories help to motivate and engage students in STEM learning and are one potential solution to the problem of declining interest by K-12 students in learning STEM. Hands-on experiments allow students to “directly manipulate the tools and materials” (Innes et al., 2012, p. 226). Maker activities offer great opportunities for learners to learn how to setup and configure the experiments (Kist et al., 2014). Direct operation of experiments is preferable but not always possible so then RAL is a suitable alternative.

Computational tools and digital devices allow makers to tinker around with new technologies.
Digital tools such as robotics, 3D printers, and web-based 3D modeling applications are affordable to more people. Creativity, design and engineering are making their way to the forefront of educational considerations since technological devices are become accessible. LEGO Mindstorms enables makers to build robotics devices that move,

interact and remote controlled. SNAP! allows makers to assemble a set of scripts to program robots and control their behaviours (Resnick & Rosenbaum, 2013).

Coding skills are being regarded as a way to instill computational thinking in students because they combine deep computer science knowledge with creativity, analytical reasoning and problem-solving (Johnson et al., 2015). The coding process is helpful for students to construct, explore, experiment, evaluate and draw conclusions. RALfie allows PSTs to program robotics and control them locally and remotely which will help PSTs to develop their computational thinking.

RALfie as an innovative technology provides both hands-on and online modes for participants to access STEM experiments. By engaging with RALfie, PSTs have a new experience of working with technology. Students' competent achievement in building things produce a large part of their enjoyment and sense of accomplishment (Nickerson & Zodhiates, 2013). RALfie activities are in line with the requirements of the Technologies Curriculum such as "identify and explore a range of digital systems with peripheral devices for different purposes, and transmit different types of data (ACTDIK007)".

There are some key factors which influence remote learning. Combined with perceived ease of use they are the most important factors which impact on the continuance of intention and use of online learning. Motivational factors are also important for the acceptance of using technologies. Motivational factors such as control over goals, ownership, fun, continuity between contexts and communication are important (Edmunds, Thorpe, & Conole, 2012).

2.2 Bandura's Self-efficacy Theory

The importance of STEM education has been highlighted as attracting worldwide interest (Chubb, 2015). However, there have been many changes for implementation of STEM education in schools. The Australian Curriculum: Technology iss newly released and many school teachers are not familiar with the content of the Curriculum (Albion & Spence, 2013b). Many schools lack hands-on experiments and resources, especially schools in rural and remote areas. There have been many studies researching science education using self-efficacy theory to investigate science teachers' preparedness to teach science in classrooms (Kazempour & Sadler, 2015; Sangueza, 2010). This study draws on self-efficacy theory to explore teachers' self-efficacy to teach the Australian Curriculum: Technologies.

Self-efficacy theory was developed by Bandura (Bandura, 1977, 1986, 1997) as a component of social cognitive theory. In the social cognitive view, human functioning is explained in terms of a "model of triadic reciprocality in which behaviour, cognitive and other personal factors, and environmental events all operate as interacting determinants of each other" (Bandura, 1986, p. 18).

Self-efficacy has been defined as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391). Self-efficacy strongly influences how people make choices, how much effort people exert and how long people persist in the face of adversity. How people behave can be better predicted by their beliefs about their capabilities rather than what they are actually capable of accomplishing (Bandura, 1977). Personal self-efficacy indicates what people do with their knowledge and skills (Bandura, 1977).

Bandura believed self-efficacy is central to affecting human behaviour (Bandura, 1986). Self-efficacy represents how people construct their thinking about personal agency. Agency refers to "acts done intentionally" (Bandura, 1997, p. 3). Personal agency is the power to initiate actions purposefully. The essence of personal agency is that human beings exercise control over motivation, thought and feeling for a given purpose (du Preez, 2013). But whether the purposeful action contributes to positive or negative results or unintended consequences is another issue.

Bandura suggested that self-efficacy beliefs are derived from four principal sources of information, namely *enactive mastery experience*, *vicarious experience*, *verbal persuasion*, and *physiological and emotional status* (Bandura, 1997). The *enactive, vicarious, exhortative, and emotional* sources influence the cognitive processing of efficacy information (Bandura, 1977). *Successful* or *mastery experiences* have the most robust influence on people’s personal efficacy, whereas failures undermine it, especially when failures precede the firm establishment of one’s self-efficacy. By exerting persistent effort, people develop a resilient sense of efficacy. Setbacks and difficulties help people to learn from their failures and build up their capacities to exercise better control over endeavours. When people are convinced that they can succeed, they are more likely to persevere in tough times and emerge from setbacks stronger (Bandura, 1997).

Vicarious experiences also contribute significantly to self-efficacy. When people perceive others with similar skills or situations, such as classmates, colleagues and competitors, succeed in a similar activity it serves as a positive model for their efficacy appraisals (Bandura, 1997). *Verbal persuasion* provides a further means of strengthening people’s efficacy. Verbal persuasion alone may play a limited role in creating enduring increases in self-efficacy, but if verbal persuasion is within realistic realms, it can help people to change. People who are persuaded that they have the ability to achieve a given task are more likely to exert greater effort and sustain it, whereas people who doubt their personal ability and dwell on personal deficiencies are more likely to quit when adversity arises (Bandura, 1997). Evaluative feedback and verbal encouragement given to performers from others serves as persuasory efficacy information. *Physiological and emotional state* is indicated by somatic information which is relevant to physical accomplishments, health functioning and coping with stressors. In physical activities, people can read their fatigue and pain. Mood states affect people’s perceptions and performances (Bandura, 1997). Therefore, one way to change people’s efficacy beliefs is to enhance their physical state, reduce stress and negative emotional interpretations.

Self-efficacy has two components, efficacy expectations, and outcome expectancy (Bandura, 1997). Efficacy expectations represent the conviction or belief that a person can execute the behaviour necessary for some result (Bandura, 1977, 1986). It is a judgement of one’s ability to achieve some performance. Outcome expectations are defined as estimations of likelihood that a given behaviour will produce some outcomes. It is the judgement of the likely outcome such behaviour will lead to (Bandura, 1986, 1997). For example, the belief that one can run a marathon is an efficacy expectation, whereas the anticipated social recognition, applause, medal and self-recognition for the marathon contribute to outcome expectations (Bandura, 1986).

Efficacy expectation and outcome judgements are different, "because individuals can believe that a particular course of action will produce certain outcomes, but they do not act on that outcome belief because they question whether they can actually execute the necessary activities" (Bandura, 1986, p. 392). Instruments for measuring self-efficacy normally include efficacy expectations and outcomes expectations. Two separate subscales are used for the two components of self-efficacy (Bandura, 1997).

Self-efficacy has been the focus of research in various fields such as business, athletics, psychology, clinical health and political changes (Pajares & Urdan, 2006). Self-efficacy theory has been especially prominent in the educational field. Self-efficacy is important to human beings for the reason that it is about people's beliefs about their own capabilities to achieve something and the outcome of their efforts which will powerfully influence the way they behave (Usher & Pajares, 2008). Based on social cognitive theory, self-efficacy beliefs assist people to determine the choices they make, the effort they exert, the perseverance they demonstrate when faced with challenges, and the extent of anxiety or serenity they experience as they engage with the tasks in their lives (Bandura, 1997).

Teacher efficacy beliefs refer to "the extent to which teachers believe they have the capacity to positively affect student achievement" (Riggs & Enochs, 1990, p. 626). Teachers who believe that effective teaching can impact on students' learning and who are also confident about their own teaching capabilities should persist longer. They are more likely to provide greater learning focus in the classroom teaching than those who have lower expectations in terms of their ability to impact on student teaching learning (Gibson & Dembo, 1984). Therefore, teacher efficacy is important because has a positive impact on students' learning outcomes.

2.2.1.1 Self-efficacy for Teaching Science

Bandura's self-efficacy theory is seminal and has been found to be robust in a variety of research from its inception until now. It was used to analyse teachers' self-efficacy for teaching with ICT (Albion, 2000), Science (Albion & Spence, 2013a) and STEM (Yang, Anderson, & Burke, 2014). There were research studies analysing PSTs' self-efficacy in tutoring mathematics for primary school students (Bjerke & Eriksen, 2016). K-12 teachers' self-efficacy for teaching engineering were analysed as well (Yoon Yoon, Evans, & Strobel, 2014).

Self-efficacy beliefs of teachers and teacher candidates should be a focus in educational research. Self-efficacy research can inform educational practice and research agendas (Pajares, 1992). Self-efficacy can predict people's persistence and achievement in challenging subjects (Griggs, Rimm-Kaufman, Merritt, & Patton, 2013). There is a "strong relationship between teachers' educational beliefs and their planning, instructional decisions, and classroom practices" (Pajares, 1992, p. 326). It seems that "beliefs are far more influential than knowledge in determining how individuals organize and define tasks and problems and are stronger predictors of behaviour" (Pajares, 1992, p. 311). Therefore, teachers' self-efficacy beliefs are of great significance for educational research.

Teachers' self-efficacy beliefs can be used to predict their performance in teaching (Cakiroglu, Capa-Aydin, & Hoy, 2012), which will consequently affect students' learning outcomes. Research shows that teachers with higher levels of STEM teaching self-efficacy are confident in their ability to teach STEM (Yang et al., 2014). They believe that their effective teaching can contribute to the success of students' STEM learning.

Low self-efficacy has been highlighted as an issue because a large number of STEM teachers have demonstrated a low self-efficacy to teach STEM and to help students to learn STEM (Cakiroglu et al., 2012). STEM teachers with low self-efficacy are more likely to avoid teaching complex concepts which are beyond their expertise. They also tend to spend less instructional time in STEM (Cakiroglu et al., 2012). Research has shown that pre-service maths teachers who possess stronger beliefs in their capacity to teach maths are more likely to have more confidence in solving maths problems and teaching complicated maths concepts (Briley, 2012). Hence, teachers' self-efficacy beliefs are one of the most powerful variables to predict teachers' performance in teaching (Briley, 2012; Cakiroglu et al., 2012). Teachers' self-efficacy indicates teachers' professional performance which will consequently affect students' learning outcomes.

Science teaching self-efficacy is the belief in one's own ability to learn science and organize and execute skills and knowledge related to science to manage science content and the learning process (Sahranavard, 2014). A large number of science teachers have demonstrated low self-efficacy for teaching science and helping students to learn science (Cakiroglu et al., 2012). Science teachers with low self-efficacy are more likely to avoid teaching complex concepts which are beyond their expertise and tend to spend less instructional time on science subjects.

2.2.1.2 Science Teaching Efficacy Belief Instrument (STEBI)

Self-efficacy is a situation specific construct (Bandura, 1981). "From the social learning perspective, it is no more informative to speak of self-efficacy in global terms than to speak of nonspecific social behaviour" (Bandura, 1981, p. 227). It is "a context-specific assessment of competence to perform a specific task, a judgment of one's capabilities to execute specific behaviours in specific situations" (Pajares & Miller, 1994, p. 194). Explicit efficacy measurements for particular areas are especially necessary since primary teachers teach all subjects and may not be equally good at all subjects (Enochs & Riggs, 1990). It is important to use a specific instrument to measure self-efficacy in science teaching.

Based on Bandura' theory (Bandura, 1977) the *Science Teaching Efficacy Belief Instrument* (STEBI) was developed and validated and has become one of the most widely used instruments targeting science teachers' self-efficacy (Albion & Spence, 2013b; Riggs & Enochs, 1990). Even though it is more than 20 years old, the STEBI-A is still widely used in research (Albion & Spence, 2013b; Sinclair, Naizer, &

Ledbetter, 2011). STEBI-A is used for in-service science teachers (Riggs & Enochs, 1990), whereas STEBI-B has been adapted and developed for pre-service teachers (Enochs & Riggs, 1990). "The STEBI is a valid and reliable tool for studying elementary teachers' beliefs towards science teaching and learning. The STEBI might easily serve as a needs assessment for future in-service and pre-service training" (Wenner, 1993, p. 464) which is consistent with Riggs and Enochs (1990). Therefore, the STEBI is a valid and reliable instrument which has been justified and used in different areas. Figure 3 is Science Teaching Efficacy Belief Instrument-B which is categorized according to outcome expectancy and self-efficacy subscales.

Please indicate the degree to which you agree or disagree with each statement below by placing an "X" on the appropriate letters to the right of each statement. SA= strongly agree, A=agree, UN=uncertain, D=disagree, SD=strongly disagree. * means reverse score.

Outcome Expectancy Subscale

1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.
4. When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.
7. If students are underachieving in science, it is most likely due to ineffective science teaching.
9. The inadequacy of a student's science background can be overcome by good teaching.
*10. The low science achievement of students can not generally be blamed on their teachers.
11. When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.
*13. Increased effort in science teaching produces little change in students' science achievement.
14. The teacher is generally responsible for the achievement of students in science.
15. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.
16. In parents comment that their child is showing more interest in science, it is probably due to the child's teacher.
*20 Effectiveness in science teaching has little influence on the achievement of student with low motivation.

Self-efficacy Subscale

2. I will continually find better ways to teach science.
*3. Even if I try very hard, I will not teach science as well as I will most subjects.
5. I know the steps necessary to teach science concepts effectively.
*6. I will not be very effective in monitoring science experiments.

*8. I will generally teach science ineffectively.
12. I understand science concepts well enough to be effective in teaching primary science.
*17. I will find it difficult to explain to students why science experiments work.
18. I will typically be able to answer students' science questions.
*19. I wonder if I will have the necessary skills to teacher science.
*21. Given a choice, I will not invite the principal to evaluate my science teaching.
*22. When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand.
23. When teaching science, I will usually welcome student questions.
*24. I do not know what do to turn students on to science.

Figure 3: Science Teaching Efficacy Belief Instrument-B (STEBI-B)

The original STEBI has been modified as the basis for similar instruments, including the *Microcomputer Utilization in Teaching Efficacy Beliefs Instrument* (MUTEBI) for measurement of teachers' self-efficacy for classroom computer use (Enochs, Riggs, & Ellis, 1993). The *Mathematics Teaching Efficacy Belief Instrument* (MTEBI) for pre-service teachers resulted from the modification of the STEBI-B (Bursal & Paznokas, 2006; Enochs, Smith, & Huinker, 2000). Based directly on the STEBI-B, the STEBI-CHEM was created to measure teaching confidence in teaching chemistry (Rubeck, 1990). The STEBI-B was used as a model to develop the Self Efficacy Beliefs about Equitable Science Teaching (SEBEST) instrument which measures teacher beliefs in regard to ethnical identities, language minorities, gender issues, and socioeconomic status (Ritter, Boone, & Rubba, 2002). The SEBEST was modified to include talented and gifted students with diverse learning needs.

There were two subscales in STEBI-B in Figure 3, namely, Personal Science Teaching Efficacy Belief (PSTE) and Science Teaching Outcome Expectancy (STOE). The two subscales were calculated separately. The total subscale scores were calculated to measure changes in teaching self-efficacy of participants involved in various interventions (Bleicher, 2004).

2.2.1.3 STEM Anxiety

There are numerous reports of clinical research on the topic of anxiety and the associated misbehaviour and therapy (Taylor, 2014). Anxiety is defined as a state of worry and discomfort when individuals are faced with a threatening situation (Sahin, Caliskan, & Dilek, 2015). Anxiety is developed out of a trauma which can stimulate a readiness to become frightened very easily and result in a vicious circle. People vary greatly in their sensitivity to experiencing anxiety. Some experience anxiety symptoms very easily, whereas others feel anxious only under the most stressful situations. Based on empirical and conceptual evidence, anxiety is among the most common problems in childhood and in youth (Laurent et al., 1999). Anxiety has been connected to heart diseases, suicidal behaviour and decreased quality of life which undermine teaching (Li & Goldsmith, 2012).

The concept of science anxiety was developed in 1977 by Mallow who cofounded the first Science Anxiety Clinic at Loyola University Chicago (Mallow, 1978). Science anxiety was defined as a diffuse or vague fear which comes from science learning environment (Sahin et al., 2015). Science anxiety, like any other negative feeling, results from intervening self-messages rather than from science learning itself. Self-messages include claims about their own ability which produce anxiety and result in low achievement. Self-messages include “I can never solve these problems because I do not have a scientist’s mind” or “if I cannot pass this science exam, I will never graduate from school” (Mallow, 1978).

Science anxiety has been defined as a fear of, or aversion towards, science concepts, scientists, and science related learning activities (Sahin et al., 2015). Science anxiety is also described as “involving feelings of tension and anxiety that interfere with the manipulation of scientific equipment in a wide variety of ordinary life and academic situations” (Idowu, 2013, p. 304). Anxiety leads to panic, tension, and loss of ability to concentrate (Idowu, 2013).

The reasons for science anxiety can also be related to family, school, or the environment (Sahin et al., 2015). There are diverse factors contributing to science anxiety, negative thoughts, unwanted negative memories of the past, and worries about the future. There are many examples of these factors. Science anxiety can result from the humiliating and insulting behaviour of a science teacher in the past, an unsuccessful experiment, or parents’ discouraging comments on children’s science learning. When teachers teach outside of their expertise, it is very likely to lead to anxiety.

Maths anxiety is defined as "negative cognitions, avoidance behaviours, and feeling pressured and inadequate in performance that combined interfere with solving math related problems in both general life and academic situations" (Andrews & Brown, 2015, p. 3). Mathematics anxiety is the most ordinary type of mental illness which affects the emotional, mental and physical responses associated with mathematical thinking (Yeo, Tan, & Lew, 2015). The symptoms related to mathematical anxiety include physical symptoms such as increased heart rate and sweating hands, psychological symptoms such as being unable to concentrate in class, and behavioural symptoms such as avoiding maths class. Students feel panic when they attempt to solve mathematical problems because their self-esteem is being threatened, therefore causing them to have negative attitude towards mathematics learning.

To solve students' STEM anxiety, it is pertinent to help pre-service teachers because they are the implementers of the dictates of the STEM curriculum and the ones to create an anxiety-free classroom environment (Idowu, 2013). By the same token, STEM teachers who possess stronger beliefs in their capacity to teach STEM are more likely to have more confidence in solving STEM problems and teaching complicated STEM concepts (Briley, 2012).

STEM anxiety plays a negative effect in daily life and also people's social status. In the United States, the majority of individuals have a fear of, and express their dislike about, mathematics (Andrews & Brown, 2015). Individuals who have STEM anxiety often avoid studies related to STEM subjects, which may limit their career options in the future.

Teachers' anxiety can be reduced through specific training, education and interventions that target the anxiety itself (Beilock et al., 2010). There is a large number of teachers required to teach STEM who have STEM anxiety (Bryant et al., 2013). For teachers who have STEM anxiety it is detrimental to the effective teaching of STEM subjects in the classroom. Therefore, it is very important for teacher professional learning to alleviate teacher STEM anxiety and to enhance their capacity to teach STEM. Effective teacher professional development will enhance teacher instructional practices which will improve student learning performance (Opfer & Pedder, 2011).

Negative attitudes towards STEM teaching result in teachers' STEM anxiety (Ucar & Sanalan, 2011). What is worse, a teacher's attitude can pass on to students which will be influential in motivating and engaging students in learning STEM (Knezek et al., 2011). It is important for STEM teachers to have a positive attitude about STEM (Ucar & Sanalan, 2011).

There is an interactive relationship between anxiety and self-efficacy. Self-efficacy is associated with key motivation constructs, such as anxiety, value, causal attributions, and achievement goal orientation (Usher & Pajares, 2008). Regardless of previous accomplishment or capacity, self-efficacious teachers may work harder, persist longer, demonstrate greater optimism and lower anxiety, and achieve higher (Pajares & Urdan, 2006).

The relationship between STEM anxiety and STEM teaching self-efficacy is dynamic. There are many STEM teachers who have demonstrated STEM anxiety in their teaching practice in primary and secondary schools (Ping et al., 2011). Teachers' STEM anxiety and negative attitudes is very likely to be passed on to students which will cause students' STEM anxiety and their negative attitudes in learning STEM subjects.

2.2.1.4 Positive and Negative Affect Schedule (PANAS)

Physiological and emotional state is one source of self-efficacy. Bandura argues that mood states affect people's perceptions and performances (Bandura, 1997). Assessing the changes of PSTs' emotional status will help us to better understand the changes of their self-efficacy before and after the engagement with RALfie activities. The Positive Affect and Negative Affect Schedule (PANAS) is a self-report measure assessing adult experiences of positive and negative affect (Watson, Clark, & Tellegen, 1988). There are twenty items related to various affective items which are adjectives describing mood states. There is a Likert-type scale from one to five to rate about their mood.

One means very slightly or not at all, whereas five represents extremely. There are ten items related to Negative Affect (NA) and ten items related to Positive Affect (PA). The PA and NA have been identified as two dominant and relatively independent dimensions of the structure of affect (Watson et al., 1988). PA and NA can be used and analysed separately because they are two independent constructs (Hughes & Kendall, 2009). The PANAS in Figure 4 has become a widely used self-report measure instrument for PA and NA.

Listed below are a number of words that describe different feelings and emotions that you might have prior to participating in the RALfie project today. Read each item and then circle the appropriate answer next to that word. Indicate to what extent you have felt this way before participating in the pilot project today. 1=very slightly 2=a little 3=moderately 4=quite a bit 5=extremely

Interested	very slightly	a little	moderately	quite a bit	Extremely
Distressed	very slightly	a little	moderately	quite a bit	Extremely
Excited	very slightly	a little	moderately	quite a bit	Extremely
Upset	very slightly	a little	moderately	quite a bit	Extremely
Strong	very slightly	a little	moderately	quite a bit	Extremely
Guilty	very slightly	a little	moderately	quite a bit	Extremely
Scared	very slightly	a little	moderately	quite a bit	Extremely
Hostile	very slightly	a little	moderately	quite a bit	Extremely
Enthusiastic	very slightly	a little	moderately	quite a bit	Extremely
Proud	very slightly	a little	moderately	quite a bit	Extremely
Irritable	very slightly	a little	moderately	quite a bit	Extremely
Alert	very slightly	a little	moderately	quite a bit	Extremely
Ashamed	very slightly	a little	moderately	quite a bit	Extremely
Inspired	very slightly	a little	moderately	quite a bit	Extremely
Nervous	very slightly	a little	moderately	quite a bit	Extremely
Determined	very slightly	a little	moderately	quite a bit	Extremely
Attention	very slightly	a little	moderately	quite a bit	Extremely
Jittery	very slightly	a little	moderately	quite a bit	Extremely
Active	very slightly	a little	moderately	quite a bit	Extremely
Afraid	very slightly	a little	moderately	quite a bit	Extremely

Figure 4: The Positive Affect and Negative Affect Schedule

Positive Affect (PA) reflects the degree to which a person feels positive such as enthusiastic, active and alert (Watson et al., 1988). High PA is a state where people demonstrated full concentration, high energy and enjoyable engagement. Low PA reflects negative experience which is characterized by sadness, disengagement and boredom. Low PA is linked to depression which is different from anxiety. Even though depression and anxiety “share a substantial component of general distress, they can be differentiated on the basis of factors specific to each syndrome” (Clark & Watson, 1991, p. 316). Low PA means anhedonia which is categorised as depression. Anxiety is an elevated level of physiological hyperarousal (McCrae, Terracciano, & Costa, 2003).

Negative Affect (NA) is defined as the disposition to experience and communicate a negative emotional state. NA is characterised by subjective distress and disengagement which is composed of a variety of negative mood states such as fear, guilt, disgust and anger (Watson et al., 1988). High NA is very negative which reflects an aversive emotional state, whereas low NA is a positive indicator which demonstrates calmness and serenity. High NA is categorized as anxiety.

Both PA and NA represent largely independent constructs ranging from low to high levels of emotional status (Hughes & Kendall, 2009). PA and NA represent dimensions of affective state which are related to corresponding affective trait elements of positive and negative emotionality. Trait PA and NA correspond to the dominant personality factor *of extraversion* and *anxiety/neuroticism* (Ebesutani, Okamura, Higa-McMillan, & Chorpita, 2011). Trait PA and NA are linked respectively to the “psychobiological and psychodynamic constructs of sensitivity to signals of reward and punishment” (Watson et al., 1988, p. 1063). Low PA and high NA are the most distinguished features of depression and anxiety, respectively.

The PANAS in Figure 4 has demonstrated reliability and validity in both school-based and clinic-referred settings (Ebesutani et al., 2011). There are a number of mood scales created to measure positive and negative affect. However, many existing measures demonstrated low reliability or poor convergent validity (Watson et al., 1988). The PANAS has been found to be highly internally consistent and largely uncorrelated. The scale has also been stable in appropriate levels for a two months period. The scales have presented evidence of convergent and discriminant validity (Watson et al., 1988).

Additionally, the PANAS is brief and easy to manage with a large sample size. Therefore, PANAS is a reliable, valid and efficient measurement.

In this study, the pre-service teachers were native Australians who can understand the PANAS very well. Therefore, cultural background is not an issue. Secondly, the pre-service teachers are students at USQ who have enough time to respond to the survey. They have one month to respond to the online PANAS survey. Thirdly, it is voluntary for participants to participate in this study which is in line with the USQ research ethics requirement. For this study, the participants are pre-service teachers of adult age. The only concern for this study is the sample size. Therefore, the PANAS was used in this study to measure pre-service teachers' positive and negative affectivity.

2.3 Approaches to Understanding Learning

2.3.1 Piaget's Learning Stages Theory

In order to understand PSTs' STEM learning, it is important to use different approaches to explore their learning stages in the RALfie activities. Piaget's learning stages theory was helpful to investigate PSTs' different learning in hands-on and remote activities. It was also helpful to answer the research question related to the ways that RAL experience influenced PSTs' self-efficacy.

Piaget's developmental stages theory argues that learning starts from concrete and moves to abstract. There are four stages of development: sensorimotor, preoperational, concrete and formal operational stages (Piaget, 1974). The four stages of development are all about the capacity to learn at different ages from childhood to adulthood based on the development of logic. Piaget believed that in the concrete operational stage, children start to replace intuitive thought by their own logic which is a vital development in their brain. In the formal operational stage during adolescence, people are capable of using abstract thinking, hypothetical and deductive reasoning skill. In the final stage, adolescents cultivate the capability to reflect on their thinking processes and grasp abstract concepts such as identity and existence (Piaget, 1974).

Many educators believe that teachers and adults learn best with hands-on experiences (Jacobs, 2001). Hands-on activities open more opportunities for learners to be engaged. Learners are more self-directed and responsible for their own learning and development. The interactive learning environment provides more choices for learners to choose which allows them to be actively engaged and make learning meaningful to them. Educators and teachers need to create opportunities for students to make and invent in classroom. Hands-on experiences are helpful to engage students emotionally because hands-on activities are related to personal expression (Martinez & Stager, 2013).

Technologies enable teachers and adults to make things using computers via programming. LEGO Mindstorms can be programmed by computers and can be used for learning powerful ideas while tinkering with things. Scratch and Snap! are popular programming languages to control robotic constructions using computers (Martinez & Stager, 2013). The power of a programming environment is to stimulate thinking and making with the reason that computers can serve various different functions. Computers help people to invent by producing some new action (Papert, 1980). In the LEGO environment, PSTs are in control. They use computers to program LEGO EV3 which will control the robot to follow instructions and produce actions. Therefore, PSTs playing with LEGO provides opportunities for successful experience which is one source of self-efficacy (Bandura, 1997).

Successful experience is the most influential source of self-efficacy. Past successful experience is the most effective way of developing a strong sense of self-efficacy (Bandura, 1977). Hands-on experiences of working with the RALfie project provide successful experiences. Constructivism is related to pedagogical approaches that promote learning from hands-on experiences (Skamp, 2015). Constructivism argues that teachers draw on their prior learning experience to construct new knowledge (Begg, 2015).

2.3.2 Vygotsky's Social Constructivism Theory

Constructivists argue that learning is an active process. Students are active learners rather than empty vessels. Teachers are not the sage on the stage pouring knowledge into students' heads. Students need to construct their own understanding and knowledge based on their existing knowledge (Bryant et al., 2013). Constructing means that "there is a developmental path from some initial state, rather than a teleological progress towards some final state" (Riegler, 2012, p. 236). Knowledge must build on existing knowledge and students' background and experience contribute to the learning process.

Social interaction and cultural influences have a significant influence on learning. Cooperative learning is an integral part of creating a social constructivist learning environment which helps us to have a deeper understanding (Kalina & Powell, 2009). Students should work with peers and collaborate with one another because students have a lot of existing knowledge to offer. Social interactions help students to internalize knowledge and new information at their own pace. Whether learning is constructed internally depends on a situation at a point in time. Social constructivism and situated learning affirm that learning is inherently social and embedded in a particular cultural setting (Kalina & Powell, 2009). Social interactions allow students to bring in their existing knowledge which opens up new opportunities for students to share and learn. Therefore, in a classroom teachers need to create group work to allow students to collaborate with one another which will help students to construct and internalize new knowledge individually and collaboratively.

It is important for teachers to realize the diversity of students' backgrounds and embrace their differences. Students have diverse background characteristics such as ethnicity, identity, culture and biological differences which gives individuals different experiences and understanding (Kalina & Powell, 2009). Teachers should enhance students' dialogues related to the learning target so that students can think critically about their learning because communication is enriched through diversity. Critical thinking enables students to construct their own understanding and personal meaning.

Bandura suggested that vicarious experience is one source of self-efficacy which is mediated through modelled attainments (Bandura, 1997). Self-efficacy beliefs are influenced by observation of others' behaviour and the consequences of those behaviours (Maddux & Gosselin, 2003). Modelling is another effective tool for enhancing a sense of self-efficacy. Seeing people similar to oneself achieve successfully raises self-efficacy in observers that they themselves can attain the capacities to master comparable tasks (Bandura, 1997). Social constructivists believe that social interaction is an integral part of learning (Vygotsky, 1978). Collaboration with more competent peers raises people's self-efficacy due to more competent peers playing the role of modelling. Social interactions and group work provide opportunities for vicarious experience which are helpful to promote self-efficacy.

2.3.2.1 The Zone of Proximal Development (ZPD)

Maker activities provided opportunities for PSTs to interact with engineering experts face to face. Maker activities also provided group work with peers for PSTs. It was important to investigate whether working with experts and more competent peers built up PSTs self-efficacy. Vygotsky defined the Zone of Proximal Development (ZPD) as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). The ZPD theory was helpful for investigating the ways that RALfie activities influenced PSTs' self-efficacy.

The Zone of Proximal Development (ZPD) was conceptualised by Vygotsky while critically evaluating research about children's intelligence in relation to learning and mental development. Children learn easiest within their ZPD when others are involved with collaboration. Through collaboration with more competent adults, children exceed their age-expected performance. The difference in intelligence test scores between collaborative and independent action suggested the child's ZPD which affects how a child learns and grows. The ZPD is most widely used in educational fields such as language learning (Davin, 2013), teacher training (Murphy, Scantlebury, & Milne, 2015) and therapeutic psychology (Zonzi et al., 2014).

ZPD is a gap between the learning a child can make independently compared with the learning attained with teacher's guidance (Murphy et al., 2015). The ZPD defines functions that have not yet matured but are in the process of maturation. These functions are defined as flowers of development rather than the fruits of development which will mature tomorrow but are currently in an embryonic state. The ZPD is a powerful concept which can enhance the effectiveness of the diagnostics of mental development to educational issues.

Traditionally children's mental abilities are judged by whether they can do the task on their own in respect to the task difficulty level. Traditionally people think that learning should match in some manner with children's developmental level. However, the traditional view missed the opportunity to assess children's ability to solve a problem with teachers' assistance or team work with peers. The state of children's developmental process to learning capabilities can be classified by two levels, namely *the actual developmental level* and *the zone of proximal development*. The actual developmental level is a completed level where a child's mental functions have been established and matured. It is revealed by children's independent problem solving ability which is regarded as the end product of development (Vygotsky, 1978). ZPD is the potential developmental level where children cannot solve the problems independently but can achieve with teachers' assistance and or in collaboration with more competent peers.

The ZPD theory helps psychologists and educators to understand the internal course of development which enables us to take account of the matured and completed processes and functions that are begin to mature (Vygotsky, 1978). The ZPD allows us to portray children's immediate future by their matured capacities and their dynamic developmental state by their potential capacities. The ZPD permits us to understand not only their completed achievement but also what is in the process of development. Simply, children's zone of proximal development today will be the actual developmental level tomorrow. What children can do today with teachers' assistance or more competent peers they will be capable of doing by themselves independently in the future.

Vygotsky argued that an essential feature of learning is that it provides the zone of proximal development (Vygotsky, 1978). “Learning awakens a variety of internal developmental processes which are able to operate only when the child is interacting with people in his environment and in cooperation with his peers. Once these processes are internalized, they become part of the child’s independent developmental achievement” (Vygotsky, 1978, p. 90). Therefore, learning is not development. The developmental processes do not coincidentally align with the learning processes. The learning process precedes the developmental process which consequently results in zones of proximal development.

ZPD has been used to successfully explain setbacks. Setbacks occur when teachers’ interventions exceed children’s ability to understand. It is beyond children’s current ZPD. Faced with such interventions, children fail to make advancement (Zonzi et al., 2014). Teachers’ assistance, demonstrations and learning questions are considered as teachers’ guidance to help students to develop within their ZPD. Collaboration with more competent peers also contributes to enhance students’ ZPD.

The ZPD provides a pedagogical framework for co-teaching in science PST education (Murphy et al., 2015). PSTs are placed with experienced teachers who play the role of mentor during student apprenticeship. PSTs collaborate with more competent teachers which helps PSTs to put theory into teaching practice and reflect on how their teaching is developed and improved. Co-teaching brings teachers together which is helpful to share their expertise and knowledge. Evidence shows that working with experts expands PSTs’ agency which improves their confidence and performance (Murphy & Martin, 2015). The mentor’s verbal persuasion and demonstration are important to strengthen PSTs’ self-efficacy (Bandura, 1997). The mentor’s modelling and illustration provides vicarious experience which enhance PSTs’ self-efficacy for teaching (Bandura, 1997). ZPD highlights the significance of social environment for learning (Vygotsky, 1978).

2.3.2.2 Scaffolding

Scaffolding is a metaphor to explain guiding learning and development paths. It is a term to describe the way that teachers or peers supply students with the assistance they need in order to learn and they slowly withdraw help as students are capable of doing more independently (Jacobs, 2001). Students construct their learning by social interaction with the environment.

There are various basic elements of scaffolding. The scaffolds help learners to build on their prior knowledge and internalize new knowledge. Appropriate scaffolding needs to be provided for learners within their ZPD. It is very important to allow learners to complete as much of the learning task as possible independently. Once the learners have achieved the ability and mastered the task, the scaffolding needs to be removed. Scaffolding is task-oriented guidance which needs to be "just-in-time, just enough, just-for-me and just-in-case" (Jacobs, 2001, p. 2).

Scaffolding has been used substantially in face-to-face education. However, technologies enable us to learn online which requires different scaffolding. There are four categories for supporting activities in the online environment: *pedagogical, social*, *managerial* and *technical* (Berge, 1995). The pedagogical support covers teachers using their pedagogical knowledge to facilitate online communication, using questions to trigger students' thinking and responding, and engaging students in group discussion related to critical concepts. The social support is to build a friendly learning environment, recognize students' insights and contribution, promote group work and maintain the group as a unit, and facilitate students to work collaboratively. Managerial support covers administration and organization which involves setting goals, timelines, rules and decision-making norms. Technical support covers the reliability of the network system.

The scaffolding concept is intertwined with social interaction, which provides opportunities for vicarious experience and verbal persuasion (Bandura, 1997). It is argued that distance scaffolding should adjust to the online environment (Jacobs, 2001). Technologies enable us to undertake online and face-to-face education which can be combined. The support strategies for online education and scaffolding strategies for face-to-face education can be combined (Jacobs, 2001). For the students, scaffolding can include instructional scaffolding, social scaffolding, administrative scaffolding, and technical scaffolding. The RALfie activities were scaffolded in the above four perspectives. The RALfie activities were scaffolded by the professional engineers and the course staff. For more details about scaffolding check section 3.3.1.4 on p. 62. The scaffolded RALfie activities were used to impact on PSTs' self-efficacy so that they were better prepared to teach the Technologies.

Scaffolded professional development was significantly superior to PD through self-study in terms of teacher beliefs and motivation, student performance and quality of instruction (Kleickmann, Tröbst, Jonen, Vehmeyer, & Möller, 2016). Teacher training scaffolded by an expert in science teaching had a positive impact on teachers' beliefs and self-efficacy (Kleickmann et al., 2016).

Scaffolding has been used to assist learning processes that support ZPD (Kalina & Powell, 2009). Scaffolding helps us to understand the next level of students' learning from assistance of teachers, competent peers or other adults. Internalization occurs in scaffolding within individuals. This process takes place when students are able to perform some tasks with assistance. The task might be challenging for students to perform on their own but the support system from teachers will provide opportunities for students to solve the problems.

2.3.3 Motivation and Engagement (MeE) Framework

The Motivation and Engagement (MeE) Framework has been used for students across primary school, high school and universities (Liem & Martin, 2012). It has been adopted for adult students at tertiary level. This research drew on the MeE Framework to analyse PSTs' self-efficacy in the maker and user activities.

Substantive engagement has been defined as a multidimensional construct that unites behavioural, emotional and cognitive dimensions in a meaningful way (Fredricks, Blumenfeld, & Paris, 2004). The fusion of behaviour, emotion and cognition under the overarching concept of engagement is of great value. The integration of the three components of engagement provides a richer characteristic of people than merely using any single component. Multi-dimensional engagement is dynamically interrelated within the individual component. There are many robust research studies that address each of the components separately. They examine antecedents and consequences of the three components simultaneously and dynamically to test the effects.

Behavioural engagement has been defined in three ways (Fredricks et al., 2004). The first is related to student conduct. Positive conduct entails following rules, completing homework and obeying classroom norms. Negative conduct refers to disruptive behaviours such as frequency of absences, tardiness, fighting and interfering with the work of others (Finn & Rock, 1997). The second definition concerns participating in learning and behaviours exerted in academic tasks. Positive behaviours involves making effort, persistence, concentration, asking questions and participating in group discussion (Fredricks et al., 2004). The third definition involves taking part in school-related extracurricular activities such as athletics, drama, debating and school governance. Being persistent to achieve and overcome setbacks is related to research about self-efficacy. When students demonstrated positive behaviours such as persistence, exerting effort and participation, they also demonstrated they have high self-efficacy in learning (Bandura, 1977).

Emotional engagement refers to students' affective reactions in the classroom such as interest, boredom, happiness, sadness and anxiety (Fredricks et al., 2004). It is identification as belonging and value. Students feel that they belong to school and they are important to the school. Students value the success in school-related outcomes. Emotional engagement echoes an earlier body of research on attitude which examined feeling likes and dislikes towards school, the teacher or school work; feeling happy or upset in school; being interested or bored in school work. Emotions incorporated in the engagement construct were also overlapping and examined by motivational research. *Physiological and emotional status* is one source of self-efficacy (Bandura, 1977). Physiological and emotional state is relevant to physical and health status and stress level. People feel more self-efficacious when they are calm than when they are aroused and distressed (Maddux & Gosselin, 2003). In physical activities, people can read their fatigue and pain. Mood states and emotional interpretations affect people's perceptions and performances (Bandura, 1997). When students demonstrated negative attitudes, feeling stressful and feeling anxious in learning, they had undergone negative emotional engagement and low self-efficacy.

Cognitive engagement draws on the idea of investment which integrates thoughtfulness and willingness to make effort to master complex concepts and acquire difficult skills (Fredricks et al., 2004). Cognitive engagement also refers to psychological investment in learning, willingness to go beyond the requirement and a preference for challenges which go beyond the current ZPD (Vygotsky, 1978). Cognitive engagement refers to the amount and the type of learning strategies that students employ in tasks. A high level of self-efficacy in academic success is related to the use of cognitive strategies that translate into higher academic achievement (Walker, Greene, & Mansell, 2006). One important outcome of motivation is cognitive engagement in learning.

There is a significant difference between meaningful and shallow processing. Meaningful processing involves relating to prior knowledge, creating an integrated structure of knowledge. Shallow processing involves rote learning, memorization, basic rehearsal and simply re-reading one's class notes which are all labelled as superficial engagement. Meaningful cognitive engagement has been defined as strategy use that combines meaningful processing and self-disciplinary strategies such as planning and checking one's work to monitor progress (Walker et al., 2006). Using meaningful cognitive strategies will enhance students' self-efficacy to achieve in academic success and they are more likely to be cognitively engaged in the future. Research has shown that cognitive engagement leads to enhanced performance on achievement which will contribute to enactive mastery experience as one source of self-efficacy (Bandura, 1977).

Self-efficacy is a motivational construct. Self-efficacy is key to enhancing students' engagement and learning (Linnenbrink & Pintrich, 2003). Self-efficacy facilitates students' behavioural, cognitive and motivational engagement in the classroom. People who feel self-efficacious about their abilities are more likely to exert positive behaviours and persist longer in the face of difficulties. People with high self-efficacy are more likely to show an increase in the adoption of deeper processing strategies to be engaged cognitively (Linnenbrink & Pintrich, 2003). Emotional status as one source of self-efficacy indicates people's emotional engagement.

2.3.4 Theoretical Framework

Drawing on the self-efficacy theory, the theoretical framework for this thesis was developed and constructed. The focus of this study was how to improve teachers' self-efficacy to teach the Australian Curriculum: Technologies. Therefore, self-efficacy theory was the main theory for this study. The MeE Framework, Vygotsky's social constructivism and Piaget's learning stages theory provide the outer layer of theoretical support for this study. RALfie was a vehicle in this study which was used as a means to influence PSTs' self-efficacy.

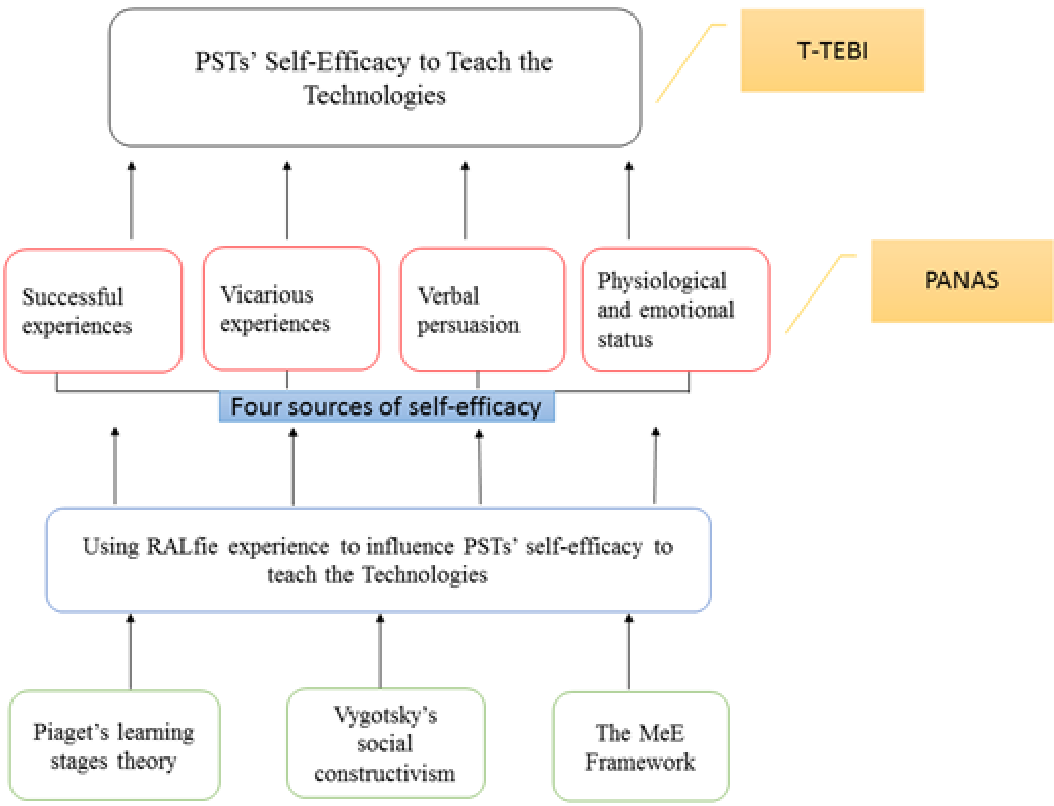

Figure 5: The Theoretical Framework

The top layer of Figure 5 is the focus of this research which is PSTs' self-efficacy to teach the Australian Curriculum: Technologies. The second layer shows the four sources of self-efficacy. The third layer talks about RALfie activities which influence self-efficacy. The bottom layer shows that RALfie maker and user activities are guided through the following approaches, including Piaget's learning stages theory, Vygotsky's social constructivism and the MeE Framework. PANAS is used to assess PSTs' emotional status. T-TEBI is used to measure PSTs' self-efficacy to teach the Technologies.

The ultimate goal of using RALfie in this study was to build up PSTs' capacity and confidence to teach the Australian Curriculum: Technologies in classrooms. RALfie provided technical and content scaffolding to increase their ZPD to teach the Australian Curriculum: Technologies. Different modes of RALfie experiences were used to motivate and engage PSTs to teach the Technologies. More exposure to technology experiences and having success in doing them were expected to alleviate their technology anxiety, enhance their self-efficacy and better prepare them to teach technology in the future.

2.3.5 Research Gaps

Many studies have researched about preparing primary school teachers to teach science (Albion & Spence, 2013b; Fitzgerald, Dawson, & Hackling, 2013; Gillies & Nichols, 2015; Wang, Tsai, & Wei, 2015). They include studies about how to prepare teachers to teach with ICT where technology was a vehicle to facilitate teaching rather than a subject (Tondeur et al., 2016; Valtonen et al., 2015). However, there were fewer research studies about preparing primary school teachers to teach Technology (Reynolds & Chambers, 2015). Science has been an important subject in schools for a long time, whereas Technology has become important in recent decades. Compared to Science teacher training, there were fewer documents and fewer professionals in Technology teacher training. Primary school teachers are required to teach across different subjects which may result in a low sense of self-efficacy to teach the

Australian Curriculum; Technologies. Therefore, it is important to address the gap by researching how to prepare primary school teachers to teach Technology in classroom.

There was limited research on using remote access laboratories in teacher education (Bowtell et al., 2012). RAL has been used extensively for the remote experiments for students who work in engineering, nursing and farming, but it was rare to use RAL in teacher education. Using RAL for PSTs' education program is addressing a gap in the research literature.

There is a relationship between self-efficacy theory and social constructivism. There are four sources of self-efficacy information: enactive successful experiences, vicarious experiences, verbal persuasion and physiological and emotional status (Bandura, 1997). The most effective way of developing a strong sense of self-efficacy is through past successful experiences which are defined as authentic success in dealing with a particular situation. Social constructivism argues that the learning process is affected by personal characteristics as well as by social interactions with teachers or more competent peers in the Zone of Proximal Development (ZPD) (Vygotsky, 1978). It is argued that PSTs learn better on a given task when they were working with experts than working on their own. PSTs make independent use of their earlier engagement which enabled them to perform more effectively. This process is based on language and articulation of ideas, which are key concepts in learning and developing theory (Vygotsky, 1986). Mastery experiences were the most authentic evidence of achieving a particular thing.

There were fewer instruments to assess teachers' self-efficacy in Technology teaching compared to those in science. The Science Teaching Efficacy Belief Instrument (STEBI) has been established and used for the past 26 years (Enochs & Riggs, 1990). STEBI has been adapted to assess teachers' self-efficacy in teaching mathematics, biology and microcomputer utilization. However, there is not a specific instrument for teacher's self-efficacy to teach Technology.

Positive and negative emotional states are one source of self-efficacy information. Positive emotional status helps people to be self-efficacious where negative emotions such as anxiety and frustration decrease people's self-efficacy. The combination of PANAS and T-TEBI addressed a gap in assessing self-efficacy.

2.3.6 Research Questions

Drawing on the theoretical framework and research gaps, the literature review highlighted a gap associated with teachers' self-efficacy to teach Technology. There are many primary school teachers who are anxious about teaching Technology. It is important to prepare primary school teachers to be able to understand the Australian Curriculum: Technologies and to be self-efficacious about teaching technologies in the classroom. This study was developed to explore ways to build up primary school teachers' capacity and capabilities to teach technologies.

The literature review also highlighted a gap relative to using RAL for teacher education. It was important to have some access to online teaching resources. It is important to improve RAL experience so that RAL can be used as a powerful treatment to better prepare PSTs in the future.

The main research question is:

- In what ways does engagement with Remote Access Laboratories influence pre-service teachers' self-efficacy to teach the Australian Curriculum: Technologies?

The sub-questions are:

- How has the RAL experience influenced pre-service teachers' self-efficacy to teach Australian Curriculum: Technologies?
- How can the RAL experience be improved in the future?

These research questions were used to guide this research.

2.4 Summary of Chapter 2

Chapter 2 was divided into three parts. Part one reviewed the context of this study. It reviewed literature about the importance of STEM education and then identified problems in STEM education, with emphasis on the Australian context. STEM education problems include the STEM divide, teacher shortages, insufficient STEM teacher professional development and teachers' low self-efficacy to teach STEM. All of these issues contribute to students' low engagement and low performance in STEM.

It then introduced the new Australian Curriculum: Technologies which was approved for implementation in 2015. The new curriculum emphasizes the digital skills and design skills. Remote Access Labs has been increasingly investigated as a partial solution to the challenge of hands-on labs.

Part two reviewed the literature of self-efficacy theory and four sources of self-efficacy information. The T-TEBI modified from the STEBI is used to measure teacher's self-efficacy to teach Technology subjects. Teachers' anxiety to teach STEM is related to their low self-efficacy. In order to measure anxiety, PANAS was introduced to assess positive affect and negative affect.

Part three reviewed different approaches to professional development for PSTs. It reviewed Piaget's four learning stages theory to highlight the importance of learning through active exploration. Vygotsky's social constructivism helps to understand that social interaction and culture influences have a significant influence on learning. The MeE Framework highlighted the interactive relationship between motivation and engagement. The conceptual framework was constructed for this study drawing mainly on self-efficacy theory.

Chapter 3: Research Methods

This chapter introduces the research methods used in this study. It begins with pragmatism as the research paradigm and continues with discussion of mixed methods. The RALfie project and associated maker and user activities are described together with how the quantitative and qualitative data were collected and analysed. The ethics, reliability and trustworthiness are discussed. Finally, the summary of the chapter is provided.

3.1 Research Paradigm

A research paradigm is a worldview which is defined as a basic set of beliefs that guide research action (Guba, 1990). A worldview is "a general orientation about the world and the nature of research that a researcher holds" (Creswell, 2009, p. 6). Worldviews are shaped by the discipline, beliefs and past research experiences. The pragmatic worldview derives from actions, situations and consequences (Creswell, 2009). Based on the intended consequences, pragmatist researchers focus on what to research and how to solve the research problem. "Pragmatism is not committed to any one system of philosophy and reality" (Creswell, 2009, p. 10). Researchers are free to choose what works for the research. Pragmatism claims that truth is what works at the time, which represents a very practical and applied research philosophy (Tashakkori, 1998). Pragmatism claims that individuals have freedom of choice. Researchers are free to choose research methods, research techniques and the procedures of research. To put it simply, pragmatism considers the research questions to be more important than the research method and the worldview that is supposed to underpin the method.

Pragmatism applies to mixed methods research. Mixed methods researchers need to establish a purpose for their mixing to explain the reasons why two sets of data need to be mixed in the first place (Creswell, 2011). Researchers use both qualitative and quantitative methods because the combined methods provide the best understanding of the research questions (Creswell, 2009). Pragmatism is open to multiple methods, different worldviews and different approaches to data collection and analysis techniques which meet the needs of mixed method researchers (Tashakkori, 1998). Therefore, pragmatism is the philosophical paradigm that led to the mixed methods research design in this study.

3.2 Mixed Methods Research

Mixed methods refers to the use of both qualitative and quantitative data collection techniques and analyses in a single research study (Tashakkori, 1998). Mixed methods provide a more comprehensive understanding of a research problem than can be achieved by using one approach alone (Creswell, 2007). The qualitative approach is helpful in hearing directly the voices of participants. The quantitative approach will collect data from a large group of participants which is beneficial to generate valid findings (Creswell, 2011). The mixed methods approach "provides strengths that offset the weakness of both quantitative and qualitative research" (Creswell, 2007, p. 9). Both quantitative and qualitative data will be integrated for the interpretation of the overall results. The structure of mixed methods in this study is qual+quan (Palinkas et al., 2011). Two samples will include the same individuals because this study will "corroborate, directly compare, or relate two sets of findings" about pre-service teachers' self-efficacy to teach the Technologies (Creswell, 2011, p. 183).

Mixed methods research allows researchers to use all appropriate tools to collect data and to address the research questions rather than being restricted to one approach. Drawing on two sets of data contributes to validated and substantiated results (Creswell, 2007). However, conducting mixed methods research is not easy. It takes time to collect and analyse two sets of data. The procedures may be complicated and require clear presentation of data from two sources (Creswell, 2007). It also requires the researcher to be trained to analyse two data forms, which takes greater effort.

The results generated by two forms of data will be integrated or compared side by side in a discussion chapter of the thesis (Creswell, 2007). The side-by-side integration in the discussion chapter will allow this research to provide quantitative statistical results first and then use qualitative data to support, clarify and extend the quantitative results (Creswell, 2009).

In this research, participants responded to the pre and post surveys first as quantitative data and later they were interviewed to collect qualitative data. For the data analysis, quantitative data were used to identify cases for closer examination. The size of the quantitative sample is much bigger than that of the qualitative sample, which will be helpful to obtain a rigorous quantitative examination and an in-depth qualitative exploration of the topic. Parallel data collection questions were designed in both the quantitative and qualitative data collection efforts to address the self-efficacy concepts (Creswell, 2011). Therefore, the two data sets can be compared and merged to have a more extensive understanding of pre-service teachers' self-efficacy.

The main research question is to investigate in what ways the engagement with RAL influences pre-service teachers' self-efficacy to teach the Technologies. Pre-test and post-test surveys were used in this study. The T-TEBI, which is a modified version of the STEBI-B (Enochs & Riggs, 1990), was used to trace changes of pre-service teachers' self-efficacy which is a context specific construct (Bandura, 1997). PANAS (Watson et al., 1988) was used to measure the changes of pre-service teachers' anxiety.

Quantitative methods have been dominant in analysing self-efficacy beliefs in education since very early research. Quantitative methods have been validated and shown rigorous results in many research studies (Albion & Spence, 2013b; Lamb, Vallett, & Annetta, 2014; MacPhee, Farro, & Canetto, 2013; Painter & Bates, 2012). However, surveys are unable to provide specific reasons why participants' self-efficacy changed. Self-efficacy is related to their inner voice and their internal beliefs. A quantitative approach is insufficient to investigate the nuance of pre-service teachers' self-efficacy for this study. Quantitative approach only is inadequate to explore the relationship between pre-service teachers' self-efficacy for teaching STEM and engagement with RAL. Therefore, it is important to use a qualitative approach to understand pre-service teachers' self-efficacy to teach the Australian Curriculum: Technologies. The limitation of a quantitative approach can be offset by the strengths of qualitative methods (Creswell, 2011). Additionally, this study is complex because RAL is not the only intervention in the class. It is important to use a qualitative approach to attribute reasons to changes in pre-service teachers' self-efficacy.

Interview questions were used to answer the research questions and to explore the specific reasons for changes of self-efficacy.

More researchers have adopted mixed methods to analyse self-efficacy in recent years. Mixed methods has been used to analyse the impact of service-learning on PSTs' self-efficacy beliefs in science teaching to diverse learners (Yang et al., 2014). PSTs were enrolled in a STEM pedagogy service-learning course during two semesters. STEBI-B was used to collect quantitative data and PSTs' reflective assignments were used to collect qualitative data. Mixed methods were used to analyse PSTs' self-efficacy to teach science which demonstrated rigour and reliability in the data analysis.

The value of mixed methods needs to be highlighted. Qualitative research methods have been typically used in social science for exploratory research in order to develop a deep understanding of a phenomenon and to generate new insights into an existing theory (Tashakkori, 1998). Quantitative methods have typically been applied to address confirmatory research questions such as theory testing (Venkatesh, Brown, & Bala, 2013).

Mixed methods has the capacity to provide stronger inferences than a single method or worldview (Tashakkori, 1998). Interviews, which are a qualitative data collection technique, can provide depth in research by allowing researchers to gain deep insights from rich narratives. Surveys, which are a quantitative data collection technique, can bring breadth to research by helping researchers gather data about different aspects of a phenomenon from many participants. Together, mixed methods can help a researcher to make better and more accurate inferences, that is meta-inferences (Venkatesh et al., 2013). Meta-inferences represent an integrative view of findings from both strands of mixed methods which are essential components of mixed methods.

Mixed methods provides a great opportunity for divergent or complementary views (Tashakkori, 1998). When conducting a mixed methods study, a researcher might find different conclusions which might be contradictory or complementary from two data sources. It is valuable to find divergent findings which lead to re-examination of the conceptual framework and the hypothesis or assumptions underlying each of the data sources. The contradictory findings not only enrich our understanding of a phenomenon but help us to appreciate the boundary conditions of a phenomenon and open new ways for future research directions (Venkatesh et al., 2013). Complementary findings are equally valuable in the quest of generating substantive theories because these findings provide a holistic perspective of a phenomenon and additional insights to understand the interrelations among its components.

Both data sources can be triangulated, which enhances the reliability and validity of research findings (Bleicher & Lindgren, 2005). Therefore, mixed methods will be used in this study to explore the relationship between self-efficacy for teaching Technology and the impact of RAL on change of self-efficacy.

Different strategies were used to ensure quality in data collection, analysis and reporting. During the RALfie Maker events, the researcher assumed the role of participant observer, which allowed for continuous data collection and thorough engagement in the data collection process. There are issues associated with conducting mixed methods such as time constraints and the lack of participants. This researcher collaborated with her Principal Supervisor who is the course lecturer at USQ. This research also involved team work with five other USQ lecturers and trying different ways to engage more participants. For the data collection, Survey Monkey and LimeSurvey systems were used to conduct electronic surveys and broadcast the survey to the Learning Management System for participants. This researcher also met regularly with supervisors to discuss observations and further research modifications and the data collection process as the study proceeded.

3.3 Data Collection and Analysis

3.3.1 RALfie Activities

The Remote Access Laboratories for Fun, Innovation and Education (RALfie) project is a joint effort between academics in Engineering and Education at USQ. Professional engineers are responsible for the technical aspects of building the RAL system. Educators provide support from pedagogical perspectives (Kist et al., 2011).The RALfie system is a modular design which allows participants to create rigs and house those individually at distributed locations (Maiti, Kist, & Maxwell, 2014a). The distributable feature makes RALfie more flexible and accessible for any users (Kist et al., 2014). RAL has been used widely in engineering and computer science but there was little research on how RAL may afford valuable learning outcomes in other faculties or disciplines such as education (Kist et al., 2014). This research used RAL in teacher education to investigate its impact on pre-service teachers' self-efficacy for teaching the Technologies curriculum.

RALfie is not only helpful for enthusiasts but also very helpful for talented and gifted students to become involved with professional STEM educators at university level. This provides an opportunity for them to work as a researcher in a science project which demands higher STEM skills and greater intellectual engagement. They can also be incorporated in a research institution directly to discuss with supervisors with professional research backgrounds. In the RALfie project, there are expert STEM teachers in tertiary level who joined the online community. Students with special talent in STEM could contact expert RAL users directly and discuss with them. They could also be challenged by each other and collaborate with their peers.

The RALfie team developed a prototype of the online RALfie system. This research project used the RALfie system but was not responsible for its development. The focus of this study was on the effects of RAL activity on pre-service teachers' self-efficacy for teaching STEM content. This study used the RALfie system and also provided feedback for the Engineering academics to modify and refine the RALfie activities to suit pre-service teachers' needs.

The RALfie project is an innovative and brand new project which makes RAL available for primary and secondary pre-service teachers to create and access STEM experiments remotely. One of the aims of the RALfie project is to develop STEM teachers' understanding of STEM teaching and the Technology Curriculum whilst fostering a positive attitude to STEM teaching. The RALfie project provides two types of activities, maker and user activities. The purpose of maker and user activities is to make STEM activities motivating and engaging for pre-service teachers (Orwin, Kist, Maxwell, & Maiti, 2015).

3.3.1.1 The LEGO Mindstorms EV3

LEGO Mindstorms EV3 is the third generation robotics kit. (http://www.lego.com/en-us/mindstorms/learn-to-program) The EV3 brick is the brain of the robot. Figure 6 shows the EV3 brick linked to a LEGO model. The first step in programming a LEGO construction using EV3 is to download the LEGO Mindstorm EV3 software to a computer and connect the EV3 brick to the computer using the USB cable. The software shows the details of the programming on the brick. Participants can use the EV3 software to create a program, download it to the EV3 brick, open the program and run it in the EV3 brick. Figure 7 shows the LEGO Mindstorms software.

Figure 6: The LEGO Mindstorms EV3 Brick

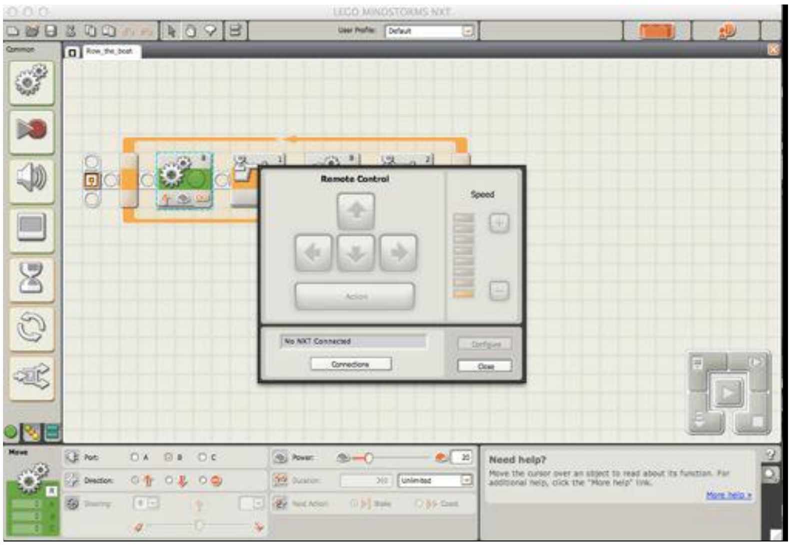

Figure 7: The LEGO Mindstorms Software

In order to make the robot move, it is important to connect the EV3 motors to the EV3 brick. Participants can set the speed, number of rotations and degree of rotation for the motors. To make the robot perform the way people want it to, it is important to use the programming blocks in the EV3 software. Participants can use the start blocks in orange to start the program. There are action blocks in green where participants build the program and make the robot perform.

RALfie activities were built using the LEGO Mindstorms kit and remote controlled by the interface via computers. The LEGO EV3 needed to connect to the RALfie box. The LEGO EV3 was connected to a Wi-Fi adapter which allowed LEGO EV3 to talk to the RALfie box. The RALfie box was a router. It was important to make sure the RALfie box was switched on. The IP camera needed to connect to the RALfie box and to power. It was important to check the connectivity at the back of the RALfie box. The professional engineers talked through the functions of the LEGO Mindstorms software. Participants asked questions and had discussion with the LEGO experts.

3.3.1.2 Maker Activities

In the maker activities, PSTs were invited to come to engineering laboratories at USQ. They assembled and modified LEGO Mindstorms components to construct hands-on experiments. It was a face-to-face activity which allowed PSTs to tinker with rigs and interface to build hands-on experiment. They connected LEGO Mindstorms to server computers and programmed them using Snap! The server computers were connected with IP cameras which were used for remote observation. The maker activities covered programming, connectivity and designing skills in line with the *Australian Curriculum: Technologies*.

PSTs worked in groups to interact with their peers. The maker activities were new and foreign to the majority of PSTs. The scaffolding provided by professional engineers was essential. There were three professional engineers available in the lab. One was responsible to provide a 20 minute orientation workshop about maker activities for PSTs. One was responsible to explain how the RALfie system worked for remote control. One was responsible to facilitate how to program using Snap! All of them facilitated PSTs' group work when they needed further assistance. For more details of maker activities, check section 4.1.1 p.75 and section 5.1.1 on p.101.

3.3.1.3 User Activities

The professional engineers developed the RALfie prototype to provide online access to experiments. In the user activities, PSTs were able to remotely control activities located in the engineering laboratory. PSTs needed to sign up for user activities and access them via an online link. The user activities had broader relevance to the *Australian Curriculum: Technologies*. PSTs need more instructional and technical scaffolding to access the online interface. For the pilot study, the researcher sat beside the participant to provide one on one instructions to assist the login process. For the major study, the course lecturer built the user activities into his course and provided instructions based on user activities. PSTs asked questions using the USQ online learning management system. For more details about user activities, check section 4.1.2 on p.78 and section 5.1.2 on p.103.

3.3.1.4 Scaffolding

In maker and user activities, scaffolding was provided for PSTs by engineers and educators. The scaffolding concept is intertwined with social interaction, which provides opportunities for vicarious experience and verbal persuasion (Bandura, 1997). It is argued that distance scaffolding should adjust to the online environment (Jacobs, 2001). Technologies enable us to undertake online and face-to-face education which can be combined. The support strategies for online education and scaffolding strategies for face-to-face education can be combined (Jacobs, 2001).

Scaffolding for the maker and user activities were combined. Administrative scaffolding allowed learners to manage their educational process in the informal learning environment. The RALfie project engaged PSTs to participate in the activities. Instructional scaffolding allowed learners to learn in a network and work collaboratively with one another. Working with professional engineers allowed PSTs to learn from modelling which is helpful to enhance PSTs' self-efficacy (Bandura, 1997). Social scaffolding allowed learners to build relationships and exist in a network (Vygotsky, 1978). Social interactions provided opportunities for PSTs to collaborate and learn from each other which was helpful to enhance their self-efficacy with the reason that social interactions offered vicarious experience and verbal persuasion from peers and experts (Bandura, 1997). Technical scaffolding helped the utilization of the online tools and made communication and learning affordable (Jacobs, 2001). The RALfie project provided the RALfie website through which students could access different user activities. Technical scaffolding was helpful to make RALfie activities more approachable, especially for students who lacked related experience.

Table 1: Scaffolding provided by the RALfie project

Types of Scaffolding	**Strategies**	
	Maker Event	**User Event**
Administrative Scaffolding Objectives: to help to engage pre-service teachers to use RALfie	It is a face-to-face activity where PSTs interacted with the course lecturers and professional engineers. The course lecturer encouraged and engaged PSTs to use RALfie. Professional engineers talked to the class and demonstrated remote controlled robotic activity. This researcher went to the course and talked to the class about RALfie activities.	It is an online activity where PSTs can access RALfie activities remotely. The course lecturer built RALfie into the Technology Course at USQ. Engineering experts designed and developed different online activities. This researcher sent emails to PSTs to encourage PSTs to use the online system
Instructional Scaffolding Objective: to help pre-service teachers to learn	Engineering experts offered an orientation workshop to introduce RALfie concept in maker events. The course lecturer had taught PSTs how to use Scratch	Engineers provided RALfie demonstration videos to explain how RALfie system works.

	programming language before they attend the maker event. Engineering experts demonstrated how to use Snap! to program robots using the LEGO Mindstorms software.	Engineers also provided a website to allow PSTs to remote access online activities. This researcher made a RALfie brochures.
Social Scaffolding Objective: to help students to build relationship and work collaboratively	PSTs interacted with professional engineers and educators. PSTs work with peers in a group.	There was no social scaffolding provided online.
Technical scaffolding Objective: to ensure the technical affordance to use the RALfie system	RALfie team maintain the accessibility of the technical system In the maker event, PSTs can ask for help spontaneously when they need technical scaffolding.	Provide technical scaffolding for log-ins and webpage navigation in the pilot study. For the main study, there was an email address provided by a professional engineer who would respond to PSTs' emails if they encounter technical difficulties.

Maker and user activities provided a cumulative and culminating experience which allowed PSTs to synthesize the information in the ongoing process. Administrative, instructional, social and technical scaffolding were important to motivate and engage PSTs to participate in maker and user activities.

3.3.2 Participants

The participants in the main study were drawn from pre-service teachers at USQ who were studying to become primary teachers. They were in the Bachelor of Education (Primary) and were taking a one unit required course in Technology education. The majority of them were final year students but a few of them were at different stages of their studies. They came from three campuses, Toowoomba, Springfield and Fraser Coast and online students. They were volunteer participants in this research.

For the pilot study, five course lecturers at USQ agreed to send RALfie brochures and online resources to their students via the Learning Management System (LMS). RALfie activities were not formal parts of the courses but were additional tasks for students to do. Detailed numbers of participants are presented in Section 4.2.1.

In the main study, the course lecturer who taught Technology Curriculum and Pedagogy at USQ agreed to send RALfie information and online resource to his students via the LMS. He made RALfie an integral part of his course. Detailed numbers of participants are presented in Section 5.2.1.

3.3.3 Quantitative Data

3.3.3.1 Quantitative Data Collection

Quantitative data includes "closed-ended information such as that found on attitude, behaviour or performance instruments" (Creswell, 2007, p. 6). In this research, the T-TEBI, which is a modified version of STEBI-B (Riggs & Enochs, 1990), and PANAS instruments (Ebesutani et al., 2014) were used to collect quantitative data. As was discussed in the literature review, T-TEBI is a modification of STEBI-B, a well-developed and validated instrument which has been used in multiple contexts for pre-service teachers. The purpose of pre-test and post-test of PANAS was to identify whether there were changes in pre-service teachers' emotional status which is one source of self-efficacy information.

The questionnaires were administered in two iterations at the beginning and end of the relevant semesters. The URLs of surveys were broadcast in the Learning Management System for all students enrolled in selected courses locally and remotely. In the pilot data collection SurveyMonkey was used and in the major data collection LimeSurvey was used. Pilot data collection took place in Semester 1 and Semester 2 in 2014. The pilot study was used to refine the research process and confirm the interview questions. The pilot study was also used to test the RALfie system, and maker and user activities. The major data collection took place in Semester 1 2015 using the same instruments, T-TEBI and PANAS. The major data collection was conducted in two iterations at the beginning and end of Semester 1 2015.

The core concept of two subscales in self-efficacy did not change in STEBI-B. The STEBI-B was adapted for the measurement of pre-service teachers' self-efficacy to teach Technology. The modified version of STEBI-B is called T-TEBI which is the *Technology Teaching Efficacy Belief Instrument*. In T-TEBI, 'science' was replaced by 'technology'. Some wording was adjusted for tense such as replacing 'will' to 'am going to' as they are pre-service teachers; and 'elementary' to 'primary' to suit the Australian context.

Please indicate the degree to which you agree or disagree with each statement below by placing an "X" on the appropriate letters to the right of each statement. SA=strongly agree, A=agree, UN=uncertain, D=disagree, SD=strongly disagree.

Outcome Expectancy

1. When a student does better than usual in technology, it is often because the teacher exerted a little extra effort.
4. When the technology grades of students improve, it is often due to their teacher having found a more effective teaching approach.
7. If students are underachieving in technology, it is most likely due to ineffective technology teaching.
9. The inadequacy of a student's technology background can be overcome by good teaching.
*10. The low technology achievement of students can not generally be blamed on their teachers.
11. When a low-achieving child progresses in technology, it is usually due to extra attention given by the teacher.
*13. Increased effort in technology teaching produces little change in students' technology achievement.
14. The teacher is generally responsible for the achievement of students in technology.
15. Students' achievement in technology is directly related to their teacher's effectiveness in technology teaching.
16. If parents comment that their child is showing more interest in technology, it is probably due to the child's teacher.
*20 Effectiveness in technology teaching has little influence on the achievement of student with low motivation.

Self-efficacy Subscale

2. I will continue to find better ways to teach technology.
*3. Even if I try very hard, I will not teach technology as well as I will most subjects
5. I am going to know the steps necessary to teach technology concepts effectively.
*6. I am not going to be very effective in monitoring technology learning activities.
*8. I am going to generally teach technology ineffectively.

12. I am going to understand technology concepts well enough to be effective in teaching primary technology.
*17. I am going to find it difficult to explain to students why technology learning activities work.
18. I am going to typically be able to answer students' technology questions.
*19. I wonder if I am going to have the necessary skills to teach technology.
*21. Given a choice, I am not going to invite the principal to evaluate my technology teaching.
*22. When a student has difficulty understanding a technology concept, I am going to be at a loss as to how to help the student understand.
23. When teaching technology, I am going to welcome student questions.
*24. I do not know what to do to turn students on to technology.

Figure 8: Technology Teaching Efficacy Belief Instrument (T-TEBI)

Based on the two subscales of STEBI-B, there are two subscales in T-TEBI as shown in Figure 8. The Personal Technology Teaching Efficacy Belief (PTTE) is for efficacy expectations or self-efficacy (SE). SE measures a teacher's belief about his or her ability to effectively teach Technology. The Technology Teaching Outcome Expectancy (TTOE) is for outcome expectancy (OE). OE measures belief that teaching Technology will be successful in producing the expected learning outcomes for students (Enochs & Riggs, 1990). Because OE and SE measure the different dimensions of self-efficacy, the analysis of OE and SE was conducted separately.

3.3.3.2 Quantitative Data Analysis

3.3.3.2.1 T-TEBI Analysis

T-TEBI in Figure 8 uses a Likert scale which follows exactly the STEBI-B format of strongly disagree, disagree, uncertain, agree to strongly agree. A strongly disagree is rated as 1 point, disagree as 2, up to strongly agree as 5 points. There are 11 items in OE scale (1, 4, 7, 9, *10, 11, *13, 14, 15, 16, *20) and 13 items in the SE scale (2, *3, 5, *6, *8, 12, *17, 18, *19, *21, *22, 23, *24). Items asterisked are reverse scored. The responses totalled on each of the two subscales provide a measure of their self-efficacy beliefs.

In this research, the T-TEBI data were analysed using the Statistical Package for the Social Science (SPSS) Version 22. Reliabilities of the instrument scales were assessed using Cronbach's alpha and by examining item-total correlations for the OE and SE subscales. The Mann-Whitney U-test was used to test significance because the small samples did not support the use of the t-test (Field, 2009). The pre-post T-TEBI results were matched with individual PSTs to identify the individual change rather than group means. PANAS followed the same analysis process.

3.3.3.2.2 PANAS Analysis

The analysis of the PANAS has been varied to meet various research purposes. PA and NA can be used and analysed separately because they are two independent constructs (Hughes & Kendall, 2009). In this study, PA and NA were analysed separately. Both PA and NA scores were summed to calculate the total scores for each individual participant. The individual differences for PA and NA were produced for both the pre-test and post-test PANAS. The differences in mean scores between pre-post PANAS were calculated to identify the changes of individual's PA and NA before and after their involvement in RALfie activities.

3.3.3.2.3 Descriptive Analysis

The descriptive analysis reported demographics (Creswell, 2009). This research conducted the survey twice, at the beginning and the end of semesters but there might be participants who responded to only one of the pre or post surveys. It was important to collect their demographic information for both treatment group and non-treatment group. In this research, treatment groups who experienced RAL and non-treatment groups without RAL activities were categorized based on their limited choices because only Toowoomba PSTs could participate in maker activities. Those who chose to participate in maker and or user activities were categorised as the treatment group whereas those who decided not to participate in maker and or user activities were the non-treatment group which served as a control group.

3.3.4 Qualitative Data

3.3.4.1 Qualitative Data Collection

Qualitative data were collected from PSTs' reflections. Their responses to the open-ended questions and interview contributed to the qualitative data sources. Multiple qualitative data sources were used to improve the reliability and trustworthiness of this study (Creswell, 2007). In qualitative data collection, a sample is selected purposefully with the reason that individuals have experienced the central phenomenon (Creswell, 2009). The researcher is a key instrument because she is the one who gathers all sources of information and makes sense of them (Creswell, 2009). The researcher is involved in a sustained and intensive experience with participants (Creswell, 2014). It is important for the researcher to "explicitly identify reflexively their biases, values, and personal background, such as gender, history, culture, and socioeconomic status that shape their interpretations formed during a study" (Creswell, 2014, p. 187). In this study, it was significant to explore PSTs' background learning of STEM and their attitude to teaching the Australian Curriculum: Technologies.

The research interview is a conversation where knowledge is constructed between the interviewer and the interviewee (Kvale, 2007). The interview is a flexible tool which enables multi-sensory channels to be applied such as verbal, non-verbal, spoken and heard (Cohen, Manion, & Morrison, 2011). The aim of an in-depth interview is "to explore the insider perspective. To capture, in the participants' own words, their thoughts, perceptions, feelings and experiences" (Taylor, 2005, p. 39). The in-depth interview usually means a face-to-face and one-on-one interaction between a researcher and a participant. However, when participants and interviewer are separated by distance, face-to-face interview is expensive compared with telephone interview due to travelling cost. Telephone interview has been recognized as an important method of data collection and is common practice in research (Cohen et al., 2011). As the technology advanced, there were video calls available such as Skype, Facetime or Google Hangout. However, this research chose to use telephone interview. One of the interviewees lived in a remote area of Australia where the internet constantly dropped out. Telephone interview was used for participants who were online users. The disadvantage of the telephone interview is the absence of non-verbal interactions which deprives it of several channels of communication and may interfere with the establishment of a positive relationship.

Compared to structured-interviews, a semi-structured interview offers more flexibility. Semi-structured interviews are sufficiently structured to address research questions while leaving some space for interviewees to offer new meaning to the research topic (Galletta, 2013). Semi-structured interviews were used to collect qualitative data. At the end of Semester, focus group interviews and one-to-one interviews were used depending on participants' availability. Interviews were conducted face to face and or via telephone. Interview questions were based on self-efficacy theory and the research questions (Bandura, 1997). However, interview questions were modified and adjusted based on observation and experience working with RAL and with the pre-service teachers. Figure 9 shows the semi-structured interview questions for the pilot study.

1. Please tell me about your experience of working with hands-on RALfie activities in the March Maker Event:
    - Which parts worked well for you?
    - What do you think you learned from the successful experience?
    - Which parts did you dislike about the Maker Event?
    - How could we change that part to make it more enjoyable?
2. Please tell me about your experience of working with hands-on RALfie activities in the May Maker Event:
    - Which parts worked well for you?
    - What do you think you learned from the successful experience?
    - Which parts did you dislike about the Maker Event?
    - How could we change that part to make it more enjoyable?
3. If the participant attended both Maker Event in March and May, please ask this question. For Maker Events in March and May, which one did you enjoy more? Why?
    - Which one is more helpful for you to teach science and technology in the future? Why?
    - Compare resource provided. Videos. Websites. Snap! Handout. Two gurus.
    - Remote concept and Robot Soccer game concept

4. Please tell me about your experience of working with the RALfie online Pendulum activity?
    - Which parts did you like about that RALfie activity?
    - What do you think you learned from it?
    - Which part do you think was difficult for you?
    - How can we change it to make it easier for you?

5. Please tell me about your experience of working with the RALfie online Gearbox Activity?
    - Which parts did you like about that RALfie activity?
    - What do you think you learned from it?
    - Which part do you think was difficult for you?
    - How can we change it to make it easier for you?

6. What differences are there between the Maker Events and the online events in terms of affecting your confidence to teach technology?
    - If you only attend Maker or online event, do you think there will be a difference?
    - Compare resources provided.
    - Compare time spent.
    - Compare activities in different modes

7. In Peter's class, you learned simple Scratch programming. You also used Pendulum and Gearbox activities as part of Peter's class. Can you please comment on the cooperation between Peter and RALfie team?

- You learnt Scratch in Peter's class. Do you think that is helpful for you to enjoy the RALfie activities that used Snap!?

8. What aspects of the RALfie experience made you feel more confident to teach Technology/Science?
    - Make sure it is RALfie and / or Peter's course
    - Does your background affect your confidence to teach?
9. What aspects of the RALfie experience made you feel less confident to teach Technology/Science?
    - Make sure it is RALfie and / or Peter's course
    - How do you feel when RALfie make you less confident?
    - Are you going to use RALfie again?
10. What is RALfie concept in your opinion?
    - RALfie can be hands-on and online activities. RALfie can also be integrated into game concept and to engage a broader range of people. Remote control.
11. How does RALfie concept change the way you are going to engage with children to learn STEM?
12. Does engagement with RALfie affect your teaching philosophy?
13. If we use RALfie for teacher preparation in the future, what difference do you think that RALfie can make for teacher preparation to teach Technology/Science Curriculum?
    - The Australian Curriculum
    - Teacher preparation
    - What key skills that RALfie related to?
    - What subject areas that RALfie can be used to help teachers to teach?
14. What do you think as the strength of RAL to teach technology/Science?
15. What do you think as the weakness of RAL to teach technology/Science?
16. If I provide a RALfie kit to you, do you think you can host an experiment yourself for your class?
17. What kind of support do you need to help you use RALfie in schools to work with children?
    - Technical support
    - Content knowledge support
    - Pedagogical knowledge support

Figure 9: Semi-Structured Interview Questions for Pilot Study

For the main study, there were some questions added to the pilot interview questions in Figure 10. These added questions were about PSTs' educational background and their philosophy about teaching Science and Technology.

1. How confident are you that you will be an effective teacher of science and technology?
2. How did you feel about learning science and technology when you were a child?
3. What do you understand by learning in relation to science and technology?
4. What previous experiences have you had with LEGO in your prac or in your own learning experience?
5. How do you think playing with RALfie might contribute to learning?
6. What RALfie activities did you participate in? (Maker activities in March, Maker activities in May, online Pendulum activity, online Gearbox activity).

Maker activities in March	Maker activities in May	Online Pendulum activity	Online Gearbox activity
How many hours do you spend?	How many hours do you spend?	How many hours do you spend?	How many hours do you spend?

7. What motivated you to attend the RALfie Maker event and spend time on the RALfie activities?

Figure 10: Added Interview Questions for Main Study

There are some advantages of using interviews. Interviews provide interaction between researcher and participants which allows clarification if an answer is vague (Tashakkori, 1998). Open-ended interviews lead to abundant information about interview questions which provides opportunities for new concepts and ideas to emerge (Tashakkori, 1998). Interviews have major drawbacks and disadvantages as well. Interviews are time-consuming and may be inconvenient for respondents. If the interviewer is fatigued, it may hamper the interview quality (Cohen et al., 2011). One of the major disadvantages of the interview is that the interviewer might affect responses of the interviewee (Tashakkori, 1998).

3.3.4.2 Qualitative Data Analysis

Interviewees were selected from volunteer participants in the face-to-face maker and user activities. Interviews allow more detailed analysis for self-efficacy in consideration of different learning modes. The pre-test and post-test statistical analysis helped to identify the ‘unusual participants’ to be interviewed so that there were rich data for the reasons why they were ‘unusual’.

3.3.4.2.1 Thematic Analysis

Thematic analysis is widely used in research (Clarke & Braun, 2013). This study adopted thematic analysis to analyse the qualitative data. Thematic analysis refers to themes which are specific patterns of meaning found in the data (Joffe, 2011). The basic strategy used in thematic analysis is coding. Coding is “a process of closely inspecting text to look for recurrent themes, topics, or relationships, and marking similar passages with a code or label to categorize them for later retrieval and theory-building” (Mills, 2010, p. 927). Qualitative data were coded and examined for recurrent themes, topics, or relationships (Mills, 2010).

Thematic analysis reveals manifest content and latent content. Both of them can be drawn on by researchers. Manifest content is something obvious or directly observable (Joffe, 2011). Alternatively, thematic analysis contains latent content which is highly subjective and implicit. However, this researcher also set up rules about what can and cannot be coded to avoid highly subjective and implicit themes.

In the pilot and main study, pre-service teachers were interviewed about the particular part of RAL activities that influenced their self-efficacy to teach the Technologies. Therefore, it was relevant to generate themes related to which particular RAL elements affected their self-efficacy. However, this research was open to new themes.

A further distinctive demarcation of a theme is "whether it is drawn from a theoretical idea that the researcher brings to the research (termed deductive) or from the raw data itself (termed inductive)" (Joffe, 2011, p. 210). Deductive themes are built upon the preconceived theoretical constructs which are investigated by case study researchers (Mills, 2010). They will use their research questions, interview, or theory-derived categories as a start list of prior themes for coding data documents (Mills, 2010). The interview questions for this research were based on self-efficacy theory.

It is important to be open to new concepts or themes that emerge from raw data sources (Joffe, 2011). Therefore, this research used a "dual deductive-inductive and latent-manifest set of themes" (Joffe, 2011, p. 210). It is important to compare data with previous data findings in similar areas to avoid repetition. However, researchers also need to be open to new findings which might provide potentialities to revolutionise knowledge of the topic under investigation (Joffe, 2011). This research used inductive themes that emerge from and are grounded in the raw data (Mills, 2010). Inductive thematic analysis "avoid[s] the rigidity and premature closure that are risks of a deductive approach" (Mills, 2010, p. 927). Emergent themes were considered as well as expected themes.

3.3.4.2.2 Case Study

Case study was used in this research. Case study is defined as research in "a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time" (Yin, 2009, p. 97). It requires rich and in-depth data collection via multiple data sources, such as interviews, observations, documents and reports. The principal objective of case study is to achieve a deep understanding of processes and other concept variables, such as participants' views of their own thinking processes, intentions and contextual influences (Woodside, 2010). It is important to use multiple sources to triangulate and confirm understanding of the same event within the same case. For this study, T-TEBI and PANAS were used to identify the outliers for inclusion as case studies. The quantitative results were also used to triangulate, confirm and deepen the understanding of changes of individual PSTs' self-efficacy.

The strengths and limitations of case study are acknowledged (Yin, 2009). For social science, there are potential niches to use different methods to investigate different needs and situations rather than using case study solely (Yin, 2014). For this study, qualitative data were analysed by thematic analysis and then followed by case study. In the pilot study, only thematic analysis was used to analyse participants' interviews. In the major study, qualitative data were analysed by thematic analysis and then followed by case study.

For data analysis in case study, the investigator needs to report a case description and case themes. The data analysis process in case study research can involve a single case or multiple cases. For the data analysis process, there are five analytic techniques, namely pattern matching, explanation building, time-series analysis, logic models, cross-case synthesis (Yin, 2009). This research used multiple cases to investigate the changes of self-efficacy. Cross-case analysis was used to explore the differences and similarities among cases.

There are three principles of data collection in case study, namely using multiple sources of evidence, creating a case study database and maintaining a chain of evidence (Yin, 2009). Using multiple data sources is argued as a major strength of case study with the reason that it is more likely to generate accurate and persuasive findings based on a variety of evidence (Yin, 2009). Creating a database for case study involves organizing and documenting the data collected. Maintaining a chain of evidence serves to increase credibility and confirmability of qualitative research. It allows an external observer to "follow the derivation of any evidence" from initial questions to the final conclusions (Yin, 2009, p. 122). It requires researchers to use clear cross-references from methods to conclusions.

In the main study, quantitative results were used to identify the cases. Each case starts with a case description such as bibliography, T-TEBI and PANAS results. Case themes were generated from interviews. Cross-case comparison was used to analyse similarities and differences across cases in depth.

3.3.5 Mixing Data

Pre-test and post-test T-TEBI data were used to measure the changes of self-efficacy for teaching Technology. Pre-test and post-test PANAS were used to compare participants' emotional status before and after their access to RAL activities. Psychological and emotional state is one of the components in self-efficacy (Bandura, 1997). The T-TEBI and PANAS were used to mix data.

For the pilot study, quantitative results from T-TEBI were used to analyse the differences in self-efficacy (SE) and outcome expectancy (OE). Qualitative results from interviews were used to analyse reasons for their changes of self-efficacy to explain the quantitative results.

For the major study, the results of T-TEBI and PANAS were used to identify outliers among participants who were then analysed as case studies. Case study was applied in the major data analysis in Chapter 5. Case study allowed deep understanding of participants' perceptions, feelings, and thinking processes which were helpful to explain their responses to the experiences provided.

However, after the data collection, the sample size of the quantitative data was small and insufficient to generate statistical significance. Hence the contributions from the quantitative tests and surveys reported in Chapters 4 and 5 were merely indicative rather than conclusive.

3.3.6 Two Phases of Study

There were two phases in this research, namely the pilot study and major study. The pilot study was conducted in semesters 1 and 2 of 2014. The purpose of pilot study was to test the survey instruments and interview questions. The RALfie system was under active development during the pilot study and needed to be tested for the ease of use and reliability. It was also important to test how many PSTs would respond to the pre and post survey to collect quantitative data for analysis. The pilot study was used to inform the major study which was conducted in semester 1 of 2015.

The maker activities for pilot and main study were in same context. PSTs needed to go to the laboratory to build hands-on experiments. There were two events for maker activities in the pilot and main study. Each event lasted two hours. In the workshop three professional engineers from USQ and one professional educator were present to support PSTs. The researcher was responsible for logistical support and collecting pre-post survey data.

The user activities for pilot and main study were in a different context. In the pilot study, the RALfie system was in the infant stage which needed a great deal of scaffolding. The researcher was present to provide one to one support to guide participants to login and navigate the website. In the major study, the RALfie system was reasonably stable to use. PSTs accessed the user activities online.

3.4 Ethics

Ethical conduct is governed by the conventional rules in academia (National Health and Medical Research Council, Australian Research Council, & Australian Vice - Chancellors' Committee, 2007 (Updated May 2015)). There are four major codes namely: informed consent, opposition to deception, privacy and confidentiality, and accuracy. The general principles of ethics followed by USQ are: informed consent, voluntary participation and the right of withdrawal without sanction, confidentiality of participants and records, secure storage of relevant data for a minimum period of five years after completion of a research project, clear and coherent expression in research proposals, and regular monitoring of research outcomes. These principles were maintained throughout this research with ethics clearance number H14REA013-1.

This research did not involve any deception of, or harm to, the participants. There was no child or animal involved in this research. It was voluntary for pre-service teachers to join in and they had the right to withdraw from this research without any sanction. However, there were some ethical concerns because participants were enrolled in a course. They might be worried that if they did not join in RAL activities their grades might be affected. This research ensured and informed participants that their grades would not be affected whether they joined or not in RAL activities. Participants received a Participant Information Sheet and Consent Form. They were required to read and sign them. They filled in surveys and the Talent Release Form before they entered the RALfie lab to give permission to USQ to take photographs, vision and or audio. In the lab participants' photos and videos were taken from the beginning to the end of the trial in the lab. Students who were not willing to join in RALfie activities participated in their course activities to ensure no one was disadvantaged (Creswell, 2014). Pseudonyms were adopted to protect the privacy of participants. The accuracy of data analysis was checked by the supervisory panel. In order to increase the response rate, some gift cards were provided for a draw.

3.5 Validity, Reliability, Trustworthiness, and Credibility

The rigor of qualitative research is based on credibility and trustworthiness which require trust and confidence in the findings of the research (Thomas & Magilvy, 2011). Rigor demands the establishment of consistent research methods over time which will provide an accurate representation of similar studies (Thomas & Magilvy, 2011). Rigor provides an opportunity to duplicate a study following the consistent methods but using different samples to provide the same findings.

Credibility allows others who shared the same experience to recognize the experiences contained in the study through the interpretation of participants' experiences (Thomas & Magilvy, 2011). To achieve credibility of qualitative research, researchers need to check the similarities of data sources within and across participants. In this research, different data sources including interviews, reflections from their assignment and open responses in the survey were collected from RAL users. Themes were generated and analysed to identify similar patterns from participants which will underpin the credibility of this research.

Confirmability occurs when qualitative research is reflective and critical. Reflexivity requires the researcher to be open to the study and unfolding findings. It also requires the researcher to be self-critical of preconceptions which might affect the research (Thomas & Magilvy, 2011). In order to avoid biases or preconceptions, researchers need to immediately write or audio-tape their own feelings, biases and insights when they finish interviewing participants.

Validity and reliability differ in quantitative and qualitative research. However, the purpose of validity in both approaches is the same, that is, to check on the quality of the data and the results (Creswell, 2007). In quantitative research, validity means that meaningful inferences can be drawn from the results to a population. Reliability means that there is a consistent score over time from participants in quantitative research (Creswell, 2007). In qualitative research, trustworthiness plays a major role to determine whether the researcher and the participants produce accurate findings by using certain procedures (Creswell, 2009). It mainly relates to the reliability of multiple coders using consistent approaches across different projects. Therefore, validity in the two approaches is different.

There are several types of threat to validity in research. In quantitative research, there are internal, external and statistical conclusion validity threats (Creswell, 2009). Internal validity threats are "experimental procedures, treatments, or experiences of the participants that threaten the researcher's ability to draw correct inferences from the data about the population in an experiment" (Creswell, 2009, p. 162). External validity threats occur when quantitative researchers "draw incorrect inferences from the sample data to other persons, other settings, and past or future situations" (Creswell, 2009, p. 162).

Statistical conclusion validity threats occur when "experimenters draw inaccurate inferences from the data because of inadequate statistical power or the violation of statistical assumptions" (Creswell, 2009, p. 164). Potential threats to validity were identified and processes adjusted so that those potential threats could be minimized or were unlikely to arise. In qualitative research, threats to validity include mistakes made during transcription. Another threat is a drift in the meaning of the codes (Creswell, 2009).

In this study, NVivo was used to maintain a list of codes with examples. Triangulation from quantitative and qualitative data is helpful to improve validity in mixed methods research. The pilot was helpful to test the survey instrument and interview questions. The pilot study also helped the researcher to learn interview techniques and practise coding using NVivo. Clarifying bias that the researcher and the participants bring to the study was another way to improve validity of this research.

3.6 Summary of Chapter 3

Chapter 3 introduced the research paradigm which is pragmatism. It then presented mixed methods as the research approach. It talked about data collection and analysis, ethics, validity and reliability.

Chapter 4 presents the pilot data analysis. It illustrates pilot data collection, pilot data analysis, lessons learnt from the pilot study and discussion of the pilot study.

Chapter 4: Pilot Study

This chapter reports on the pilot study which was conducted from February to September 2014 to test instruments and inform the subsequent main study. It describes the RAL experiences offered in face-to-face and online modes, the collection of data, and analysis of both quantitative and qualitative data. It then discusses lessons learnt from the pilot study and summarises this chapter.

4.1 RALfie Experiences

There were two maker events in the pilot study, each lasting two hours. Three professional engineers and one professional educator, who was the PSTs' course lecturer, were present for support. The first maker trial was on 26th of March 2014 and included four activities. There were 8 students who participated. The second maker trial was on 2nd of April 2014. It included four activities which were very similar to those in the first trial. There were 9 students who participated in the second maker event, including 5 students who had attended the first trial.

The user activity was designed for online access and was offered from August to September 2014. At that time the RALfie system was still under active development. There were limitations on the activities available for remote access but the RALfie development team managed to arrange sufficient access to support the pilot study.

4.1.1 Maker Event

Each maker event in the pilot study included four RALfie activities. The goals of these activities were to teach basic connectivity and programming skills. The LEGO EV3 software enables participants to create programs for robotics and control movement. Because of the short time frame available for the activities and entry level status of participants, a member of the RALfie development team downloaded the LEGO Mindstorms EV3 software to the EV3 brick prior to the event. The key skills in the RALfie project activities to tinker with LEGO, build a robot using LEGO, connect the robot to the RALfie system and control the robot remotely. The first activity was the

LEGO Mindstorms Tutorials offered by professional engineers who worked in the RALfie team. It was an orientation workshop where professional engineers talked about how the RALfie system works. From the tutorials, PSTs also learnt how to program the LEGO Mindstorms software.

The second activity was **Lines, all the way home**. Figure 11 shows the experimental setup. The goal of the activity was to construct a line following robot and program it in a simple manner to follow an existing line. The white worksheet with a clearly marked circuit was provided to PSTs by the RALfie team and two IP cameras were placed as shown so that the experiment could be monitored from a remote computer. PSTs worked in groups to build a robot using LEGO Mindstorms. The robot had been programmed by the RALfie team to use a sensor to follow the line. PSTs needed to drive it to follow the line by watching where it went using the IP cameras. PSTs needed to watch and manipulate the robot via the IP cameras.

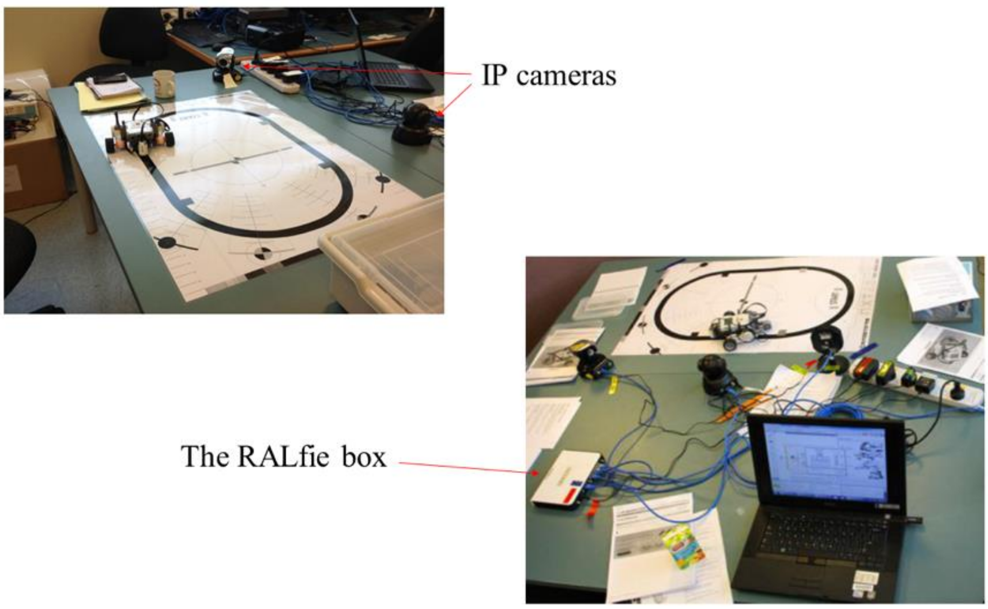

Figure 11: Lines, all the way home

The third activity was **Mouse in the House,** shown in Figure 12. The goal of the activity was to construct a basic 2-axis gantry robot and move from face-to-face to remote control of the mouse in the house. The remote control system had been created by the RALfie team. Participants needed to make the gantry robot move properly while operating face-to-face and noting any control issues. Participants then needed to use computers to capture a marble in an obstacle (the cup). The marble was a round glass marble which was easy to move. Participants raced their team-mates to chase the mouse back into its house. When participants felt comfortable with face-to-face activity, they needed to move upstairs to another laboratory to remote control the gantry using the online interface. Cameras needed to be appropriately placed for observation of the gantry. PSTs needed to use computers to login to the RALfie system where the activities could be managed remotely. PSTs used IP cameras to watch the interface and remote control the activity via computers and to kick the ball to the obstacle. The first two pictures are for face-to-face control and the last picture is for remote control of mouse in the house.

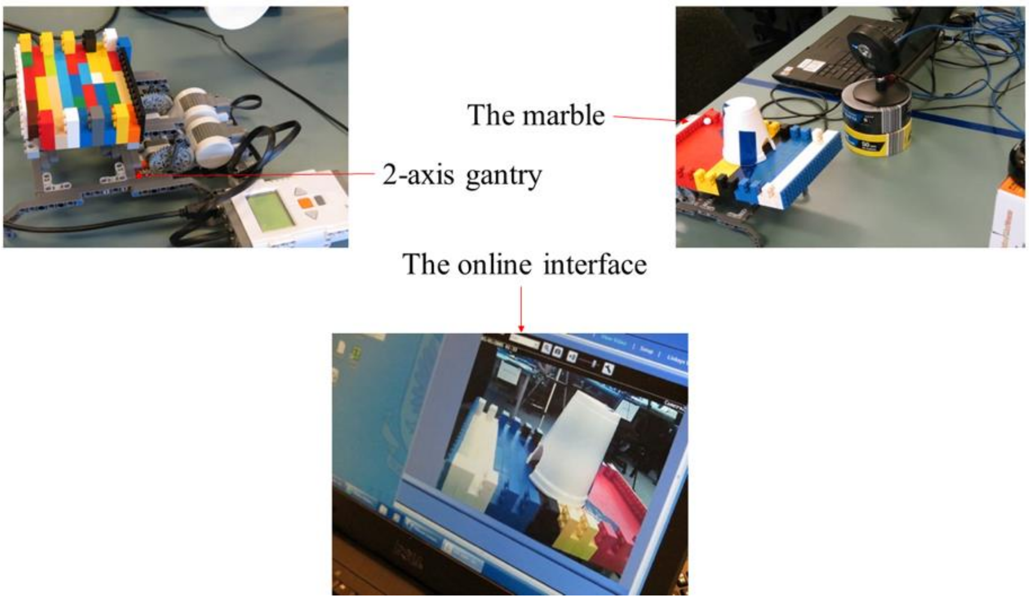

Figure 12: Mouse in the house

The fourth activity was **Marionette** (see Figure 13), a string-operated puppet. The robotic marionette provided simultaneous operation and presentation, intuitive operation of all movable joints, and display of robot motion in an easy to understand way. The robotic marionette system was used to manipulate the puppet according to programmed motion commands issued from the EV3 software. The puppet control system was developed by professional engineers. The goal of the activity was to use EV3 to control the marionette so that it could move and dance. PSTs needed to assemble the robot puppet using the LEGO kit. They also needed to tie the stings to the puppet. Motor 1 controlled two strings which tied to the feet. Motor 2 controlled one string which tied to the head. Motor 3 controlled two strings which tied to the hands. Participants needed to measure the length of the strings so that the marionette could move appropriately and to tinker with the electronic EV3 brick to start learning programming. They needed to use the EV3 software and then download into EV3 brick. Participants needed to program the EV3 via the computer and control the robotics to follow the programmed commands.

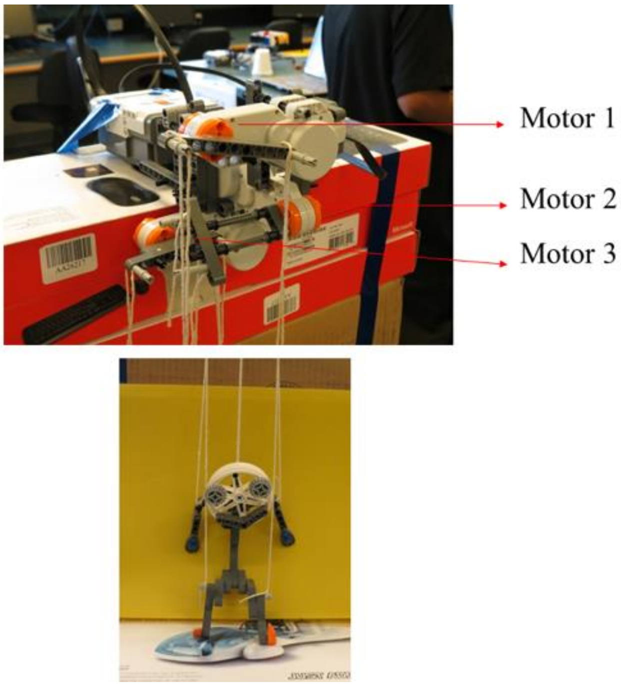

Figure 13: Marionette

4.1.2 User Activity

The prototype **Pendulum** activity was built for participants to control remotely. Figure 14 presents the apparatus in which a ball bearing could be raised or lowered to a selected distance from the pivot point and then pulled to one side and released using a mechanism constructed with the LEGO. The graphical user interface was constructed using Snap! Users were challenged to set the ball bearing at a suitable height, set it in motion, record the time for 20 swings and calculate gravity. Participants remote controlled the Pendulum and they estimated the local gravitational constant. Interviews took place after the user activity.

It was tested by team members but there were some issues remaining at the time of the pilot study. There were multiple logins for which students had to use different user names and passwords before they could access the activity. There was one login for the RALfie system, one for Google, which was used to authenticate users, and one for 3D GameLab. The connection was not stable and sometimes failed to work outside of the USQ network. The strategies used to facilitate access were to arrange for participants to access the trial from a computer lab in the Education building and to have the researcher present with each participant while they accessed RALfie. The researcher guided each participant to login using the required user names and passwords. She also talked them through the Pendulum activity.

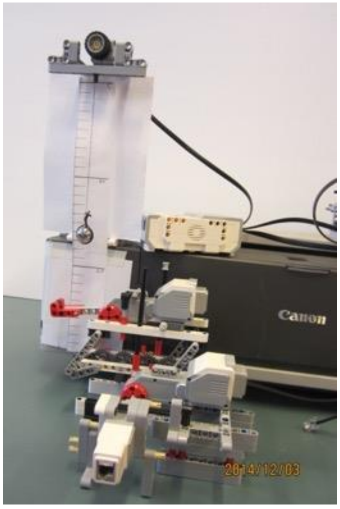

Figure 14: Pendulum

4.2 Data Collection and Analysis

4.2.1 Participants and Data Collection

Participants in the pilot study were final year PSTs enrolled in courses at USQ. Participants were different cohorts in the main study. RAL experiences were additional to the standard course components. The course lecturer agreed to invite students in his classes to participate in this study. There were 138 students in his course in Semester 1 in 2014 from three campuses. It was estimated that 10% of students might participate in a web survey (Fan & Yan, 2010). Participation was voluntary to comply with Ethics requirements. However, only 14 survey responses were recorded. That was a very small data sample which was insufficient to generate any quantitative significance. In order to increase the survey response rate, electronic and paper surveys were used during RALfie experiences to collect data. To increase the participation rate, some gift cards were provided for a draw. The pre-test T-TEBI response rate was 20%. The pre-post T-TEBI answer rate was 11%.

The survey for the pilot study was administered online twice, at the beginning and end of semester one in 2014 using SurveyMonkey. Limesurvey was used for the main study in 2015. The URLs were broadcast in the Learning Management System for all students enrolled in the course. Once the survey had closed, data were transferred to SPSS for analysis.

In total there were 14 PSTs who had RALfie experiences. There were 12 participants who attended two maker events, and 6 who participated in the user activity, including 4 students who participated in both a maker event and the user activity. Six participants were interviewed after the conclusion of the RALfie experiences. Four interviewees had participated in both a maker event and the user activity.

4.2.2 Quantitative Data Analysis

There were 28 participants who completed the pre-test for a response rate of 20%. There were 15 participants who completed both the pre-test and post-test T-TEBI surveys, a response rate of 11%. Of those, 8 students had participated in RALfie experiences, including 6 students who participated in both Maker events and User activities and 2 who participated only in a User activity by remote access. There were 7 students who had not participated in any RALfie experiences. All participants were USQ pre-service teachers enrolled in a final year Technology curriculum and pedagogy course. The responses for each participant on each of the subscales (self-efficacy and outcome expectancy) were summed and then divided by the number of items on the subscale to yield a normalized score from 1 to 5.

Figure 15 displays the differences in pre-test and post-test scores on the subscales in a bubble plot format. Filled circles represent the 8 PSTs who participated in RALfie activities while the open circles represent the 7 PSTs who did not participate in RALfie activities. For both subscales there is an unanticipated decrease in scores for the RALfie user group and an increase for the non-users.

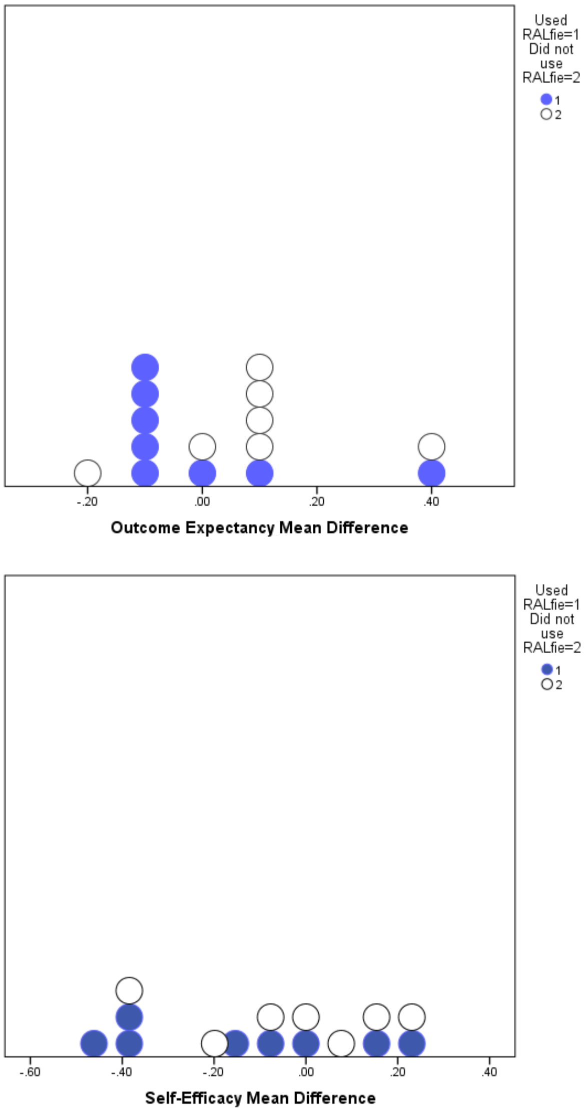

Figure 15: Differences in self-efficacy and outcome expectancy scores

Because the small numbers of respondents to the questionnaires did not generate sufficient data to support full statistical analysis, the responses to individual items were examined for trends that might inform the main study. Table 2 and Table 3 display the distributions of pre-test and post-test responses for items on the SE and OE subscales from the T-TEBI. The first number in each pair represents the responses for the group who participated in RALfie activities. For example, item 2 shows 8/7, meaning that 8 people from the RALfie users and 7 people from non-users group agreed or strongly agreed with the item 2. Reverse scored items are indicated by *. In the quantitative data analysis process, the reversed scored items were recoded.

Table 2: T-TEBI Self-Efficacy Scores (SE) N=15

***reverse score**			Pre-test			Post-test		
			SD/D	**U**	**A/SA**	**SD/D**	**U**	**A/SA**
	2	I will continue to find better ways to teach technology.			8/7			8/7
*	3	Even if I try very hard, I will not teach technology as well as I will most subjects	4/6	1/1	3/0	4/4	3/1	1/1
	5	I am going to know the steps necessary to teach technology concepts effectively.		1/1	7/6		3/1	5/6
*	6	I am not going to be very effective in monitoring technology learning activities.	3/5	4/1	1/1	4/6	1/1	3/0
*	8	I am going to generally teach technology ineffectively.	8/7			6/6	2/1	
	12	I am going to understand technology concepts well enough to be effective in teaching primary technology.		1/1	7/6		2/1	6/6
*	17	I am going to find it difficult to explain to students why technology learning activities work.	5/3	2/4	1/0	4/4	1/1	3/1
	18	I am going to typically be able to answer students' technology questions	2/0	2/2	4/5	1/0	3/1	3/6
*	19	I wonder if I am going to have the necessary skills to teach technology	3/2	3/2	2/3	3/4	4/0	1/3
*	21	Given a choice, I am not going to invite the principal to evaluate my technology teaching.	6/5	1/1	0/1	5/3	0/3	2/1
*	22	When a student has difficulty understanding a technology concept, I am going to be at a loss as to how to help the student understand	7/4	1/3		5/5	3/2	
	23	When teaching technology, I am going to welcome student questions			8/7			8/7
*	24	I do not know what to do to turn students on to technology	4/6	2/1	2/0	5/6	2/1	1/0

The most notable changes in responses for self-efficacy items as shown in Table 2 were for items 5, 12 and 22. Those items all refer to 'technology concepts' and the PSTs who participated in RALfie activities recorded decreases in self-efficacy as measured by those items. Perhaps the most likely explanation is that the RALfie activities involved unfamiliar concepts and their limited exposure was not sufficient to develop confidence. On the other hand, they recorded increases for item 24, suggesting that their experience with the RALfie activities was engaging and they see the value of such activities in their own classrooms. At the same time the students who had not participated in RALfie experiences recorded increases in their self-efficacy as indicated by items 17, 21 and 22, most likely resulting from their experience in the course they were studying.

Table 3: T-TEBI Outcome Expectancy Scores (OE) N=15

*reverse score			Pre-test			Post-test		
			SD/D	U	A/SA	SD/D	U	A/SA
	1	When a student does better than usual in technology, it is often because the teacher exerted a little extra effort.		3/4	5/3		3/2	5/5
	4	When the technology grades of students improve, it is often due to their teacher having found a more effective teaching approach		2/2	6/5		1/1	7/6
	7	If students are underachieving in technology, it is most likely due to ineffective technology teaching	0/4	3/2	5/1	0/1	2/1	6/5
	9	The inadequacy of a student's technology background can be overcome by good teaching.		0/3	8/4		0/1	8/6
*	10	The low technology achievement of students can not generally be blamed on their teachers	2/3	5/3	1/1	2/2	5/3	1/2
	11	When a low-achieving child progresses in technology, it is usually due to extra attention given by the teacher		2/2	6/5		2/2	6/5
*	13	Increased effort in technology teaching produces little change in students' technology achievement.	7/7	1/0		6/7	2/0	
	14	The teacher is generally responsible for the achievement of students in technology		2/4	6/3	0/1	2/4	6/2
	15	Students' achievement in technology is directly related to their teacher's effectiveness in technology teaching	0/1	2/1	6/5	0/1	1/2	7/4
	16	If parents comment that their child is showing more interest in technology, it is probably due to the child's teacher	0/1	3/6	5/0	0/1	4/3	4/3

Table 3 presents the patterns of responses on the outcome expectancy items. The students who participated in RALfie experiences mostly recorded positive values on the pre-test, leaving little scope for increases, though there were some on items 4, 7 and 16. Those who did not participate in RALfie experiences recorded increases on those items and also on items 1 and 9. Overall the data indicated that PSTs believed that good teaching results in positive learning.

There were no significant differences for OE (outcome expectancy) between participants with positive or negative experiences on either pre-test or post-test. That result is consistent with previous research (Bleicher & Lindgren, 2005).

In brief, the quantitative data analysis did not generate much information due to the small data sample size. The qualitative data were analysed to explore PSTs' self-efficacy for teaching the Technologies.

4.2.3 Qualitative Data Analysis

There were two sources of qualitative data, namely interviews and PSTs' reflections. Six participants were interviewed. Aby, Shasha, Jo and Bek each participated in both maker events and user activities for a total of 5 hours. They were mature aged PSTs in their final year of preparation to become primary school teachers. Daniel and George, who participated in only the user activity for 1 hour, were mature aged PSTs in their first year of preparation to become primary school teachers. Both of them had completed one year of study for an Engineering degree before switching to Education. Lilian was one of three PSTs who voluntarily wrote reflections about RALfie as part of their assignment. Lilian participated in only the maker event for 2 hours. Thematic analysis was used to analyse interview data (Clarke & Braun, 2013). Themes evident in the qualitative data are reported here.

Overarching theme 1: Advantages of RALfie
Sub-theme 1. Links to Curriculum

RALfie offered opportunities to teach the Technologies Curriculum in an innovative way. Aby said, "*Had I not known about RALfie and had the access to it in my previous courses, I would still have no idea about any other technologies that could put into classrooms. I have never seen a Mindstorms kit ever in my prac. I probably would keep doing the same old-fashioned ICT that kind of stuff like technology in the curriculum.*" RALfie broadened Aby's understanding of the new Technologies Curriculum and offered creative ways to teach the Technologies Curriculum.

The RALfie project offered a new way of teaching science and technology which may be helpful for teaching the Curriculum in schools. Aby commented that "*It [RALfie] will make a very big difference in regards to our lesson planning for the technology curriculum. Probably make us more innovative in how we are going to teach things*." Daniel commented that "*It [Pendulum activity] is just something to appeal to them [school students]. It is different to learn about physics from how they normally would in the classroom*."

RALfie provided a variety of structured experiments which were aligned with the curriculum. Aby stated that "*Well...I think gravity and forces is part of Curriculum anyway. I know it is part of [very certain tone]. You can definitely put this into a lesson and it's probably a lot easier for teachers from the teaching perspective*." Aby indicated certainty that she can see the linkage between RALfie and the Curriculum by using the word 'definitely' and a very certain tone. Shasha stated that *"I like the pendulum idea as an online activity...it was also based on science concepts of gravity. I think it is very helpful in the classroom*". Gravity and forces are in line with the requirements of the Science Curriculum. In Year 7 physical sciences, students are required to explore how gravity affects objects on the surface of earth (ACSSU118). For the science inquiry skills, Year 7 students need to communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies (ACSIS133). For the RALfie pendulum activity, students need to use the outcomes of research using effective forms of digital skills to work out the gravity which also requires mathematical skills. RALfie helps students to use digital technologies to explore and find solutions and work out the force. Students in Year 7 and 8 need to develop abstractions by identifying common elements through decomposing apparently different problems and systems to define requirements, and recognize that abstractions hide irrelevant details for a particular purpose (Australian Curriculum Assessment and Reporting Authority, 2013a).

Sub-theme 2: Maker and user activities are engaging

Aby stated that user activity combined with the maker event was very engaging. "*I thought that [remote control of Mouse in the House] was pretty fun, especially in combination with the Maker because then you can see what you made actually do whatever you want them to do. Then using the little rover it was pretty cool from the upstairs. Marionette having that dance I still be able to control it far away that was pretty cool.*" Hands-on RALfie activity was very engaging because it involved direct behavioural engagement (Munns & Martin, 2005). Moving from hands-on activities to remote control activities was engaging cognitively (Munns & Martin, 2005).

Jo shared the same view with Aby that the maker event combined with user activity was engaging and students learned more from participating in both experiences. Jo stated that "*It is good to have both User and Maker to see how it is created and how to use it. You have an understanding of how to make it and how to use it. If you only did the Maker, you will learn how to make them. But you won't get the benefit of actually using them and seeing them actually being used. If you only do the User, you're doing it on a computer but you do not get the hands-on actually playing with materials and connect them up*." Hands-on activities allow students to play with materials and connect LEGO models to the computers. Students can construct experiments and connect to the network to test the system which is in line with the curriculum. User activity allowed students to see what they made operating and being used which contributed to students' ownership of the learning.

Jo stated that "*the traditional ways were not that interesting whereas this User event and the Maker event are very interesting. It shows where the world is moving. The world is moving to remote access…so it connects the real world and where the world is heading into. It provides a small snapshot of what could be in the future*." RALfie potentially provides resources globally regardless of location. However, if hands-on activities are to be substituted by networked activities it is important to retain the sense of reality.

Aby held a view that, if students participated using remote RALfie only and missed the hands-on activity, they did not have ownership of the activity. She stated that "*but at the same time for them to construct it would be better and then for them to control it after they construct it. So I guess...that is probably a weakness of this online program. They are not constructing it. They do not have any satisfaction over controlling it in the end seeing how it come to be. They just see the end product*." Constructing the experiment allows behavioural engagement by making and tinkering with the LEGO kits. Building the experiment makes students feel the ownership which results in satisfaction and emotional engagement.

PSTs had concerns if students would be just using the end product of RALfie and missing the making process. Aby was concerned that when students are using RALfie they might just play with the experiments rather than actually engage in learning. She stated that "*I guess if the kids were not able to make it and they were just playing around with it, I guess they would not see the relevance of it. I am controlling of this. They do not know any satisfaction or pride of making something and then controlling it. Like I said before, from a teaching perspective, this would be perfect, making sure they are engaged and not mucking around or off task if they are actually playing with it."* Making an experiment gives students a sense of pride. They value the experiment they made because it is personal and they can relate to the experiment.

Bek commented on the Pendulum activity and stated that "*actually seeing what kind of programming come into life. I actually seeing it happen. The link between me using my computer here (in G433) and something actually happening in the lab (Z222) that is the big thing. Because I did the Maker event, I can appreciate how much work has gone into make that (Online RALfie) happen. For that programming to occur, there is so much planning. It is fascinating for me to be able to appreciate that*." Moving from maker to user activities helped PSTs understand the RALfie concept more deeply and helped them appreciate the engagement of RALfie.

Remote activities are abstract, which makes it more difficult for beginners to process information and figure out how to use it. Shasha commented that "*If you were teaching students how to use it (Mouse in the House) I think you would need to show them exactly what it looked like and try it in the classroom and then go to another room like we had the opportunity to do otherwise it would be quite challenging for them to just look at the camera and do it*." Compared to hands-on activities, remote activity should provide more instructions and social interaction which makes it easier for students to learn, especially for beginners who do not have much experience and knowledge of using the remote activities. Therefore, it is important for beginners to have the hands-on experience and then move to more difficult remote activities.

Sub-theme 3. Access to real robots

Shasha commented that "*When we finally got it working, it* [online Pendulum] *was really good to see that when you did press the ball down button, you can see the ball move rather than being animated sort of cartoon that you can actually see it happening which was good"*. When interacting with robots, participants can see the ball move and the pendulum work. When engaging with the real robots, it does not matter whether it is face-to-face or remote control (Kidd & Breazeal, 2004). Shasha continued that *"Because we have the live camera set up you could see it happening whereas the animation probably is not as correct. …I think with me I just like to see it is real life. I am not into computer games. I like it actually doing something. That's probably my favourite bit.*" Animation is not a physical reality so it may be perceived as not correct or not trustworthy. In animation people can fly which cannot happen in reality. Animation can be exaggerated in ways that are not real and not trustworthy.

George was a user only. He did not attend any hands-on face-to-face RALfie activities. George shared the same view with Shasha and stated that "*I think it could be exciting. The games* [Pendulum] *are real too. It is not just the animation. It is a real robot that they are controlling which is really interesting. With their interest, it is still learning because the activities are about learning so I think it is good*". Pendulum activities built from real robots are more engaging compared to animation (Kidd & Breazeal, 2004).

Sub-theme 4. Hard fun

RALfie activities were new to PSTs. They did not have much past experience of playing with LEGO. When Shasha was asked which part she disliked about the maker event, she commented that "*There was nothing I really did not like. My probably least favourite bit was when the marble got changed to the bin. It was weighted in one end and was a lot harder to get to the house depending on which marble you were using*". When asked about how that part could be changed to make it enjoyable, she replied "*It is not that was not enjoyable, it is that it is harder. It was still fun because it is like the extra bonus challenge that you were trying to get in. It was not that it is not enjoyable.*"

When Bek was asked which part she disliked about RALfie, she said "*it is all pretty interesting actually. Learning a lot of new stuff. Some of them are quite hard like the* *programming. But even that is hard it is still pretty interesting to learn those new stuff so nothing I just really did not like that what we did*." Challenge is part of the fun factor.

Sub-theme 5. Anywhere, anytime access

RAL enabled learning to be more flexible without constraints of location and time. Jo stated that "*Users can go online and it can be done anywhere in Australia as long as you've got internet".* Furthermore, Jo explained the benefit that RALfie enabled, *"so it is probably easier and cheaper alternatives for schools who cannot buy them. But it provides all students with the same chance for building knowledge and learning*". Jo's vision of RALfie resonated with one goal of RALfie. RALfie has the potential to be globally connected, which can provide an equal learning opportunity for students who are disadvantaged for learning because of their isolated location (Wu et al., 2015).

Aby commented on the benefits of the online pendulum activity, "*Because if you do this activity with hands-on materials, like just them making a pendulum, it would get quite hectic. You get kids off task. Whereas this [Online pendulum activity] is quite structured they cannot physically manipulate it they can do from a computer and physically manipulate it so that they cannot tamper with it or break it or do anything so it is safer*". RALfie is safe and cannot be damaged by children because it is remote.

RALfie activities can be used anywhere and anytime because they are on the internet. Shasha said "*I think it [RALfie] can make differences in a lot of areas. I think the most important one would be just for students to learn how connected the world is. If they are in another part of the country they can control it*."

Sub-theme 6: Trial and error attitude

Trial and error can be a great aid to learning. Aby stated that "*We have to connect certain points together otherwise it would not read properly. We have to figure out which port goes to another port which is another challenge. But again trial and error, it worked. I am pretty happy with it*." When Shasha was asked about what she learnt from the maker event, she commented that "*probably if you use it in the classroom, trial and error would be a big strategy you have to use*." She also explained that the biggest thing she learnt from RALfie activities is trial and error attitude. "*It is probably be again trial and error so that if you do not get it right the first time you can try again and that's probably the biggest bit.*"

Trial and error is a positive attitude. When engaging in a trial and error approach, different types of scaffolding are needed. Shasha commented that "*Because it sort of made me realize that you got to have a go. There is no point of being afraid of trying to engage with technology. If you do have a go, there might always be someone out there to help you can ring or you can email, if there is a problem. You are not on your own.*" Getting support is very important for students to feel comfortable to adopt a trial and error strategy.

Shasha shared a similar view when she responded "*I just really liked that we got to play with the equipment so we could understand exactly how it worked and that you got to learn the little bit of error with the controls could come opposite to a big error when you actually performing the task* [The Mouse in the House]." Bek commented on her learning from maker event by saying "*Experimentation is OK. It is OK to have a go and fiddle around with it and see what works. A lot of stuff goes wrong with technologies. You have to look at how you find out what the problem is and track down where it is*." Anxiety about making errors is a negative attitude. Emotional engagement refers to students' affective reactions in the classroom such as interest, boredom, happiness, sadness and anxiety (Fredricks et al., 2004). Anxiety toward errors indicates low emotional engagement and results in students' low engagement and low performance in learning. Technology is new and challenging which requires trials, testing and exploration and also learning from errors and moving on. Anxiety about making errors indicates low self-efficacy because if students feel anxiety toward errors that might result in avoidance of related behaviours (Fredricks et al., 2004). Hands-on activities were helpful to develop positive attitudes towards experimentation rather than being anxious about errors.

Jo shared her experience of testing the online Pendulum activity with trial and error. Jo commented that "*Maybe ensuring that you do a tester run first just to get heads around with what you were asked to do. I had a tester (online Pendulum activity) and I did it again and I timed it because I did not realize that the ball had to let go the time which was not accurate so just to have a look at it and play with it before actually properly using it.*"

When Bek was asked whether there was anything about the RALfie experience that made her feel less confident to teach technology and science, she replied *"Definitely no. if anything only increase confidence."* When she was asked why she was so certain, she said *"Because any explore in this area is a good thing like it gives you more confidence. It certainly not take it away. Does not make me scared of it at all."* When she was asked why, even though access required multiple login stages, she did not feel scared, she replied *"ye...but see that is one of the things I learn. You know things happen and technologies break down. Part of technology learning is figure out how to fix it and how to get around stuff. That is probably one of the thing that I have learnt that has helped with the whole confidence thing."* Technology is innovation and always changing. It is important to develop and foster a positive attitude in learning Technology especially being positive about errors. A positive attitude helps them to reduce anxiety and be positive about errors. A positive attitude towards learning is important because it contributes to positive impact on self-efficacy and engagement. It is important to teach students up front that they need to be positive about errors. They need to learn from errors and move on for further experimentation.

Sub-theme 7. Learning through play

Bek commented that a perceived weakness of using RALfie to teach Science and Technology in classrooms might be that students are seen to be playing rather than learning. She explained that "*possibly a weakness might be that students are more concerned with playing with it or mucking around without actually engaging in the learning. Because it is so engaging they might spend their entire time engaged with it rather than using it as a learning tool. That just might happen unless the learning experiences are designed toward that so it would be up to the teacher to make sure* *that the way they are implementing technologies was a way that students are learning technologies as they go rather than just playing with it*." Bek is uncertain whether playing with RALfie is learning or not. As noted above, she needs more exposure to RALfie and more scaffolding of how to integrate RALfie into teaching.

Shasha believed that playing with RALfie was learning. "*I just really liked that we got to play with the equipment so we could understand exactly how it worked and that you got to learn the little bit of error with the controls could come opposite to a big error when you actually performing the task, the Mouse in the House that we had to do*." Shasha thinks that playing with the equipment helps her to learn how RALfie works. She also developed her awareness that she learnt from her errors. Learning by making, tinkering and inventing is in line with Piagetian Theory because hands-on activities are concrete (Martinez & Stager, 2013). Learning starts with concrete learning and proceeds to more abstract learning which is in line with people's learning stages (Piaget, 1973). Children learn best in an interactive environment that provides hand-on activities. Many educators believe that teachers and adults learn best with hands-on experiences as well (Jacobs, 2001).

Sub-theme 8. Influenced self-efficacy for robotics

RALfie experiences have a positive influence on PSTs' self-efficacy for using robotics. Table 4 shows the four sources of self-efficacy information identified from the pilot study. The table displays the sources of self-efficacy information, PSTs' self-efficacy identified from interviews and links between theory and interview data. The italicised phrases were selected as relevant to explain the corresponding source of self-efficacy.

Table 4: Sources of Self-efficacy Identified from the Pilot Study

Sources of SE	PSTs' SE identified from interviews	Reasons why they indicate SE
Enactive mastery experience	Aby: I guess I am not scared of it as I once was. *Before we actually had the RALfie Maker sections, I do not know anything about it. But now I guess more relaxed about the subject*	Lack of past successful experience results in low self-efficacy whereas the more successful

		but I still probably need help from someone who knew what they are doing like to set it up. Jo: *Once you used it a couple of times, it was pretty easy to use after that.* I think it improves my confidence as we were doing it. *The more you use things the more confidence you get in doing it*.	experience PSTs have working with RAlfie the more self-efficacious they will be.
Vicarious experiences		Lilian: At first this activity [RALfie Maker activity] was daunting and I felt overwhelmed, as I had never used this software [Lego Mindstorms] before. *Although after collaboratively working through the explicit instructions with my group we were able to successfully create the car to move around its assigned network.* Aby: *if you have not been there to show me I would not know what I am clicking*. Bek: The instructions are really quite hard to understand and *you were here so you know I have to ask you for support* along the way so an [online] student certainly would not be able to understand it [without your support]. The languages used were really hard. It was hard for me to see the purposes of the activity or the challenges. Before I was given instructions, I was confused to what my challenge was and what my task was. *But once you kind of help me figure that out, I kind of read the instructions more, it was heaps of fun to complete it.*	Working with peers provides opportunities for PSTs to learn from others. Teachers' support, instructions and demonstrations serve as vicarious experience which help to improve PSTs' self-efficacy.
Verbal persuasion		None	
Physiological and emotional state	Positive emotion	Aby: *It was fun once we put them together and all the cords were in the right spot*. Nathen: *because none of them impact on me negatively*. *It is all good.* It would not make it	When PSTs felt interested, they demonstrated positive emotions after treatments with RALfie.

		hard for me to teach. I think I know how to do it. George: *I think it could be exciting.* The games [Pendulum] are real too. It is not just the animation. It is a real robot that they are controlling which is really interesting.	
	Negative Emotion	Jo: *It could be frustrating* if you did not like there are delay. The more you press the button, you got to wait each time for the movement. *It could be annoying.*	When PSTs felt frustrated and annoyed, they experienced negative emotions after the treatment with RALfie.

Overarching theme 2. Issues with RALfie experiences

Sub-theme 1. Technological issues

Aby commented on the technological difficulties which made her feel less self-efficacious to use RALfie to teach, "*Probably the only thing is to set up the computer and trying to use it remotely from our User session (refer to maker event section 2). I remembered that something was not clicked on, he had to go to upstairs. Peter was there. He made it work and finally it worked. But we did not know what is wrong…That would probably be a little bit difficult to deal with if you have it in the classroom and it was not working, you have to figure out what was wrong. Meanwhile you got kids disengaging because it is not working, that probably be the scariest part of it*." PSTs need the Technology to be reliable and sustainable otherwise there is potential for classroom management issues.

When Aby was asked about what would happen in the absence of the appropriate technical person to help, she stated that "*probably I mean I still probably use it but if I could not get it work, then obviously I would not because obviously I do not know what I am doing. If something like that happened, I probably would not use it again. But it depends. If I fiddle with it and it worked, I probably use it. If I fiddle with it and* *still cannot work, I will give up probably*." PSTs have concerns about the setup of RALfie.

Aby commented that the most difficult part was logging in. "*Maybe there are too many clicks to get into the actual activity. But the activity itself is fine. Just trying to figure out what you have to click to get into the camera to see what you are looking at maybe that could be a bit easier. If you have not been there to show me I would not know what I am clicking*." The ease of use of the Technology is very important for users.

Sub-theme 2. Inadequate instructions

Daniel stated that the instructions were not sufficient, "*I felt that there are not too much instructions not really knowing what I was doing…it is a just a little bit confusing*." Providing adequate instructions as a scaffolding strategy is very important to support students to be engaged and motivated to learn.

Aby stated that "*but now I am more relaxed about the subject but I still probably need help from someone who knew what they are doing like to set it up. I still would not be able to set up Mouse in the House for my kids in classrooms unless I have an instruction manual or some sort of instructions on how to work*." PSTs need clear and complete instructions about how to set up the RALfie system.

Sub-theme 3: Need technical support

Technical support is very important for PSTs to feel self-efficacious to use the RALfie system. Aby commented that "*Once it is heavily scaffolded, I am pretty happy to use it*". Technical support is important to make PSTs feel self-efficacious to use the RALfie experiments.

Bek stated that "*I did not like the programming so much. I found that quite complicated".* The cognitive activities were beyond Bek's current ZPD and she required more scaffolding to learn the relevant skills. However, being able to express her preference of RALfie activities demonstrated her agentic engagement by communicating likes and dislikes (Reeve & Tseng, 2011). Additionally, she may need to be matched with Daniel and George who are more comfortable with programming. In that way, there may be opportunities for Bek to learn vicariously from her peers (Bandura, 1997). Collaborating with more competent peers will help Bek to increase her ZPD due to the competent peers provide scaffolding (Vygotsky, 1978).

Overarching theme 3. PSTs' background has a significant influence on their self-efficacy.

Sub-theme 1: Background

Table **5** displays the background differences in education, prior knowledge of robotics and knowledge of the Australian Curriculum: Technologies. The table also illustrates PSTs' different modes of activities.

Table 5: PSTs' background influenced their self-efficacy

Differences	Maker and User	User only
Educational background	Aby, Shasha, Jo and Bek are enrolled in the Technologies Curriculum course; No engineering background	Daniel is a first year student. George is a third year student. Both of them had one year of engineering background and then switched to education
Prior knowledge of robotics	Never have robotic and programming experience; Never seen robotics in their teaching practice	Seen robotics in teaching practice school; Very good at using computers.
Knowledge of the Curriculum	They see the connections	It is peripheral to the curriculum
Anxiety of robotics	Yes	No

There are two groups in Table **5** PSTs' background influenced their self-efficacy, PSTs who participated in both maker and user activities, and PSTs who participated in user activities only. The striking differences between two groups are not the different modes of using RALfie but their prior knowledge and past experiences. Past successful experiences are the most influential source of efficacy information (Bandura, 1997) because past mastery experiences provide the most authentic evidence of whether one can succeed or not. George and Daniel were very keen to try RALfie because they had past experiences of seeing others using the LEGO at practice schools. They also had one year of engineering background, which made them feel confident and competent to use the online system. However, they did not see much relevance and connections between RALfie and the curriculum. They did not learn much about the Australian Curriculum: Technologies.

For the four PSTs who participated in both maker event and user activity, the connections between the Curriculum and the RALfie activities were evident. They had learned about the Technologies Curriculum at University and they had more exposure to the RALfie activities which helped them to see the connection. They had experienced feeling overwhelmed, frustrated and worried about RALfie because they never had any past experience of using robotics. They did not have engineering background which means they did not have much prior knowledge related to robotics and had low self-efficacy to use RALfie at the start because of the lack of successful experience (Bandura, 1997).

Sub-theme 2. Anxiety about RALfie

Anxiety caused by RALfie was identified in PSTs' reflections. Lilian wrote in her reflection: *"At first this activity* [RALfie Maker activity] *was daunting and I felt overwhelmed, as I had never used this software* [LEGO Mindstorms software] *before. Although after collaboratively working through the explicit instructions with my group we were able to successfully create the car to move around its assigned network".* The lack of previous successful experience resulted in anxiety and low self-efficacy for using RALfie which is in line with self-efficacy theory (Bandura, 1997).

Anxiety caused by RALfie was also identified in PSTs' interviews. Shasha commented that "*I know a lot of people when we started courses related to RALfie, they were so worried that they had no experiences in ICT and technology. Something like that might really intimidate them and put them off*." RALfie as an innovative technology is foreign and new to PSTs. The lack of previous experience of working with RALfie leads to anxiety.

The reasons for their anxiety were their lack of prior knowledge of robotics and lack of engineering background. Bek did not enjoy the online activities. She participated in both the maker event and the user activity and said, "*I like working with the hands-on part. I did not like the programming so much. I found that quite complicated. Physically move it and handle the stuff are lots of fun. I found it is pretty engaging.*" Although she participated in both modes of RALfie, she did not enjoy the programming side of the user activity and was more engaged at the behavioural level.

However, both George and Daniel enjoyed the RALfie online activities and felt positive about the experience. They studied engineering as their major for one year before they switched to education. They had seen other people using robotics in their teaching practice. They were very confident in their abilities to use computers. Bandura suggested that past experience provided the most authentic evidence of one's ability in doing something successfully (Bandura, 1997). George commented on the online system by stating that "*I like how it has experiment, system, levels and quests. Good fun stuff like that. I like interacting with a lab remotely. I feel that is exciting*." It was clear that George was engaged with RALfie cognitively by manipulating the experiment and emotionally by feeling excited about the online system (Munns & Martin, 2005). Daniel said "*You play with Lego Mindstorm kits and you are doing it remotely. For high school students it would be amazing experience just to be able to set it up and get it working and play with it."* Daniel's view is that using the online system is highly engaging.

In summary, the overarching theme 1 is the advantages of RALfie with the subthemes of link to the Curriculum; maker and user activities are engaging; access to real robots; hard fun; anywhere and anytime access; trial and error attitude;

learning through play; influenced self-efficacy for robotics. Overarching theme 2 is issues with RALfie experiences. The subthemes are technological issues; inadequate instructions; need technical support. Overarching theme 3 is that PSTs' background has a significant influence on their self-efficacy. The subthemes are background and anxiety about RALfie.

4.3 Discussion

Programming is an important skill which is required by the Australian Curriculum: Technologies. Programming allows PSTs to construct new knowledge using higher order thinking strategies such as analysis and synthesis which are in line with cognitive engagement (Munns & Martin, 2005).

The connection between hands-on experiments and remote access makes RALfie real and engaging for PSTs. Learning starts with concrete learning and proceeds to more abstract learning. The physicality of the maker event is concrete and the user activity is more abstract, involving aspects of system thinking and conceptual thinking.

Maker events allow students to work in a group to construct the experiment and interact with others. The social environment and face-to-face interaction is engaging and helpful for students to learn from each other. By working with a group, PSTs learn from each other in a collaborative way. That is consistent with Vygotsky's theory that interaction with peers is an effective way of developing skills (Vygotsky, 1978). Social interactions with peers provided opportunities for verbal persuasion and vicarious experience to influence PSTs' self-efficacy (Bandura, 1997). The lecturer's clear instructions scaffolded and facilitated PSTs' learning. Scaffolding is important for students to increase PST's ZPD (Vygotsky, 1978).

Hands-on activities open more opportunities for learners to be engaged. Learners are more self-directed and responsible for their own learning and development which is in line with social constructivism (Vygotsky, 1978). The interactive learning environment provides more choices for learners to choose which allows them to be actively engaged and make learning meaningful to them.

PSTs were engaged substantively in working with the RALfie experiences. The multidimensional construct of behavioural, cognitive, agentic and emotional engagement is substantive engagement (Munns & Martin, 2005). Multiple levels of engagement represent substantive engagement which is a positive indicator for impacting on self-efficacy. Multiple levels of engagement helped students to build up their capacity and confidence to teach and gain more sense of self-efficacy.

Anxiety about using RALfie was identified from interviews. Anxiety as a negative emotional status had negative influence on PSTs' self-efficacy (Bandura, 1997). The reasons for PSTs' anxiety included their lack of prior experience of working with robotics, the technical issues from the RALfie system, and insufficient instructions for user activities. The anxiety of PSTs can be monitored for change and used for professional training. PSTs need to have more time exposure to RALfie Maker and User experiences. The RALfie activities need to be monitored to a reasonable level of difficulty to meet individual learning needs.

PSTs who used RALfie may have had an over-inflated view of what they knew about Technology before they started the RALfie activities. Encountering RALfie in a one-off high level maker event, instead of in the structured progression of activities from simple to more complex, might be far from the zone of proximal development (Vygotsky, 1978). They may have had too little contact with the system to learn enough background information for the task they encountered. One or two experiences may be too little. The activity may not be suitable for novices so choosing a simpler activity might not have the same effect.

From a technical point of view, RALfie is a prototype system which will keep developing and progressing. It is important to reassure PSTs that the Technology will keep improving. Future versions of RALfie will be more comfortable and stabilized. Alternatively, the RALfie team needs to demonstrate how RALfie has evolved from a concept to reality. Over time the remote control capacity has been expanded. It started within an Engineering building at USQ and now can be accessed worldwide. Reassuring PSTs is important so that they can believe that future RALfie activities will be more user-friendly. Therefore, PSTs can persist through current setbacks and use RALfie in the future.

4.4 Lessons Learned from Pilot Data Analysis

The pilot study allowed for simple trials with the T-TEBI instrument derived from the STEBI-B (Riggs & Enochs, 1990) as described in Chapter 3. Although the small number of participants precluded statistical analysis of the data, including standard checks of reliability, the pilot study provided an opportunity to test operation of the online questionnaire and to confirm that participants were able to interpret the questions in the T-TEBI instrument.

The analysis of T-TEBI data allowed the researcher to think deeply about the emotional status which is one source of self-efficacy information. The qualitative data analysis clearly identified the PSTs' anxiety which needed to be further explored. In the main study, PANAS was administered with the T-TEBI at both pre-test and post-test. In addition, in the main study the researcher was more aware of PSTs' anxiety and asked more questions related to anxiety in the interviews.

The pilot study also provided an opportunity to test interview questions and practise the techniques to be employed in conducting interviews and analysing the data. During the interviews it became apparent that the previous histories of participants as learners of Science and Technology in schools or beyond were significant. Those experiences influenced participants' initial attitudes to the activities as well as the knowledge and skills they were able to bring to the activities. Interviews in the main study were adapted to ensure that relevant information about previous experiences would be collected. There were some added interview questions related to educational background and teaching philosophy of science and Technology for the main study. Techniques for managing and analyzing transcribed data in Nvivo were tested and adapted and that experience informed the main study.

The design of maker and user activities needed further exploration. For the maker activities, PSTs needed to know their challenges and their task more explicitly. They needed more time and more exposure to learn programming using Snap! software which was difficult for them. Difficulties experienced with the user activity in the pilot study highlighted the need for a stable internet connection for acceptable performance of remote activities. The multiple logins required for the Pendulum activity were confusing for users and the RALfie system needed to be developed to offer a more user-friendly experience. The scaffolding in the user activity needed to be more detailed and more frequent. In order to provide for independent use of the remote activities that would require more complete instructions for the online activities using simplified and non-technical language. PSTs needed more teacher support, instructions and demonstrations to help them to improve their self-efficacy to use RALfie because the majority of them have limited or no background knowledge of robotics.

4.5 Summary of Chapter 4

Chapter 4 presented the pilot study with descriptions of maker and user experiences and data collection. That was followed by analysis of quantitative and qualitative data which led to discussion. Lessons learned from the pilot study will inform the main study in Chapter 5.

Chapter 5: Main Study

This chapter presents details of data collection and analysis for the major study. Based on the experience of the pilot study, a case study approach was adopted for the main study. Quantitative data analysis was used to identify participants of interest who were then selected for development of cases. The chapter presents the individual cases followed by cross-case analysis to identify differences and similarities among cases. Some elements of this chapter have been published in a conference paper (Albion et al., 2016).

5.1 RALfie Experiences

5.1.1 Maker Events

In the first maker event, students engaged in programming using Snap! which is a graphical, free, drag and drop programming language (Garcia, Segars, & Paley, 2012). It is an extension to the Scratch programming software. Figure 16 shows the Snap! Programming interface.

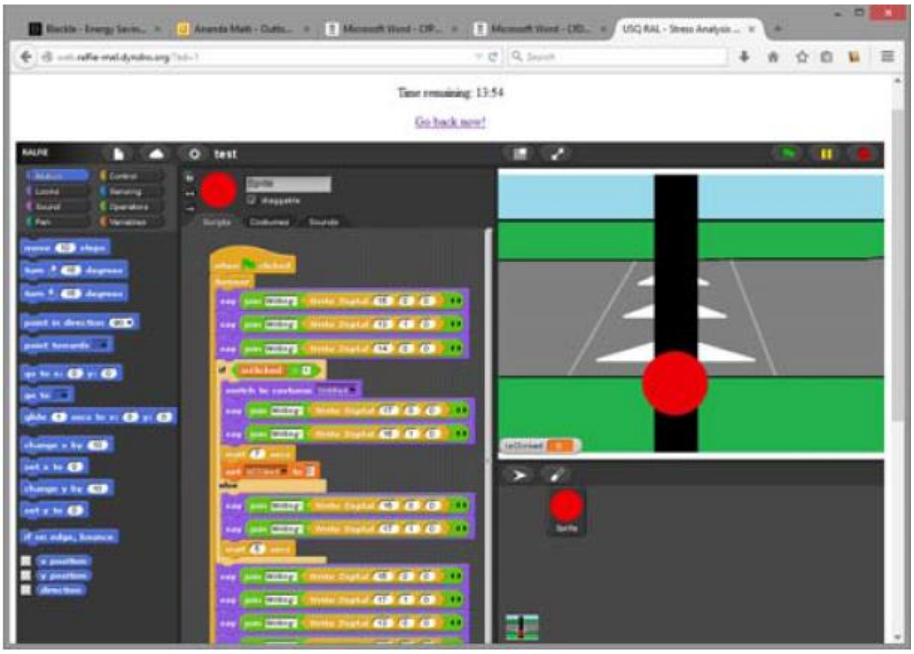

Figure 16: The Snap! Programming Interface

In the maker events, three ready-made robots were provided by the RALfie team. Students brought their own laptop computers and worked with their team to use Snap! During the two hour workshop, one professional engineer gave an introduction to students about the LEGO EV3 and other successful maker activities that the RALfie team organized in the previous year. One professional engineer spent 15 minutes to explain how the RALfie system was connected to allow remote control. One professional engineer spent 15 minutes to explain how to use Snap! software to program LEGO EV3. Students were organized into three groups to use the Snap! language to program the LEGO EV3. Ready-made robots were connected to the server computers by the professional engineers. Students then used the server computers to control the robots.

In the second maker event, students explored Robot Soccer. The second maker event was at the Makerspace in the USQ library which is open for the public to use 3D printers, robotics and other advanced technology (Rogers, 2016). Three professional engineers had set up the facilities ready to use. Three RALfie boxes, three IP cameras, three WiFi adaptors and three server computers were connected. Three LEGO Mindstorm kits were provided for students to use.

Professional engineers spent 15 minutes to give an orientation of the LEGO Mindstorm Kit. Students played with LEGO and built their own robot with their team mates. PSTs used Snap! to program the robots via computers. Students drove the robots around and played soccer. Two robots were shooters and one was goal keeper. When they were familiar with the face-to-face control of the robots, they then moved to downstairs with their server computers. They manipulated and played the robot soccer game remotely. Figure 17 shows the PSTs working with their robots and robots playing soccer.

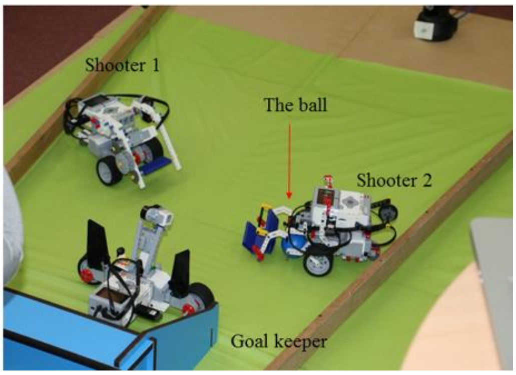

Figure 17: Robot soccer

5.1.2 User Activities

In the user activities, participants were able to remotely operate experiments mounted in the Engineering laboratory. Two of the experiments being tested as part of the RALfie project development were selected as the basis for learning activities that could be undertaken by pre-service teachers. Both offered experience with remote operation of the equipment and had broader relevance to the curriculum. Each was presented as step-by-step instructions with illustrations in a webpage within the course materials and included background information, links to relevant resources, and questions for reflection. The RALfie system will time out users in 15 minute slots so as to avoid having a student monopolize an activity and prevent access by others.

The Pendulum activity in Figure 18 was the same activity described for the pilot study in section 4.1.2. Users needed to set the ball bearing at a suitable height, set it in motion, record the time for 20 swings, and enter that time and the length of their pendulum in a Google form where the data entered by all users were aggregated and displayed on a graph driven by a Google sheet. The intention was to use the pooled data to estimate the gravitational constant which users were also invited to calculate directly for comparison with the pooled result.

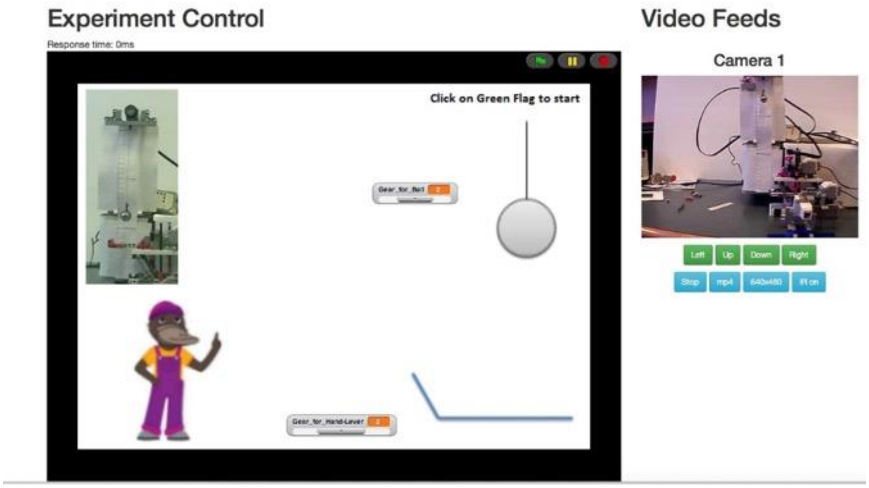

Figure 18: RALfie Pendulum activity

The Gearbox activity in Figure 19 presented users with a gearbox constructed using LEGO and the challenge is to determine the ratios among the 4 gears, A to D. The setup included a graphical user interface similar to that shown in Figure 18 RALfie Pendulum activity but omitted in Figure 19 to afford a clearer view of the gears. Users were able to remotely control the motor to rotate Gear C through a selected angle (in degrees) and observe and record the rotation of the other gears to determine the ratios.

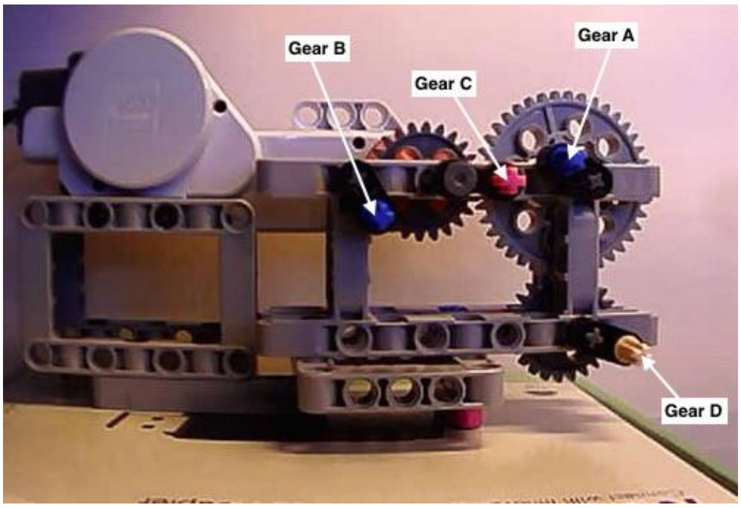

Figure 19: RALfie Gearbox activity

The main research question was:

- In what ways does engagement with Remote Access Laboratories influence pre-service teachers' self-efficacy to teach the Australian Curriculum: Technologies?

The sub-questions were:

- How has the RAL experience influenced pre-service teachers' self-efficacy to teach Australian Curriculum: Technologies?
- How can the RAL experience be improved in the future?

5.2 Data Collection and Analysis

5.2.1 Participants

Participants were pre-service teachers who were enrolled in a course, *EDP4130 Technology Curriculum and Pedagogy*, in the final year of their primary education program at USQ. There were 168 students enrolled in the course; 22 enrolled at the main campus where the study was located, 16 and 32 enrolled at other campuses, and 98 enrolled online.

As in the pilot study, there were maker and user experiences offered to students enrolled in the course. Two maker events were offered to students enrolled at the main campus. There were 12 participants in the maker event offered in March 2015 and 6 of those also participated in a second maker event offered in May 2015. The online user activities were available to all students enrolled in the course and 35 students participated in one or more of those activities. Those included 5 students who were participants in a maker event. Seven participants were interviewed, including five who participated in both maker and user activities and two who participated in the user activity only.

5.2.2 Quantitative Data Analysis

There were 123 respondents who participated in pre-test T-TEBI and PANAS. However, there were missing data. When respondents missed the majority of the survey, their responses were deleted from the data analysis. The process of the T-TEBI data collection was explained in Chapter 3. The T-TEBI data were analysed using Statistical Package for the Social Science (SPSS) Version 22 to obtain Cronbach's alpha as a reliability scale test. Two subscales for T-TEBI and PANAS were checked for instrument correlation. Table 6 shows the inter-item correlation matrix for the self-efficacy (SE) scale. Rev represents reverse score. Item 24 has to be taken out of the self-efficacy analysis because the inter-item correlation score is negative.

Table *7* shows the inter-item correlation matrix for the outcome expectancy (OE) scale. Item 20 was missing when the survey was conducted. For an item to be acceptable the correlation score should be above 0.3 (Field, 2009).

Table 6: Inter-Item Correlation Matrix for T-TEBI Self-Efficacy (N=119)

*means reverse score

	2	5	12	18	23	*3	*6	*8	*17	*19	*21	*22	*24
2	1.00												
5	.529	1.000											
12	.486	.650	1.000										
18	.243	.384	.398	1.000									
23	.478	.439	.536	.409	1.000								
*3	.372	.382	.540	.294	.379	1.000							
*6	.226	.313	.313	.327	.294	.395	1.000						
*8	.328	.300	.543	.270	.527	.586	.370	1.000					
*17	.365	.215	.228	.362	.227	.333	.230	.253	1.000				
*19	.276	.162	.306	.388	.248	.438	.240	.335	.347	1.000			
*21	.382	.307	.405	.357	.436	.419	.318	.497	.416	.366	1.000		
*22	.489	.470	.518	.377	.603	.560	.380	.690	.484	.415	.577	1.000	
*24	-.326	-.335	-.359	-.391	-.403	-.472	-.394	-.446	-.409	-.392	-.466	-.621	1.0

Table 7: Inter-Item Correlation Matrix for T-TEBI Outcome Expectancy (N=119)

*means reverse score

	1	4	7	9	11	14	15	16	*10	*13
1	1.000									
4	.418	1.000								
7	.272	.212	1.000							
9	.236	.193	.116	1.000						
11	.342	.318	.118	.244	1.000					
14	.163	.344	.339	.217	.391	1.000				
15	.170	.192	.225	.253	.260	.509	1.000			
16	.068	.320	.007	.321	.289	.270	.358	1.000		
*10	.027	.008	.135	.098	.142	.118	.120	-.075	1.000	
*13	.101	.040	.091	.199	.008	.068	.025	-.080	.212	1.000

The PANAS instrument was also analysed following the same process to test the inter-item correlation for PA and NA. Table 8 shows the inter-item correlation matrix for positive affect. Table 9 shows the inter-item correlation matrix for negative affect.

Table 8: Inter-Item Correlation Matrix for Positive Affect (N=109)

	Interested	Excited	Strong	Enthusiastic	Proud	Alert	Inspired	Determined	Attentive	Active
Interested	1.000									
Excited	.614	1.000								
Strong	.397	.388	1.000							
Enthusiastic	.681	.717	.509	1.000						
Proud	.367	.461	.483	.627	1.00					
Alert	.463	.473	.499	.678	.572	1.00				
Inspired	.595	.595	.535	.791	.611	.681	1.000			
Determined	.607	.576	.513	.759	.512	.630	.771	1.000		
Attentive	.568	.526	.469	.757	.478	.681	.756	.847	1.000	
Active	.553	.515	.517	.641	.488	.647	.650	.702	.646	1.00

Table 9: Inter-Item Correlation Matrix for Negative Affect (N=111)

	Distressed	Upset	Guilty	Scared	Hostile	Irritable	Ashamed	Nervous	Jittery	Afraid
Distressed	1.000									
Upset	.347	1.000								
Guilty	.331	.710	1.000							
Scared	.526	.442	.388	1.000						
Hostile	.362	.435	.455	.425	1.000					
Irritable	.398	.579	.560	.494	.584	1.000				
Ashamed	.315	.614	.759	.311	.497	.617	1.000			
Nervous	.442	.124	.166	.636	.078	.187	.083	1.000		
Jittery	.427	.334	.283	.582	.342	.468	.361	.508	1.000	
Afraid	.552	.424	.342	.738	.335	.481	.367	.608	.696	1.000

Cronbach's Alpha tested the reliability of the scales for pre-test of T-TEBI and PANAS. When the Cronbach's Alpha is greater than 0.7, it means the test is reliable (Field, 2009). The outcome expectancy subscale consisted of 10 items (α=0.697, N=119). If item *10 were deleted from OE subscale, the result will be α=0.701, N=119. If item *13 were deleted from OE subscale, the result will be α=0.707, N=119. The self-efficacy subscale consisted of 12 items (α=0.880, N=119). The positive affect subscale consisted of 10 items (α=0.935, N=109). The negative affect subscale consisted of 10 items (α=0.874, N=111). The T-TEBI and PANAS are suitably reliable instruments for the purposes of this study.

There were 41 participants who completed both pre and post T-TEBI survey among which 36 participants participated in some RALfie experiences and 5 participants did not access RALfie experiences. The small sample pool was insufficient to support the application of the independent samples t-test.

Instead, the Mann-Whitney U Test was used to test for pre-post significant differences between groups. The result showed that there was no significant difference between pre-post mean OE values (U=78, p=0.656). There was no significant difference between pre-post mean SE values (U=62, p=0.283). There was no significant difference between pre-post mean PA values (U=77.5, p=0.760). There was no significant difference between pre-post mean NA values (U=43, p=0.81). $P < 0.05$ is the cut off line for statistical significance. There was no significant difference between RALfie treatment group and non RALfie group. Therefore, this research considered the individual results for pre-test and post-test comparison and the qualitative data were further analysed to explain the quantitative data.

5.2.3 Qualitative Data Analysis

There were two sources for qualitative data collection. The major source of qualitative data was the interviews. Respondents to the online questionnaire were invited to offer comments about each of the remote activities that they attempted. In total there were 36 respondents to the online questionnaire who wrote feedback comments about their experiences with the RALfie user activities. PSTs' feedback comments collected on the post-survey served as a complementary data source which was used to validate the interview data.

There were 41 PSTs who answered both pre-test and post-test T-TEBI and PANAS. There were 7 PSTs who were interviewed, including 5 on campus students and 2 online students. The five on campus students participated in both maker and user activities. The two online students participated in the user activities only. Seven PSTs were interviewed and one of them was missing from the scatter plots presented below because she did not answer the pre-post survey. Therefore, there were 6 interviewees identified on the scatter plots. Table 10 shows the information for interviewees in the main study.

Table 10: Information for Interviewees in Main Study

Numbers in the plots	Nick Name	Modes of RALfie	Colours on the plots	Pre-post Mean OE Score	Pre-post Mean SE Score	Pre-post Mean PA Score	Pre-post Mean NA Score
No.4	Ryan	User	Green	3.10-3.40	3.00-4.08	3.60-4.00	3.50-2.30
No.8	Susan	Both	Red	3.50-3.60	3.15-3.62	2.50-1.90	2.10-1.70
No.20	Anissa	Both	Red	3.40-3.70	3.38-3.62	2.40-2.90	1.40-2.00
No. 21	Mathew	Both	Red	3.50-3.30	2.38-2.38	2.30-2.60	3.30-2.80

No. 28	Sally	User	Green	3.70-3.50	3.62-4.54	1.50-3.20	1.70-1.20
No. 41	Hila	Both	Red	3.90-3.90	3.62-4.00	3.00-3.80	1.60-1.60
Missing	Dana	Both	Missing				

5.2.3.1 Thematic Analysis

Thematic analysis using Nvivo was undertaken for the interview analysis for the main study. There were four overarching themes and several sub-themes generated from the main study. The themes that emerged in the main study were very similar to the themes from pilot interview analysis.

Table *11* shows the interview themes from the main study.

Table 11: Interview Themes from Main Study

Overarching theme	Sub-theme in the Main study	Sub-themes in the pilot study	Interview quotes
1. Advantages of RALfie	Links to Curriculum	Yes	Mathew stated that "*Well, the curriculum for that subject is about design and technology and then also about digital technology. So it relates to both subjects within the Technology Australian Curriculum because you're doing the design component with coming up with the model and with the programming that, doing programming design I guess and there's the actual digital component of actually using computer programming to get the model moving and active. So I think it addressed both subjects of the curriculum.*"

	Maker and user activities are engaging	Yes	Susan likes maker event and stated "*that whole process making, building, programming and testing, and seeing that too, live, how it works on the camera in a separate room and seeing it in the room with the robots there was all good. And as well, working with other classmates as well and being able to interact with the robot, and made the robots interact with one another as well, that was fun*". Dana stated that "*Well I think it was an online one, it's also there's not someone there watching you straight away, so sometimes I'd be more confident to have a go, and if it didn't work the first time, then I'd be like, oh okay, well I'll try this, or I'll try that, whereas maybe if there's someone like right behind me, like in the Maker Event, I'm just like, oh you do it, and like get them to do it, whereas if there's not someone there online then I'd probably be more willing to have a go and keep persisting*".
	Course lecturer's scaffolding is important	N/A	Susan stated that *"I guess Peter's class, the tutorial activities for scratch; it kind of provides you with the basis of what, of programming which is needed for RALfie, when you program your robots. Without that experience or playing around at a beginner's level making shapes or simple games, I don't think I would be able to do RALfie or understand what I have to do in RALfie when I'm programming".*
	Positive attitudes	Yes	Anissa stated that *"Probably anything is possible. Like you don't have to be scared of it because it is like doable like it is attainable if you set your mind to it. Like if you go in with the attitude that oh I don't*

				know what to do you probably won't achieve in it so you have go in with an open mind"
	Influenced self-efficacy for robotics	Enacting successful experience	Yes	Dana stated that *"now that I've had a go, I did it myself, and I've experienced success, then I feel confident that I could guide my students in, like experience in that same success working as a team together, and yeah, so I've experienced it first. I know that it works, so now I could help my students with it"*.
		Vicarious experience	Yes	Mathew commented on demonstration provided by professional engineers in RALfie and stated that *"Andrew explained things quite well and Alexander as well just the different components and how it all sort of works and the remote aspect of it all of that was interesting"*.
		Verbal persuasion	N/A	Anissa commented on the course lecturer's encouragement and stated that *"He really wanted us to learn Scratch and do the activities…Like he was always very encouraging that we at least try to do it even if we couldn't – like give it the time; give it a chance."*
		Emotional status	Yes	Ryan stated that *"So that's what I enjoyed the most out of that as well – as well as the fact I was able to turn on a light. As strange as it might sound to feel like I actually some sort of control over what I seeing and I was seeing it, because initially I don't think I realised that I was able to turn a light on and then somehow from my computer I was able to turn a light on and I thought that's incredible how have I been able to do that from my computer, so I was*

				pretty impressed with that. And again that comes back to the technology thing the gearbox side of it might have only been one aspect just the fact that I could – and control the camera as to angles and that sort of – I just – I found it absolutely amazing I really did, I was just engrossed in it".
2. Issues with RALfie experiences	Technological issues		Yes	Ryan stated that *"So and I was living in an area that constantly dropped out our internet service just kept dropping out all the time".* Anissa stated that *"Probably the time that's involved like of making a RALfie like setting up the Scratch and setting up the robot. Probably knowing what the curriculum is like there is not enough time. So I think if were using RALfie you would be limited on how much you could teach from it because of the time it takes to set it up and like teach about it. I would worried that you would only be able to do an activity but then you would have to keep it there – like end it there and you wouldn't be able to extend on it".*
	Inadequate instructions		Yes	Susan stated that *"Just a lack of instruction online, that didn't really motivate me to continue to try and experiment".*
	Need technical support		Yes	Susan stated that *"Teaching the pedagogical perspective, that would be just like teaching any other subjects, I'm not too worried about that, it's just the technological side that I'm not too familiar with, even programming sometimes depending on how the activity is supposed to go, if I'm comfortable with doing the advanced stuff".*

3. Background had a great impact on their self-efficacy	Pre-perception of science learning	N/A	Anissa stated that *"I think it's really personal. I think it's something you either like or you don't like. I think there is a perception at school. Like science is like the smart subjects and like you can't do them at school – you're not going to be able to do them at uni. It's really formed – like it's a society forming thing I think".*
	Educational background	Yes	Sally commented that *"I'm sure that really does just being confident in that area or having a good experience myself in that area especially with science in the classroom, quite positive to teach that one. So in that regard so I think it does I mean if I didn't have a very good experience with that when I was a child in the classroom I'm sure I wouldn't be as positive to yeah let's g o and teach science".*
	Being scared of technology	Yes	Ryan stated that *"I guess it's an area that I haven't had a lot of experience in. The whole technology doesn't come easily to me. That's something I have to work at. I guess being a mature age student it's not as familiar as maybe some others who've grown up a bit more with the digital world".*

The overarching themes for the main study and the pilot study were the same. The sub-themes generated from the main study and the pilot study were similar. The different themes were course lecturer's scaffolding and the verbal persuasion. It was obvious that the course lecturer provided more scaffolding and more encouragement in the class during the main study. It was one of the lessons learnt from the pilot study that PSTs need more support and more scaffolding. The PSTs needed more encouragement to participate in the RALfie activities to alleviate their anxiety about using robotics. In the main study, there were some additional interview questions about PSTs' pre-perception of science learning. Therefore, there was one theme generated from the main study about pre-perception of science learning. It was one of the lessons learnt from the pilot study that PSTs' background had impact on their self-efficacy. It was confirmed from the main study that PSTs' background has a significant impact on their beliefs, attitudes and self-efficacy.

5.2.3.2 Participants' Overall Comment Analysis

Respondents to the online T-TEBI and PANAS questionnaire were invited to offer comments about each of the remote activities that they attempted. In total there were 36 respondents to the online questionnaire who wrote feedback comments about their experiences with the RALfie User activities.

Of those, 23 (64%) commented about difficulties they experienced with accessing and navigating the RALfie website. There were specific comments about Internet connection issues, slow loading of activities, difficulty with finding tasks and commands for operation, crashes in their web browsers or apparent freezes in the RALfie system and difficulty with zooming in to see detail. Some commented on the restrictions inherent in allowing access by only a single user at any time when they might have benefited by observing the activity of another concurrent user.

On one occasion the ball for the Pendulum activity became detached, making the activity inoperable until somebody in the Engineering laboratory could be advised and effect a repair. That caused frustration for students who had set aside time to complete the activity. The lighting on the Gearbox activity was insufficiently bright for clear observation and the labels on the gears were difficult to read, making it difficult for users to operate the interface. As many as 9 (25%) commented about being confused by the instructions and unable to understand what was required by the activities.

Despite those apparent difficulties, only 20% of respondents used “frustrated”, “overwhelmed”, or “struggled” to describe their experience, mostly in reference to the interface or unreliability of access which caused frustration. As noted earlier, lack of familiarity with STEM content, including in some cases lack of experience with LEGO, meant that the activities were challenging for many students with a level of abstraction and requirement for computational thinking or other problem solving skills.

Moreover, respondents reported that when their Internet connection worked well they had a positive experience with the RALfie user activities. Those who participated in the Maker events found working with LEGO was motivating and engaging and those working online enjoyed remotely manipulating the camera, light and other equipment. One student reported sharing the online activities with his family. They did comment on the need for additional teacher support, the value of collaboration and social feedback from peers, and the need for more time to spend on the activities in order to develop familiarity with concepts and operation.

5.2.4 Case Study Analysis

Case study allows deep analysis of individuals, especially with consideration of the individual’s background, preconceptions and attitude. For this study, case study allows deep analysis of the changes of self-efficacy. Self-efficacy is an inner voice which is a subtle and specific construct (Bandura, 1997). Case study will help readers to understand the reasons for positive or negative change of PSTs’ self-efficacy. Importantly, quantitative data analysis did not generate much information about self-efficacy for the groups due to the small data pool. Therefore, pre-test and post-test of quantitative result was used to match pairs for individuals. The pre-post results were helpful to identify interesting individuals for case study from among those who volunteered for interview. Additionally, thematic analysis of interview data in the main study did not generate much different information from the pilot interview analysis. It is important to use case study to explore the changes of self-efficacy before and after the RALfie experience for individuals.

5.2.4.1 Case Study

Each case study will start with PSTs' biography, modes of RALfie activities, scores for pre-post mean for OE, SE, PA and NA. Cases were selected based on where they fell on the plots of the quantitative data.

Figure 20 shows the pre-post comparison of self-efficacy scores. It presents scatter plots of pre-test score (X-axis) against post-test score (Y-axis) for SE with the four groups of respondents identified as shown in the legend. Points above the diagonal line represent respondents who scored higher on the post-test than pre-test. Points below the diagonal line represent respondents who reported decreases on the relevant scales. There seem to be dominantly more participants reporting increases in self-efficacy than decreases, indicating that the RALfie experience had a positive influence on PSTs' self-efficacy no matter which mode of RALfie they experienced.

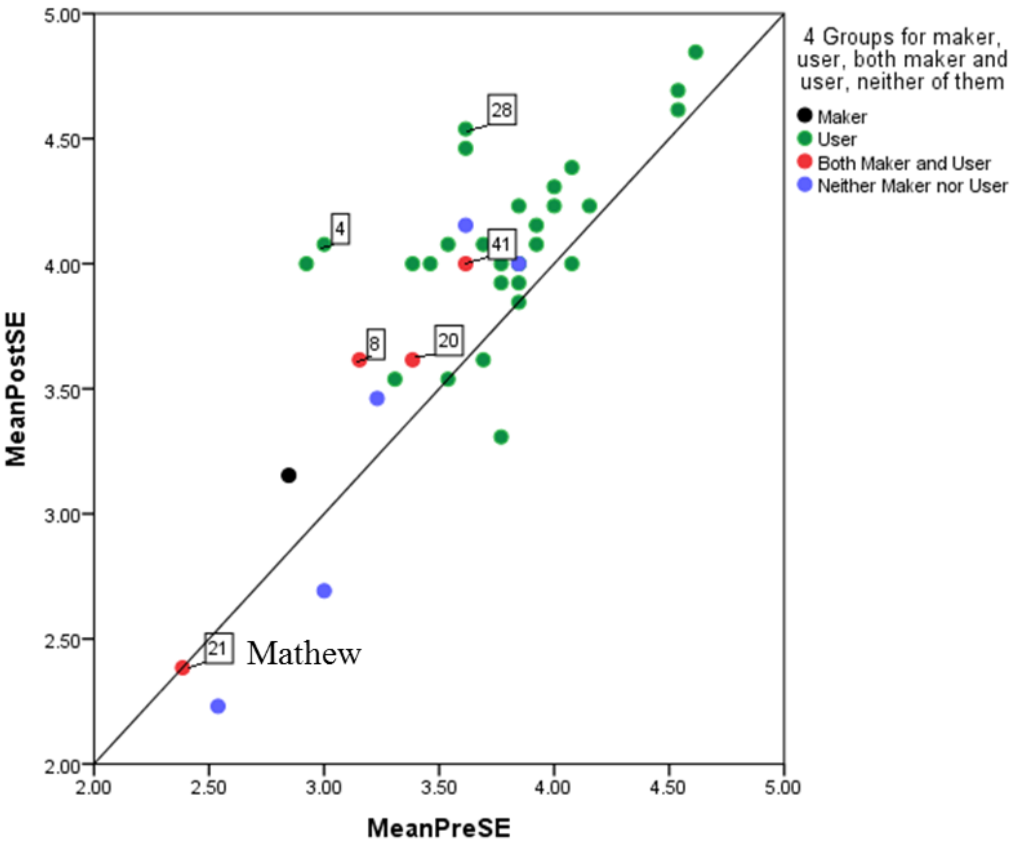

Figure 20: Pre-post comparisons of Mean Self-efficacy

For the pre-post SE scores, Mathew fell toward the bottom of Figure 20. His pre-test SE score was lowest and remained the same for the post-test. Mathew (No. 21) was identified for case study and there were themes identified from his interview analysis to explain his low SE.

Figure 21 shows pre-post comparisons of outcome expectancy scores. Generally speaking, the pre-post OE scores were quite stable. Mathew's pre-post OE score was relatively high compared to his low SE score. His OE needs further exploration to have a full understanding of his self-efficacy.

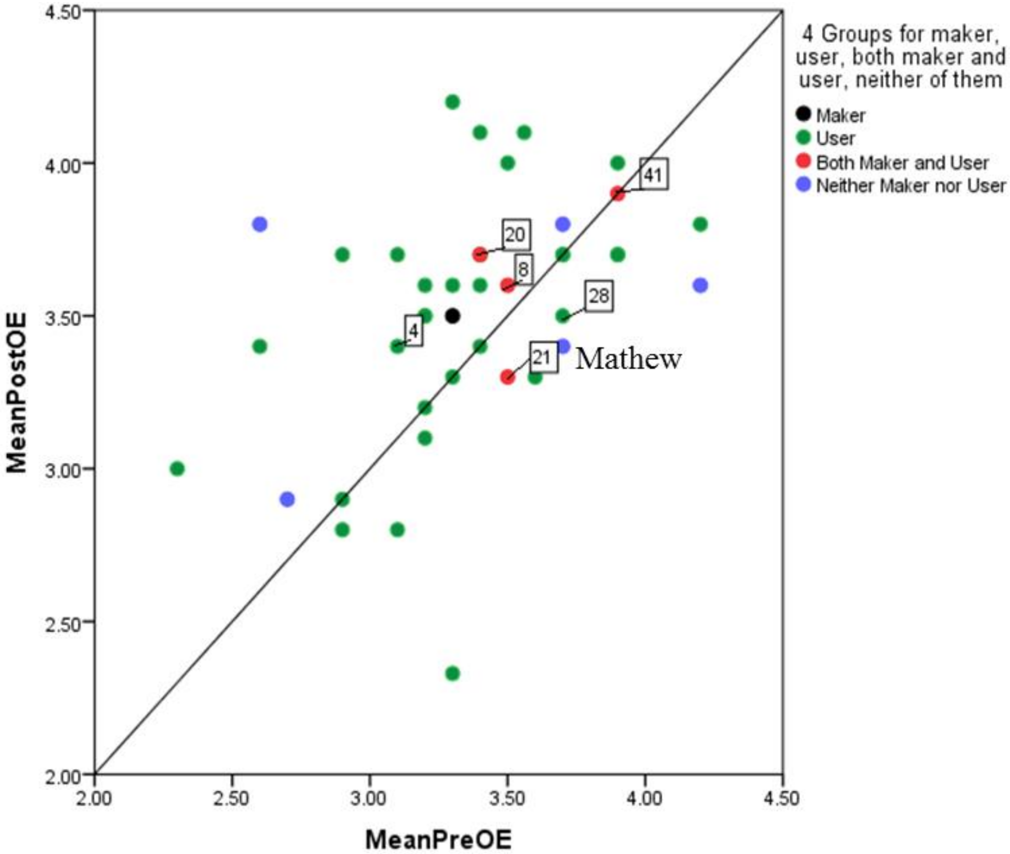

Figure 21: Pre-post comparisons of Mean Outcome Expectancy

Figure 22 shows estimated time spent for both maker and user activities in minutes. The treatment group spent time from a few minutes to 18 hours. Ryan spent 18 hours using the online RALfie system. The reason why he was chosen to be interviewed was that 18 hours spent on RALfie needed to be confirmed and clarified and his online experience needed to be explored.

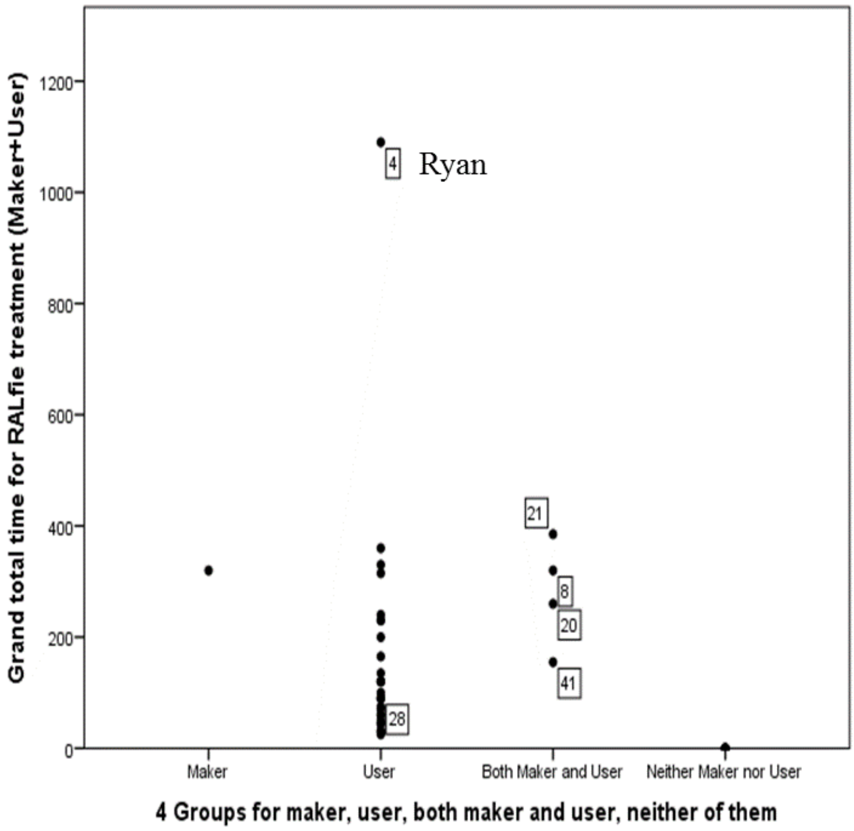

Figure 22: Grand Total Time Spent forMaker and User

Figure 23 shows pre-post comparisons of mean positive affect scores. There were about half of PSTs located above the diagonal line who had a positive emotional status. They demonstrated enthusiasm, engagement and concentration after RALfie treatment. There were about half of PSTs below the diagonal line who had a negative emotional status. They experienced negative emotions such as sadness, disengagement and boredom after the participation in the RALfie activities.

For the pre-post PA score, Sally was an outlier whose pre-post PA score increased most by 1.7 among 6 interviewees, meaning that Sally had a positive experience with RALfie. Sally started with a low PA in the pre-test which means that she was disengaged before she used RALfie. Sally's post-test PA was very high which means that during the process of RALfie treatment she was highly engaged and enjoyed it.

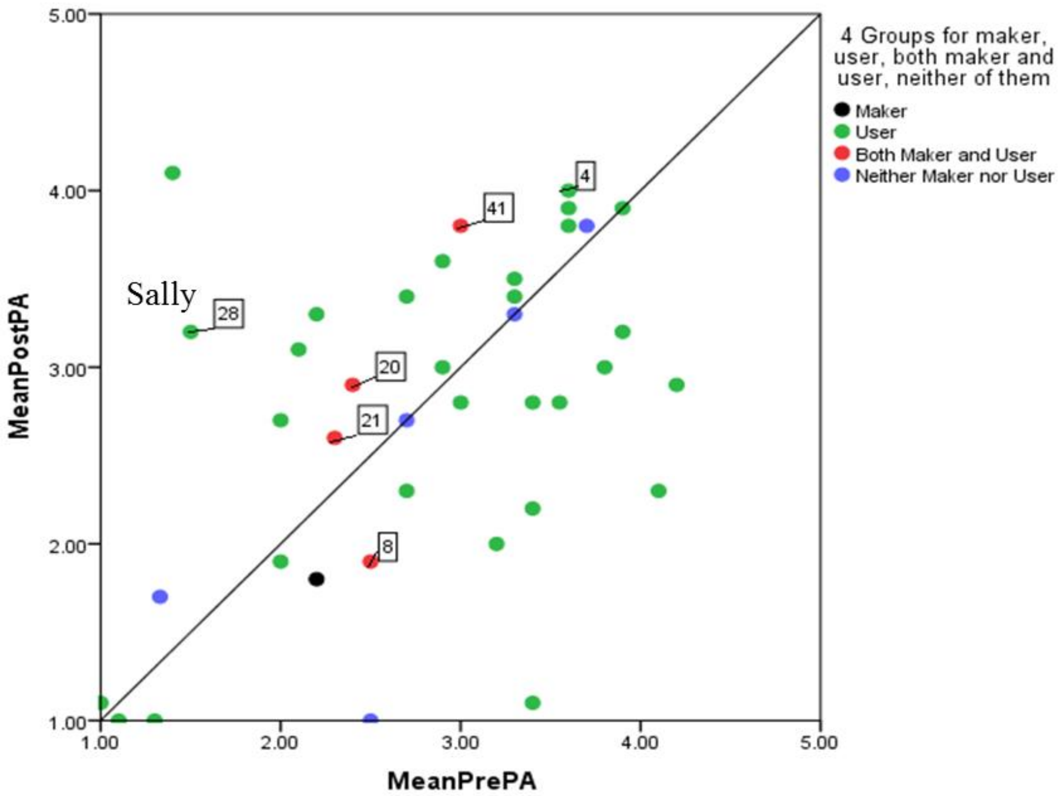

Figure 23: Pre-post comparisons of Mean Positive Affect

Figure 24 shows the pre-post comparisons of NA scores. On each plot points below the diagonal line represent respondents who scored lower on the post-test than pre-test. Points above the diagonal line represent respondents who reported increases on the NA scales. There were half of PSTs located below the diagonal line and half above. PSTs who located below the diagonal line had low NA and they demonstrated calmness and serenity. PSTs located above the diagonal line had high NA and they demonstrated anxiety. For Anissa (No. 20), her pre-post NA was increased most among 6 interviewees which was a negative indicator. Anissa had experienced anxiety working with RALfie.

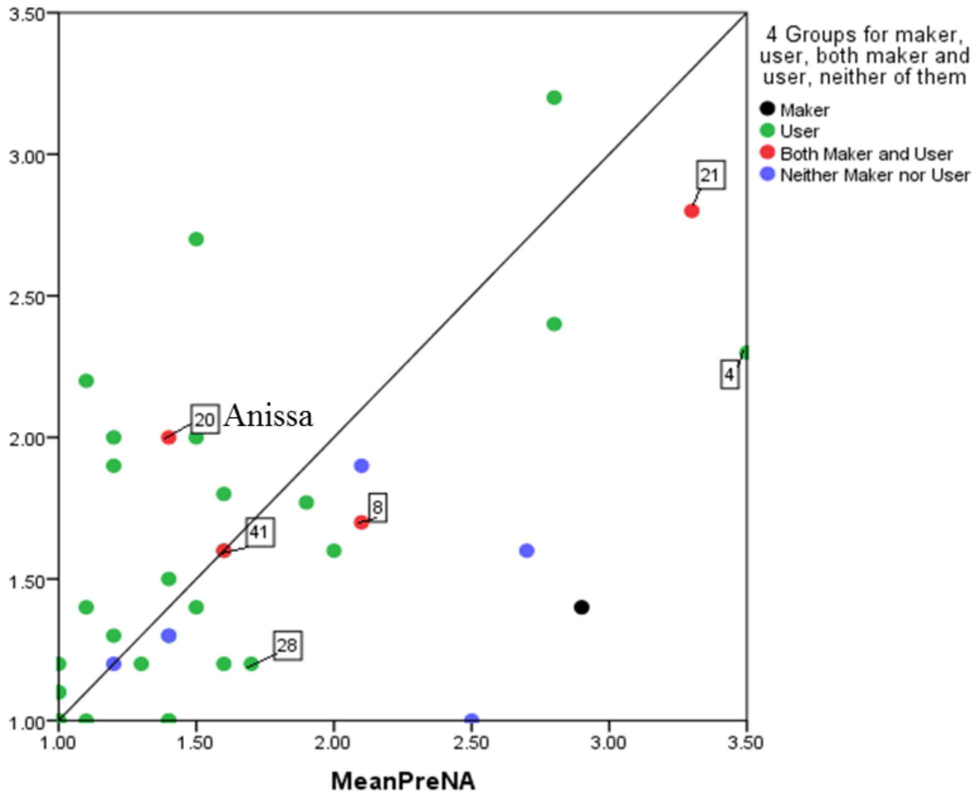

Figure 24:Pre-post comparisons of Mean Negative Affect

The selected cases are Mathew, Ryan, Sally and Anissa. Qualitative data will be analysed to help readers to understand quantitative data. Cross-case comparison will be adopted to analyse the differences and similarities across cases.

Case 1: No. 21 Mathew

Mathew was a male student whose age was 40+. He spent 10 years as a salesman and did drafting for house builders. He learnt by himself how to use CAD drawing programs. He did not grow up with technology and he thought he was a pre-digital native person. He would like to become a Sport Health and Physical Education teacher because sport was his strength. Mathew has a strong motivation to be a teacher. He wants to work with little children to serve as a male model for kids who live in a dysfunctional family. His children's schools used LEGO which made him realize that robotics was important. This was one of the motives for him to join in RALfie.

He participated in both maker and user events, spending a total of 7 hours using RALfie. His pre-post scores for OE were 3.50 and 3.30, SE scores were 2.38 and 2.38, PA scores were 2.30 and 2.60, and NA scores were 3.30 and 2.80.

He commented on his mentality of being scared of technology. He stated that *"I think it's partly my generation. Once we hit a hurdle with technology we think oh if I press the wrong button it's going to ruin it or it's going to break or it's going to freeze totally and I'm going to lose everything I've done. We sort of have that mentality, or I do rather than thinking oh well doesn't matter we'll just try it again and try it again or. We sort of think oh no it's really broken now."* Lack of past successful experience of working with technology resulted in contributed to his low self-efficacy to use technology.

Mathew did not learn much science when he was in primary and high school. He stated that *"I guess it's an area that I haven't had a lot of experience in. The whole technology doesn't come easily to me. That's something I have to work at…It was not a part of my growing up at all really. So yeah it's, as I say, I think I was pre-digital native. So there wasn't a lot of technology introduced in the learning as a primary school student or even in high school for me."* It was in line with his low pre-post SE score. Mathew lacked past learning experience with technology which made him feel less self-efficacious to teach Technologies. It was also in line with the literature that many primary school teachers did not have much technology learning experience in their childhood, which made them feel anxious to teach the Technologies in classroom.

Mathew felt frustrated when online activities did not work. He also felt frustrated because only one person could use it at one time. He had to wait until somebody finished their use and then it was the next person's turn to use the online activity. He stated that *"that made it a bit frustrating that if you wanted to have a go and it was being, you had to wait the, whatever it was the 15 minutes or something until that person had finished and then that might not suit you to try and go back in."* It was consistent with his low pre-post PA and high pre-post NA score. Mathew experienced a low level of enjoyment and high level of frustration of using RALfie. Technical difficulties made him felt frustrated.

The user activity did not work properly which resulted in his frustration. He stated that *"Well I just felt oh that's a shame. I was looking forward to trying to work out the activity and then when it froze, for me, as soon as anything a bit technical is unusual I go oh forget it. I sort of go oh I won't bother trying anything else I just sort of leave it and don't go back to revisit it. I haven't actually gone back in to have a look at the pendulum since."* He had a low self-efficacy to use RALfie which was consistent with his low pre-post SE score. The lack of science and technology learning background could be the reason for his low self-efficacy. His low pre-post PA and high pre-post NA score demonstrated his anxiety about using RALfie.

The engineers who were available during the sessions were very helpful. When Mathew was asked about which parts of RALfie activities worked well for him, he commented that "*I think being in the room with the technology and seeing the different setup. Andrew explained things quite well and Alexander as well just the different components and how it all sort of works and the remote aspect of it all of that was interesting. So actually being in the lab room with the equipment and sort of hearing them sort of explain and describe the different components was quite helpful."*

Group work was engaging and helpful to build up his self-efficacy to learn technology. He stated that *"I think the hands on involved in it like practical activities and being guided through that sort of tutorial type of things is helpful for me. So having somebody that, and even working in a group, in the small group context like we did. Having some other students that maybe felt confident to do certain things and I could learn from that as well."* Group work provides opportunities for PSTs to interact with peers and experts in a social environment. Group work helped PSTs to share knowledge and learn from each other which was helpful to build up their self-efficacy to teach technology.

Instructional scaffolding was important to build up PSTs' capacity for teaching technology. Mathew stated that *"I thought that was good, I thought it linked in well. Obviously Scratch and Snap! are very compatible or it's the similar understanding. So what works in Scratch works in Snap! in terms of understanding, I think as I* *understand it. Understanding instructions and directions and that programming side of it. So they're quite aligned I didn't see many issues there. I think Peter was very positive about encouraging people to do RALfie and to get more experience and to try that and could see that it was beneficial for his students to have that experience. So I think it was a good match and I think it was compatible cooperation I thought it was good."*

Mathew felt comfortable with building LEGO but he was nervous about programming robotics. He stated that *"I am sort of a mixture of that would be fun and that's a bit daunting to be able to learn how to work with that technology wise. So not so much the working with LEGO and building, that's quite fun, I quite enjoy that but driving it from a computer and doing the programming side of it versus the building. I was probably more nervous about the programming, understanding that and how that communicates with what you build."* Mathew was very excited about building LEGO which was consistent with his learning background as a builder.

For the user activities, he needed experts on hand to provide scaffolding. Mathew stated that *"Well I guess the online attempts I did by myself and hit a problem so I gave up whereas in the maker events when we were working with groups and with experts there like Ananda and Alexander and Andrew, we could call on their assistance if we got stuck. So it helped us to progress even when we came to a challenge, whereas when I was doing it on my own I came to a challenge and gave up".* Mathew was in the lowest range of pre-post SE score from all participants. It was obvious that Mathew had a low self-efficacy for using RALfie. He also experienced some difficulties using online activities which caused anxiety and frustration and led to giving up on using them.

Even though Mathew felt frustrated using RALfie and was scared of using technology, he believed that RALfie is a good teaching technology. He also believed that good teachers will have a positive impact on students' performance and learning attitudes.

Mathew commented positively about the purpose of using LEGO for designing rather than playing with it as a toy. He stated that *"I guess it's enabling kids to see that even* *something that appears just like a toy that might occupy time it's actually something that can be constructed to achieve a purpose or yeah develop an understanding of the real world and how things can be translated from a toy, giving direction to a toy or a construction to something that could be used in a real world example or make those sort of connections between design and productivity I guess."* Playing is learning. Playing with robotics required skills such as programming skills and problem-solving skills.

RALfie used robotics to help students to develop their programming skills, coding skills and problem solving skills with an emphasis on science and technology. Mathew stated that "*Pendulum and the Gearbox, so all of that helps teach into Maths and Science. You've got your ratios and all that sort of thing, your length versus the momentum and those sorts of Science and Physic Mathematics subject areas. I guess you've got your Visual Literacy, so Literacy in terms of being able to read the program, the instructions and the directions and the way that Snap! or Scratch works to program. So that's a literacy thing I guess. So all of those, Science, Math, and English*" RALfie can be integrated into different learning subjects.

When he was asked whether his attitude and pre-perception of technology will have an impact on students' learning outcome, he firmly believed that teacher's attitudes have an impact on students' learning performance and students' learning attitudes. He stated that *"Yes I think, I think if I get in the situation where I'm working with kids and technology I need to be willing to let them just go with it because I think they will just try stuff, they won't panic about it. They'll relax and I need to be a bit more relaxed about it and just treat it as more let's have a go, let's see what happens rather than you've got to get it right and make sure you follow all these steps. Just let them sort of explore because they're used to"* He believed that teachers need to be open-minded and explorative rather than being panicked about the technology because students learn more when teachers are relaxed and adventurous. It is consistent with his relatively high pre-post OE score compared to his low SE. High OE score means that he believes that good teaching has a great impact on student learning outcomes.

In summary, Mathew had a very low self-efficacy to use RALfie. He struggled to use the online RALfie activites. He needed more technical support and instructions. He was scared of technology and he did not have any background in learning about technology in his primary and secondary schooling. However, he believed that RALfie is a good educational tool. His relatively high outcome expectancy shows that he believed that good teaching leads to students' good learning outcomes.

Case 2: No. 4 Ryan

Ryan was in his late 40s. He lived in a remote area in Australia where the internet constantly dropped out. He was very interested in science and mathematics when he was young. However, one of his school teachers told him that he was hopeless at science so he gave up on science. He was very rebellious in high school and he did not like the education system. He was scared of technology because there was no technology course in schools at that time. He had trouble using calculators in high school. He heard of computers later in high school but he never touched any computers and did not think computers would be important in the future when he was in high school. He was a chef by trade when he graduated from school. His wife was a primary school teacher. Ryan visited school and saw his wife teaching with children. He started to miss school and became determined to become a teacher to help children who had a difficult childhood. He was a highly motivated pre-service teacher.

Ryan was a user only. He spent 15 hours on the Gearbox activity and 3 hours on the Pendulum activity. His pre-post OE scores were 3.10 and 3.40, SE scores were 3.00 and 4.08, PA scores were 3.60 and 4.00, and NA scores were 3.50 and 2.30. There were themes identified from his interview.

Ryan is scared of technologies. Ryan stated that "*I'm forty eight. I am a little scared of technology especially digital technology".* The lack of past learning experiences with technology results in technology anxiety. It was also in line with the literature that many primary school teachers were anxious to teach technology because they did not learn much technology in their primary and secondary schools.

Ryan lacked educational background of technology in his primary and secondary schools. He stated that "*It wasn't even something that we discussed, in fact I don't even think we talked about technology until I was at university, I hadn't even thought about technology."* It was in line with the literature that many primary school teachers lacked technology learning in their education.

Ryan felt frustrated when the internet kept dropping out. He stated that *"I was frustrated with was the fact that my internet kept dropping out and therefore I couldn't get the answer".* Even though he was frustrated by the internet connection problems, he was very persistent to use the Gearbox activity for 15 hours. The cause of his frustration was the internet connection problem rather than the content of RALfie activities. Ryan stated that *"I'm a lot more confident now than what I ever was".* From his pre-post SE score (3.00-4.08), his self-efficacy increased the most among all the participants. It was obvious that the activities designed by the RALfie project were very positive for him which drove him to spend 18 hours despite the internet connection problems. In the future, he would like to set up RALfie for his students and give them assignments based on RALfie when he graduates from USQ.

When Ryan was asked about whether RALfie had any negative influence on his self-efficacy, he commented that *"Nothing there is not one thing in that RALfie that made me feel less confident about teaching technology or science, it – there was no – I had no negative from that at all – except for the fact that I had problem with – that was the only thing, if the internet connection hadn't dropped out there would be absolutely nothing negative that happened during that RALfie exercise."* It was important to provide reliable technology for PSTs to use as found in the pilot study. The ease of technology use had an influence on PSTs' emotional status which contributes to their self-efficacy.

The lecturer's scaffolding and teaching in the Technology Curriculum course helped PSTs to build up their self-efficacy. Ryan stated that *"It was the biggest eye opener that I've ever had it really was, it was absolutely sensational he would – I would rate it as probably the – the best or the second best course in the entire of education unit that I've been doing, so oh without a doubt it has opened my eyes absolutely to what* *people are capable of doing… what I've learnt and especially in that course that Peter had was just absolutely phenomenal."* The technology course that Ryan enrolled was eye opener for him. The course lecturer's teaching and scaffolding was phenomenal which also contributed to his big increase in his self-efficacy.

When Ryan was asked about further reasons for his improvement, he clarified that the RALfie project also contributed to his increased self-efficacy. He was very interested in the Gearbox activity because he could use the cameras to watch the gear moving in real time. He was very motivated to calculate the ratios and got them right. Ryan stated that *"it took my interest, it captivated me in so far as number one it was something that I could see and I very rarely got to have that camera setup so that we could go in and actually watch those gears moving around and then to try and calculate how far one cog had gone as opposed to how far another cog had gone, it just stimulated me to I really wanted to know that answer and I thought it was a really great resource to have."* Manipulation of physical equipment allowed PSTs to realise the experiments were real as opposed to simulations. The real equipment was stimulating

He enjoyed doing the calculation task which involved mathematical simulations. He stated that *"I guess because it's a visual thing that I was able to do in my own time, so there wasn't a particular time that I had to go on to have a look… I was pretty happy, so I thought there were three questions that were there. I ended up answering and I got all three correct on the very first go, so I was pretty happy with that. I guess also there's that mathematical stimulation as well, I'm stimulated by that mathematical side of looking at ratio."* The gearbox activity was associated with science, technology and mathematics which were engaging cognitively because it required high order thinking skills. He was happy with his achievement in Gearbox activities which were in line with his high pre-post PA. It was identified that Ryan demonstrated high engagement and enjoyment using the Gearbox activity.

The RALfie user activity allows PSTs to do it in their own time. PSTs have more control and autonomy over the learning process. Ryan made a comparison between face-to-face and online RALfie activities. He stated that *"when you're face to face and you make a mistake you sometimes you feel a bit silly a bit stupid…with the gearbox* *one was the fact that I could do it in my own time and I didn't having someone watching over my shoulder saying oh you should have done this or you could have done that, or what are you thinking now, or why aren't you doing this. But by doing online you're taking away that embarrassment you're allowing probably more risk taking*". Remote activities allowed participants to use experiments on their own time and at their own pace. RAL provided opportunities for participants to develop a sense of control and autonomy which was engaging.

Ryan commented that he had some control over the Gearbox activity. He stated that *"I guess it was fun, it was different, it was a technology that I had never come across before so I was interested in how it was going to work and knowing that I has some control over some factors there as well"*

Ryan commented on his motivation for spending 15 hours on the Gearbox activity. He stated that *"There was a drive there to actually go back and it doesn't matter how long it's going to take and what the difficulties that I'm going to have and yes those difficulties were mainly to do with the technology of my computer or how I was receiving the signal, but I had to know the answer I had – I had to find out and calculate the answer myself to be happy and I – it would have driven me nuts if I hadn't have been able to eventually work the answer out or even go into a point where I was able to give an answer. So whether I was right or wrong in the answer that – I guess I was just lucky in that I got the answer right the first time otherwise I can assure you if I had have – if I had have put those three answers down and they had have come back as incorrect, I can assure I would have gone back in and I would have taken another fifteen hours if necessary to go and get that right answer ... make sure I got the right answer. So yeah it as I said it's made a huge impact."* Calculation of ratios was engaging which required mathematics, science and technology skills. It required high order thinking skills which were engaging cognitively.

Turning on lights and using live cameras gave Ryan a sense of control which was engaging. Ryan stated that *"So that's what I enjoyed the most out of that I was able to turn on a light. As strange as it might sound to feel like I actually some sort of control over what I seeing and I was seeing it, because initially I don't think I realised that I* *was able to turn a light on and then somehow from my computer I was able to turn a light on and I thought that's incredible how have I been able to do that from my computer, so I was pretty impressed with that. And again that comes back to the technology thing the gearbox side of it might have only been one aspect just the fact that I could – and control the camera as to angles and that sort of – I just – I found it absolutely amazing I really did, I was just engrossed in it"*

Enactive successful experience with RALfie helped Ryan to build up his self-efficacy to use LEGO in his class. Ryan stated that *"I had nothing to do with LEGO in fact I very rarely even played with LEGO as a kid and now – now I would include a lot of LEGO in my – if I had depending on the age group of kids that I was working with, I think I would include a lot more LEGO. In saying that I would need to go out and do a lot more with LEGO myself, but I can understand now that they … of these sorts of things and the same with that – that Gearbox activity, I can now recognise the value of it."* Past successful experience was the most influential source of self-efficacy information. Ryan had some successful experience using LEGO in the RALfie project which was helpful to build up his self-efficacy to work with robotics in the future.

RALfie project and the technology course had a big impact on Ryan's self-efficacy in teaching technology. Ryan commented that *"I guess that fact that number one I got the answers right on the first go, so that always helps. Number two the fact that again I wasn't under any pressure, well I didn't have anybody there with me, nobody was sitting there in the background saying you should have done this, or you – have a look right there and you'll see the answer or whatever and knowing what can be done. Now I'm more at – as I said before I'm more likely to take a risk with using technology in my classroom when I eventually become a teacher. So it's made a huge impact, that RALfie was pretty big for me as far as that goes as well as Peter's class, but that course was just brilliant."* The successful experience with RALfie activities and the technology course were helpful to build up his self-efficacy by taking a risk of using technology.

RALfie experience made him feel more self-efficacious to learn technology. He stated that *"Well that I guess recognising the interest that I had – that I had before in* *technology as opposed to the interest that I now have in technology. Recognising that yep I will actually take the time to – take the time to actually learn more about technology, take the time to consider how I can implement technology in my – as resources in my teaching, in my lesson plan, in my unit plans all that sort of thing so yeah it's made a huge impact as far as that goes and in my own personal learning. It's actually made me stop now and look at things differently as opposed to I guess looking at anything these days and I just look at – and I start now to look at the technology involved in making certain things and what we can make and how we can stimulate the students into actually wanting – or feeling that they need to take the time to become involved and actually find their answers."* The RALfie project and the technology course had a significant influence on his self-efficacy. Ryan was more self-efficacious to teach technology which was consistent with his increased pre-post SE score (3.00-4.08).

In summary, Ryan enjoyed the RALfie online activites. He spent a significant amount of time using RALfie. One of the reasons was that the internet kept dropping out which caused frustration. The other reason was that the content of RALfie user activities was motivating for him. He was willing to use RAlfie in teaching technology in the future.

Case 3. No. 28 Sally

Sally was in her early 20s. She was in the final year of her preparation to be a primary school teacher. She loved science experiments since primary school because her science teacher was very positive and hands-on. She still kept her primary and high school science books and referred to them when she did some courses about science at USQ.

She was an online student and participated in the RALfie user activities, spending a total of 1.5 hours. The Pendulum activity did not work for her but the Gearbox activity did. She did not have any issues with log-in or internet connection problems with the Gear Box activity in Figure 18. She read the RALfie brochures, visited the RALfie website and watched RALfie Youtube videos. She was very interested in RALfie. She was confident about teaching Science and Technology. She learnt Scratch programming tools at USQ and she taught students how to use it in her teaching practice with children. She saw children using LEGO in her teaching practice. She was willing to use RALfie to teach technology in the future. She thought she could host an experiment herself for the class if she was provided with a RALfie kit. Her pre-post OE scores were 3.70 and 3.50, SE scores were 3.62 and 4.54, PA scores were 1.50 and .20, and NA scores were 1.70 and 1.20.

Sally had a very positive learning experience with science and technology when she was a child. Sally commented that *"When I moved to Queensland the teacher I had in Queensland he was very positive toward, especially science and things and trying to make it interesting and very hands-on and have all the forms whereas we didn't have to write a lot down. So it was okay so let's go and do this and then do this and everyone was able to have a go and be involved and we did a science experiment each week so that was something exciting to look forward to each week anyway."* It was consistent with the literature that her teacher's attitude and self-efficacy had a great impact on Sally's attitudes and beliefs.

Sally had a positive science learning experience in primary school which led her to continue to learn science at university. Sally stated that *"I know some science. I did a couple of science courses here as well– I was on campus for that one actually and that was good. They did some really good experiments and I've actually used those experiments as well that they did here at Uni and I think it was in 1st year the science course. So that was another good one as well".* Her past successful science learning experiences had a great impact on her self-efficacy for learning science at tertiary level.

Sally believed that her positive science learning experience during childhood helped her to become a confident teacher to teach science. She stated that *"I'm sure that really does just being confident in that area or having a good experience myself in that area especially with science in the classroom, quite positive to teach that one. So in that regard so I think it does I mean if I didn't have a very good experience with that when I was a child in the classroom I'm sure I wouldn't be as positive to yeah let's go and teach science."* Past successful experience was the most influential source of self-efficacy information. Sally's positive learning experience of science in primary school provided the most authentic evidence that she was capable of teaching science.

She used LEGO to teach in her teaching practice. Her past successful experience with LEGO built up her self-efficacy to use RALfie. She stated that *"I've had a positive use with it in the classroom and things like when kids have been really excited to use it so it gives you I guess more of a positive outlook toward it."* Her successful past experience with LEGO in the classroom helped her to be self-efficacious to use RALfie.

When Sally was questioned about whether playing with RALfie was learning or not, she firmly believed that playing with LEGO was a learning process. Sally stated that *"I think they are definitely learning to do it themselves as well because they did ask questions like oh why that makes it do that. I think there was one they did, there was a rubber band and they had it on the back and they twisted it up I think and the thing went, and they were asking oh why does it do that and things like that. So they were not just playing they were actually obviously interested in what they were making and why what they made could do that. So I don't think it's just a case of playing I think it's, they're learning through what they're creating."* Her past experience in classrooms helped her to understand how RALfie contributes to learning through creating.

Sally had seen LEGO kits when she was in her teaching practice placements. Sally stated that *"I'd actually seen that before on a previous prac that they used the little LEGO kits in the classroom and the kids, you know if they chose something to make and then they'd make it and then they'd pull it all apart and choose something else and make that again"* Vicarious experience was helpful to build up her self-efficacy to teach Technology. She further explained that *"it could've been 2 to 3 times I've seen LEGO being used and it was sort of a thing like oh I want to go too."* Her vicarious experience was one of her motivations to use RALfie. People compare themselves to particular associates in similar situations, such as colleagues, classmates, competitors, or people in other settings engaged in similar endeavours. Efficacy appraisals were partly influenced by vicarious experiences mediated through modelling. Modelled attainments served as another effective tool for promoting a sense of self-efficacy (Bandura, 1997).

Sally had a positive experience going through RALfie brochures, RALfie websites, and YouTube Videos. She commented that *"Advertised it at the start on the brochure…I found it quite easy to get around and click on different things and have a look and the instructions…It wasn't a just a there you go, go make what you want there was actually activities where, I think there was a couple of activities where you made a game and they gave you step by step how to make a game and then there was a challenge. Okay now you go and use all that knowledge you've built on and all the instructions you've used and now create your own games... I found getting through the different activities and quests wasn't too bad and your website as well"* Brochures, websites and were used to scaffold PSTs' learning with RALfie. The scaffolding helped learners to build on their prior knowledge and internalize new knowledge. Instructional scaffolding and social scaffolding provided by the RALfie project helped PSTs to construct knowledge in a social online environment.

Sally commented on the cooperation between the course lecturer and the RALfie team. Sally stated that *"I think that was done really well especially with the quests and it was really easy to access from the course, the main course page there and encouraged to have a go and he was always available if you had any questions to ask about the scratch or the different activities that you had to do."* The course Lecturer's scaffolding was very important to engage PSTs to use RALfie. Teachers' scaffolding was very important for PSTs to build their knowledge and achieve a higher level of ZPD.

Sally preferred participating hands-on with RALfie because the hands-on activities were concrete and playful. She explained that *"Just being able to touch it and feel it and play with it would be a bit easier… make connections…whereas I'm watching it online. Sometimes you've got to watch something a couple of times online to fully grasp what is being done or what is being said whereas just being, doing it yourself you're getting it better in your head. I find for myself anyway."* Hands-on learning is much easier compared to abstract remote activities and better suited for PSTs' ZPD because they were at the beginning level of learning robotics. However, she did appreciate the online option which gave online students opportunities to have a go.

When Sally was asked whether using RALfie had an impact on her teaching philosophy, she thought RALfie changed her teaching philosophy. Previously she did not think of using the online activity. After experience with RALfie, she would like to combine the face-to-face activity with remote RALfie activities to teach children with LEGO. She stated that *"Yes so in the past I probably would not have used, especially that online program. I would never have really thought to use that if that makes any sense. To go, especially if you're in some schools and you don't have all the materials to do it as a hands-on there is always that option to look at it online and get the students to do the activities online and have a go using it that way then they're not per se missing out on something… combine the two together in the classroom I think could be an idea anyway."* She would like to make a variety of activities for students to use RALfie. Remote access activities need to start with hands-on experiences which make it easier for beginners to grasp the meaning and construct new knowledge based on hands-on experiences.

In summary, Sally had a very positive experience with RALfie. Her background learning of science since primary school made her feel interested and excited to learn science at university. Her successful experience of using LEGO to teach in her teaching practice built up her self-efficacy to use online RALfie activities. It is consistent with the literature that past successful experience provided the most authentic evidence of whether she could master whatever it takes to succeed (Bandura, 1997). Sally's past enactive mastery experience built up her self-efficacy to use robotics.

Case 4: No.20 Anissa

Anissa was in her early 20s. She was in the final year of her preparation to be a primary school teacher. She participated in both maker events in March and May and the user activities. She had a positive experience with the maker events, spending a total of 3 hours across the two maker events. She experienced some difficulties with operation of the online user activities at both university and home and spent just 20 minutes attempting the user activities. Her pre-post scores for OE were 3.40 and 3.70, SE scores were 3.38 and 3.62, PA scores were 2.4 and 2.9 and NA scores were 1.402.00.

When Anissa was asked why she was scared of learning Science and Technology, she commented that "*I just never have liked it at school. Like the perception was ruined for me I think – like the way they taught it and what was expected and stuff.*" Anissa did not enjoy learning Science and Technology when she was in primary school. It was consistent with her SE score that it was low and did not change much in pre-post T-TEBI. However, her OE score was improved after experience with RALfie. She was becoming more firm in the belief that effective teachers can have a positive impact on students' achievement. But her belief about her ability to teach Science and Technology was still low.

Anissa did not learn much Science at primary school which made it hard for her to continue to learn Science at high school. "*Well for primary school we hardly did any science so when I got to high school it was like you should have had all this knowledge which I didn't have because at my school science wasn't a big deal. It was like the other subjects that we really focussed on so that's probably why we didn't like it because I didn't know enough about it when I got to high school and it was a big deal.*" Her lack of Science learning experience in primary school made it difficult to learn science in high school. It was consistent with the literature which suggests that many teachers did not have much Science and Technology learning in primary school which caused Science and Technology anxiety in high school and at tertiary level.

Anissa further commented on the preconception that she had related to science learning. Anissa stated that "*I think there is a perception at school. Like science is like the smart subjects and like you can't do them at school – you're not going to be able to do them at uni. It's really formed – like it's a society forming thing I think*." She had a negative pre-perception of science learning which was formed by society for a long time which was hard to change.

Anissa commented on her increased confidence as a science and technology teacher and stated that "*It's developing as I go further through my degree. If you'd asked me at the beginning I would have been scared to teach science and technology but now I'm getting more confident like knowing things. I'm not a science or technology person. I never did them at school*". Anissa was scared and anxious to teach science and technology which meant that she started with a low self-efficacy. It was consistent with her low pre-post PA and high pre-post NA result.

When Anissa was asked about her motivation to participate in RALfie, she stated that "*I've heard of Robogals so I kind of knew it was something to do with that and I have friends involved with that so I was trying to get more – like see what it was about.*" Robogals (http://toowoomba.robogals.org.au/) is an international robotics organization with a branch at USQ. Robogals use LEGO Mindstorms to program robotics and teach them at local primary and secondary schools. Vicarious experience is important to increase PSTs' self-efficacy by seeing peers achieve something successfully (Bandura, 1997). When Anissa knew that her friends did Robogals which was related to robotics, she thought that she could do robotics as well. It is in line with self-efficacy theory that past successful experiences were the most powerful source of self-efficacy information. It was also evident that her level of self-efficacy with robotics increased due to her experiences working with RALfie.

Anissa commented on her successful learning experience with Robot Soccer activities in Figure 17. Anissa stated *"that I can do it; that I shouldn't be afraid of technology as much as I am. Like the making of it wasn't hard and once you got Scratch down – like it was quite easy. And seeing it actually working on the carpet – I did that – it works and I know why because I did it properly."* Successful experience helped Anissa to be positive toward technology which was important to build up her self-efficacy.

Before the involvement with RALfie, Anissa was not confident to join in Robogals due to her lack of science and technology background. She was confident to teach but not confident to use robotics technology. However, after the RALfie experience, she was more likely to join in Robogals and teach robotics. Anissa stated that "*I have been asked to join Robogals a couple of times but I didn't think I would be confident enough* *to do it…but probably now I would be like oh yeah maybe. Because from the RALfie like seeing it's not as hard as I thought it would be I think was my preconceptions that it was going to be really difficult but it wasn't so*." The successful experience with RALfie helped Anissa to build up her self-efficacy to try new technology which is in line with enacting successful experience as one source of self-efficacy information (Bandura, 1997).

Anissa liked the maker event "*Because I was engaged – like I had stuff to play with*." Hands-on experiences provide a sense of playfulness which was helpful to alleviate the sense of anxiety and frustration of using robotics. Maker activities are engaging as PSTs can tinker, play, and build things. Anissa commented that "*the making one was more engaging – like seeing the whole process from start to finish. It was really important instead of just programming it. You were committed to your robot. Like you wanted it to succeed because you have that personal connection of making it.*" Hands-on experiences were concrete and engaging and suitable for PSTs who were at the beginning level of learning robotics. Programming a robot helped PSTs to control it and develop a sense of agency. Maker activities were helpful to build up PSTs' self-efficacy to make and use a programmable robot.

Anissa was more positive and willing to try new technologies after the experience of the RALfie Maker Event. Anissa stated that *"Probably anything is possible. Like you don't have to be scared of it because it is like doable like it is attainable if you set your mind to it. Like if you go in with the attitude that oh I don't know what to do you probably won't achieve in it so you have go in with an open mind."* A positive attitude is important for people to learn new technology. An open mind helps people to change their pre-perception and to explore different possibilities. Her increased pre-post PA score represented that she felt more positive after the experience of RALfie. She enjoyed and was engaged when working with RALfie.

RALfie made Anissa more open to new technologies. She stated that "*It's probably made my teaching philosophy more open to new ideas. Like not just the concrete ideas that I've had formed for a while. Like open to new experiences.*" It was consistent with her increased pre-post PA score that she felt more positive towards using RAlfie.

Anissa enjoyed the freedom that RALfie provided and stated "*probably the freedom of just do whatever you want – like program your robot and yeah I think the freedom because we are adult learners, not having restrictions on what we're doing that was nice.*" It was consistent with her improved pre-post PA score that she enjoyed working with RALfie.

Remote control is engaging. Being able to do something locally and make something happen far away is engaging. Anissa commented that "*I think probably the fact that you are so far away from the actual activity and it is still working. I think that gives a sense of awe. I can see with students that would really engage them knowing that if I click this it's going to move but it's nowhere near me but gives it a sense of fun.*" Remote control was fun and engaging.

User activities associated mathematical calculations with technology which was engaging. Anissa commented on the Gearbox activities and stated that "*Because you had to think – like the maths side of it comes into it as well. Like thinking about the degrees and if I turn that one then that one's going to turn that far and then it's going to go opposite and thinking about all the different aspects that come together just to turn one little thing was really interesting.*" High order thinking skills were involved which was engaging cognitively.

For the user activities, Anissa gave up when the RALfie system did not work. Anissa stated that "*It wasn't working and there was a glitch with the computer so it wasn't working so I gave up pretty easily*." It was in line with her increased pre-post NA score that she had experienced anxiety while working with RALfie. The ease and reliability of technology was important to PSTs. She liked the Maker Event, she liked it "*Because I was engaged – like I had stuff to play with*." Hands-on experiences provided a sense of playfulness which was helpful to alleviate the sense of anxiety and frustration of using robotics. It was also in line with the RALfie project's concept that *f* stands for 'fun'. Compared to remote activities, hands-on activities were more powerful to influence PSTs' emotional status as one source of self-efficacy information.

The lecturer's persuasion was important for engaging PSTs to try RALfie. Anissa commented on "*He really wanted us to learn Scratch and do the activities. Like there was always time set out to do it so we had the opportunity. If we couldn't do it at home we could always do it in class. Like he was always very encouraging that we at least try to do it even if we couldn't – like give it the time; give it a chance.*" Verbal persuasion is one source of self-efficacy information to help people to improve their self-efficacy.

The course lecturer taught PSTs how to use Scratch to program things which helped them to use Snap! which was a more difficult programming tool. "*I think if you didn't have a knowledge of Scratch and you were told to program something you would fail. Like just the little knowledge of Scratch that I had at the first Maker event – it helped immensely…Like being able to play with it beforehand and see what they all do really helped.*" The course lecturer's scaffolding was helpful to engage PSTs to try something new. Scaffolding was important for PSTs to achieve a higher level of ZPD which helped them to build up their self-efficacy to use robotics. Playing and tinkering with hands-on equipment was important for PSTs who were at the beginning level of using robotics. Moving from concrete maker activities to abstract user activities was in line with Piaget's learning stages theory (Piaget, 1974).

When Anissa was asked about whether teachers' attitudes have impact on students' learning. She stated that *"If you have a positive attitude what you're teaching, it's going to reflect on the class but if you go in and go ugh we're doing technology – they will have that perception with them and they will be like ugh we're doing technology. So you need to be positive about what you teach. It's all like – they can read you kids – they know what you're thinking."* After the RAlfie Maker Event, Anissa was more positive and she also believed that teachers' attitudes have a great influence on students' learning outcomes. It was in line with outcome expectancy (OE) as one element of self-efficacy. It is also consistent with Anissa's improvement for her pre-post OE score.

In summary, Anissa was scared of technology because she lacked relevant learning background. Her anxiety level increased when the online activities did not work. She had a positive experience with hands-on activities. Her self-efficacy increased because she was more willing to participate in Robogals. Successful experience with hands-on RALfie activities built up her self-efficacy to use robotics.

5.2.4.2 Cross-case Comparison

From the cross-case analysis, there were similarities and differences among these four PSTs.

PSTs' background of learning science and technology has a significant impact on their self-efficacy for teaching Science and Technology. Anissa, Mathew and Ryan did not have much science background. They all felt scared of technology. However, Sally had a very positive learning experience of science since primary school. She was very positive and confident to teach Science and Technology.

Past successful experience is the most authentic and effective source of self-efficacy information. Sally saw children engaged with LEGO in teaching practice which gave her a positive outlook to use RALfie. After the RALfie experience, Anissa was more willing and more confident to join the Robogals. It is in line with the literature that the past successful experience was the most powerful sources of self-efficacy information.

Vicarious experience and verbal persuasion were sources of self-efficacy information. Group work was helpful for PSTs to learn from each other, share knowledge and solve problems. Hands-on activities allowed group work where PSTs could construct knowledge in a social environment. Hands-on activities allowed PSTs to interact with professional engineers which was engaging. Scaffolding was important to build up PSTs' self-efficacy. The course lecturer persuaded his PSTs to try RALfie and he also put aside time in class to use RALfie. If students had some questions about RALfie, he was always available to answer questions. His administrative scaffolding was important to engage PSTs to try RALfie. Importantly, professional engineers' demonstration and enthusiasm was very engaging in the maker event. Interactions with experts were important because they provided vicarious experience. Dealing with PSTs who were scared of technology, lecturers' attitudes and self-efficacy to improve PSTs' self-efficacy was very important and powerful. Lecturers' persuasion and demonstration and availability were very important to students. Lecturers' strong self-efficacy had a positive impact on PSTs' self-efficacy which was similar to how teachers' SE affect students' learning in their classrooms.

PSTs' emotional status is one source of self-efficacy information. The striking theme for this researcher was the frustration and anxiety during PSTs' use of RALfie. For user activities, the dropping out of internet connections and the difficulty of navigation led to high NA. Mathew, Ryan and Anissa had internet connection issues which resulted in frustration and anxiety. It was important to provide reliable technology. The difficulties with internet connections caused anxiety which caused high NA. However, people with different levels of self-efficacy reacted to the frustration differently. Mathew's pre-post SE score was the lowest among 41 PSTs. As soon as he encountered technical problems, he gave up easily. However, Ryan experienced constant internet connection problems he persisted for 18 hours to use RALfie. His SE score was in the middle range and was improved after the RALfie experience. People who demonstrated persistence and resilience to obstacles were more self-efficacious (Bandura, 1977).

Hands-on activities were more powerful than remote activities for beginners. Hands-on activities were concrete and easier, which made them more suitable for PSTs' ZPD. Hands-on activities were playful which was helpful to ease anxiety for beginners. Hands-on activities provided all four sources of self-efficacy information. The integration of successful experiences of using RALfie, vicarious experiences provided by group work, verbal persuasion provided by experts and peers, and emotional status were more powerful than one or two sources of self-efficacy information.

Outcome expectancy and self-efficacy are two subscales of self-efficacy which are different and separate. Mathew demonstrated very low SE because he was scared of technology and feel frustrated to use robotics. However, he believed that RALfie was a good teaching tool for children. He also believed that good teaching results in good student learning outcomes.

RALfie activities provided multiple levels of engagement for PSTs. The maker activities allowed PSTS to be on task by tinkering, building and constructing experiments using LEGO. For the user activities, PSTs were able to manipulate the cameras and turn on lights. Moreover, The Gearbox activity and the Pendulum activity integrated scientific, mathematical and technological simulations which required high-order thinking skills for problem solving and improving understanding. The user activities were engaging cognitively because they were abstract and difficult. The hands-on activities were playful and enjoyable which made them engaging emotionally. The hands-on activities were concrete and easier compared to abstract online activities. The hands-on activities were more suitable to the PSTs who were at the beginning level of robotics. The user activities were fun and interesting. Ryan was engaged by the remote control as he manipulated the lights and live cameras. Sally enjoyed the RALfie resources such as brochures, websites and videos.

5.3 Summary of Chapter 5

This chapter analysed quantitative and qualitative data from the main study. Mann-Whitney U Test was used to analyse pre-post quantitative data which did not generate much information. A thematic approach was used to analyse interview data. Themes emerged from major interview data analysis were very similar to those from the pilot data analysis. Case study was adopted to analyse individual's changes of self-efficacy. T-TEBI and PANAS analysis was used to identify the outliers who were selected as participants for case study. Cross case comparison was used to analyse the differences and similarities among cases.

From the case studies, PSTs' frustration and anxiety with using RALfie emerged strikingly and needed to be further explored. PANAS was used to analyse PSTs' emotional status which was mixed with PSTs' comment analysis. PSTs' overall comments about the RALfie experience were analysed to find out how to support PSTs in using RALfie.

Chapter 6 will present the conclusion for this research. It will answer the research questions, and elaborate on the contributions to theory, methodology and practice. Limitations and recommendations for future research will be presented.

Chapter 6: Conclusion

6.1 Introduction

Chapter 6 will address the research questions. Results presented in Chapters 4 and 5 will be used as evidence to support answers to the research questions. The chapter will then elaborate contributions to theory, methodology and practice before discussing limitations and recommendations for future research. Finally, it will draw conclusions from the study.

The main research question was:

- In what ways does engagement with Remote Access Laboratories influence pre-service teachers' self-efficacy to teach technology?

The sub-questions were:

- How has the RAL experience influenced pre-service teachers' self-efficacy to teach technology?
- How can the RAL experience can be improved in the future?

By answering the two sub-questions, the overarching research question is answered without repetition. This research will use the conceptual framework to answer the two sub-questions. Figure 25 below represents the conceptual framework developed in Chapter 2.

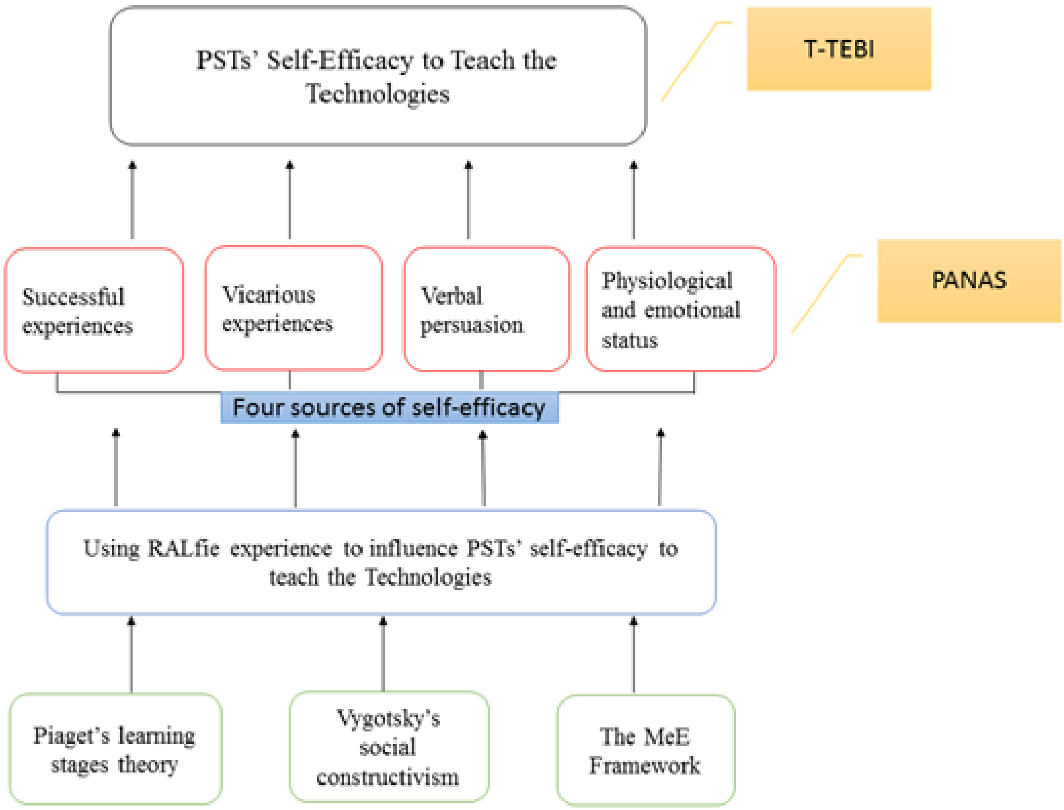

Figure 25: The Theoretical Framework

6.2 Answering the Research Questions

How has the RAL experience influenced pre-service teachers' self-efficacy to teach technology?

This research question suggests two main parts in the answer, what difference has it made, if any and how did it make that difference. The quantitative results will be presented first to address the difference it made. Qualitative results will be presented to address how RAL experience made that difference.

The match paired pre-post T-TEBI data were used to analyse the changes in individual's self-efficacy before and after the RALfie treatment. Mann-Whitney U test was used to analyse the individual's changes of self-efficacy. Because of the small sample pool (N=41) and limited exposure to RALfie experience, the statistical result were inconclusive. The quantitative result did not generate much information about individual's self-efficacy. Therefore, qualitative data were used.

From qualitative analysis, four sources of self-efficacy were identified from themes regarding to how RAL made a difference. Enactive mastery experiences are the most influential source of self-efficacy information because they provide the most authentic evidence of whether one can persist with what it takes to succeed (Bandura, 1997). Successful experiences of using RAL were essential to enhancing PSTs' self-efficacy to teach technology. Before her participation in the RALfie experiences Anissa was not confident to join the Robogals due to her limited technology background. After working with RALfie, Anissa developed a more positive attitude toward technology and felt confident to join in Robogals. It is in line with the enactive mastery experience that successful experience made Anissa more self-efficacious to use robotics. To build up PSTs' self-efficacy to teach the Technologies, it is important to provide successful experience.

Successes build a robust belief in one's self-efficacy whereas failure undermines efficacy, especially if failures occur before a sense of efficacy is firmly established. Mathew had the lowest pre and post SE score (2.38-2.38) among all cases in Figure 20. As soon as he hit a technical problem, he gave up using the online RALfie activity. The unsuccessful experiences of using RALfie undermined his self-efficacy when it was vulnerable. He felt frustrated and anxious about using RALfie which can be evidenced from his high pre-post NA score (3.30-2.80) in Figure 24. Frustration and anxiety were categorized to negative emotional status as one source of self-efficacy information (Bandura, 1997). Mathew also felt very scared to teach Science and Technology because he did not have much prior successful relevant learning experience. To build up PSTs' self-efficacy, it is important to provide reliable online activities. The online technical support and scaffolding is important.

Vicarious experiences influenced people's efficacy beliefs. Modeling has been used as another effective tool for promoting a sense of efficacy (Bandura, 1997). People compare themselves to counterparts in similar situations, such as work colleagues, classmates and competitors. RALfie offers face-to-face and online social interactions which allowed PSTs to construct experiments in a group and interact with peers. Mathew stated that "*I think the hands on involved in it like practical activities and being guided through that sort of tutorial type of things is helpful for me. So having somebody that, and even working in a group, in the small group context like we did. Having some other students that maybe felt confident to do certain things and I could learn from that as well*." Social interactions with peers were helpful for students to learn from each other. Group work with peers and scaffolding offered by professional engineers was important to build up PSTs' self-efficacy to teach the Technologies.

Social persuasion was used as a further means of strengthening people's self-efficacy that they possess the capacity to achieve their goal. It was easier to promote a sense of efficacy if significant others expressed faith in one's capacities than if they convey doubts, especially when people are struggling with adversities (Bandura, 1997). Social feedback is valuable to create increases in self-efficacy if the positive appraisal is within realistic bounds. The more the persuasive feedback raised people's self-efficacy, the more persistent they were in their efforts and the higher the level of competence they eventually sustained. Anissa stated that "*He really wanted us to learn Scratch and do the activities. Like he was always very encouraging that we at least try to do it even if we couldn't – like give it the time; give it a chance*." The course lecturer's positive feedback and persuasion were important to raise PSTs' self-efficacy to use RALfie. Social persuasion conveys faith, trust and encouragement which were positive and powerful to promote people's self-efficacy that they possess the competence to achieve what they want to pursuit. Therefore, social persuasions offered by the RALfie project were important to build up PSTs' self-efficacy to teach the Technologies curriculum.

The fourth major way of promoting self-efficacy is to enhance physical status, reduce stress levels and negative emotional inclination, and correct misinterpretations of bodily states (Bandura, 1997). The effect of affective states has been recognized for its influence on self-efficacy in diverse spheres of functioning. Anissa had experienced a great deal of stress and frustration when encountering technical problems using online RALfie which can be identified from her pre-post NA score (1.40-2.00) in Figure 24. On the contrary, Sally did not meet any technical problem when she used online RALfie. Sally's pre-post PA increased (1.50-3.20) and NA (1.70-1.20) dropped which echoed with her increased pre-post SE score (3.62-4.54). It was important to reduce stress levels and increase positive emotional reaction.

How can the RAL experience be improved in the future?

The qualitative evidence showed that hands-on experiments were more powerful than online experiments. Hands-on experiments were concrete which involved playing and tinkering. Anissa and Mathew, who were at the beginning level of robotics, stated that playing and tinkering with concrete LEGO equipment was engaging for them. Anissa preferred maker activity rather than the user activity because "*I was engaged – like I had stuff to play with*." Learning by making, tinkering and inventing were in line with Piagetian Theory because hands-on activities are concrete (Martinez & Stager, 2013). Learning started with concrete learning and proceeded to more abstract learning which was in line with people's learning stages (Piaget, 1973). A sense of playfulness is helpful to ease the anxiety of learning a new technology. By playing with concrete LEGO equipment, PSTs built real experiments which were engaging. In order to make RAL more effective in the future, RAL experience should incorporate hands-on experience.

User activities were more abstract activities which encouraged a high level of cognitive engagement because they stimulated thinking. Mathew commented on the online Gearbox activity and stated that "[I learnt that] *things aren't always as simple as you think. Even the whole variance in cog size and that one cog turning clockwise turns the other anti-clockwise and how that then impacts on the next. So that you're sort of thinking through size comparison as well as which direction it's going to turn and so where's it going to put – so thinking through those things was quite good*". In order to make RAL more effective in the future, RAL experience should integrate STEM concepts as a holistic approach to stimulate high-order thinking.

The combination of user and maker activities allowed multi-level engagement which was a powerful way to build up PSTs' self-efficacy. Hands-on experiences allowed

PSTs to construct experiments, connect experiments to cameras and computers, and test the RALfie system. Maker events provided behavioural engagement because PSTs used LEGO kits to build experiments. Playing and tinkering with the LEGO materials made PSTs feel interested, excited and at ease which allowed emotional engagement. The effect of multi-level of engagement is in line with the MeE Framework (Munns & Martin, 2005). It was valuable to provide both user and maker activities for PSTs to increase their self-efficacy. In order to make RAL experience more effective in the future, it is of great value to start with hands-on activities and move to online activities.

It was important to make the online experiments reliable and user friendly. The ease of using technology was significant and had a large effect on PSTs' self-efficacy in using them. The internet connection problems and difficulties in navigating the interface caused frustration and anxiety in using the online RALfie activities. Anissa's self-efficacy for using online RALfie was vulnerable. Anissa stated that "*It wasn't working and there was a glitch with the computer. It wasn't working so I gave up pretty easily*." As soon as she hit some technical difficulties, she gave up very easily. Consequently, she felt anxious and her post NA score was higher than pre probably because of her experience. It was significant to make the online technology reliable and stable, which was very helpful to alleviate PSTs' anxiety to use remote experiments. Therefore, in order to make RAL experience more effective, it is important to make online systems reliable to reduce participants' frustration and anxiety.

Technical scaffolding is invaluable. PSTs feel self-efficacious about their pedagogical and curriculum knowledge but they feel frustrated about their technical knowledge. PSTs were in great need of technical support because RALfie was their first experience interacting with robotics. They did not have much prior knowledge and background experience of using LEGO robotics. Technical scaffolding from professional engineers was very important for the PSTs. Mathew commented that "*Andrew explained things quite well and Alexander as well just the different components and how it all sort of works and the remote aspect of it all of that was interesting. So actually being in the lab room with the equipment and sort of hearing them sort of explain and describe the different components was quite helpful.*" Technical scaffolding is of great significance to help PSTs to build up their confidence and competence to teach technologies. In order to make RAL experience more effective, it is important to provide technical scaffolding to support PSTs.

Resources were of great importance to improve PSTs' self-efficacy to use the RALfie system. Engineering experts provided YouTube videos, brochures and LEGO kits for PSTs which were good resources. It was noted that Sally, an online user had benefited and gained self-efficacy from online resources. Therefore, in order to make RAL experience more effective, it is valuable to provide more resources.

Group work with peers and social interaction with professional engineers were helpful to raise PSTs' self-efficacy. Maker events provided face-to-face opportunities for PSTs to interact with engineering staff who are the experts in remote access labs. Social interaction with experts and more competent peers helped to develop the next potential level because PSTs could work within their ZPD (Vygotsky, 1978). Mathew stated that "*I think the hands on involved in it like practical activities and being guided through that sort of tutorial type of things is helpful for me. So having somebody that, and even working in a group, in the small group context like we did. Having some other students that maybe felt confident to do certain things and I could learn from that as well.*" Group work allows PSTs to interact with peers which helped PSTs to build up their capacity to solve problems. RALfie provided flexibility for PSTs to ask questions and interact with others in different modes. Interactions with professional engineers helped PSTs to gain technical scaffolding which helped students to build up their capacity and confidence to use RALfie. In order to make RAL more effective, it is important to provide social interaction which can enhance PSTs' self-efficacy.

Positive attitudes and positive emotional states towards technology were important to build up PST's self-efficacy. Positive attitude is very important for PSTs who are going to teach technology in their classrooms. Positive attitude results in positive behaviours and good performance. When people use technologies, it is important to be aware that technologies are changing and risky. People need to develop a positive attitude to be confident to engage in trial and error and learn from mistakes and move forward. Increasing the positive affect was important for PSTs to feel more positive and more engaged with RALfie. Decreasing the negative affect was important for PSTs to feel less anxious and less stressed to work with RALfie. Positive emotional states were helpful to improve people's performance and to increase their self-efficacy. In order to make RAL more effective, it is important to foster positive attitudes and positive affective engagement.

PSTs who had engineering background had more positive responses to the programming activity whereas PSTs who did not have engineering background preferred the hands-on activity rather than programming activity. PSTs' background knowledge and experience has an impact on their self-efficacy for using the abstract programming system. In order to build up PSTs' self-efficacy there would be benefit in seeking to include a wider range of activities in which they could gain positive experiences of working with STEM.

Interview data also indicated that the lecturer's explicit instructions helped PSTs to understand the RALfie concepts. That will have contributed to increased confidence for working with the RALfie activities and is consistent with the third source of self-efficacy information, verbal persuasion (Bandura, 1997). There would be value in offering PSTs additional instruction relevant to RALfie and other technologies activities as a means of enhancing their self-efficacy for engaging with STEM subjects as learners and teachers.

6.3 Contribution

6.3.1 Contribution to Theory

The theoretical framework for this thesis was developed and constructed drawing on self-efficacy theory in *Figure 25*. It provided a theoretical basis to analyse the impact of the RALfie project on PSTs' self-efficacy. The four sources of self-efficacy information were used to guide RALfie experiences to improve PSTs' self-efficacy.

Four sources of self-efficacy information were more powerful than a single source of self-efficacy information. Hands-on maker events offered successful experience, vicarious experience, verbal persuasion and positive emotional status. It was beneficial to have multiple sources of self-efficacy for PSTs who lacked robotics background and were scared of technology. Maker events provided social interactions with experts and peers which offered successful experience, vicarious experience and verbal persuasion.

6.3.2 Contribution to Methodology

Mixed methods were used to collect and analyse both quantitative and qualitative data to investigate changes in self-efficacy. Quantitative research methods have been the dominant method for studies of self-efficacy. Mixed methods were used in this research which allowed rich and nuanced data to emerge. It was important to understand the value of self-efficacy though the lens of PSTs as they were the agents of change. Interviews allowed PSTs to talk about their background, prior knowledge, their voice, and their attitudes which were valuable for this research to understand changes in their self-efficacy and beliefs.

T-TEBI was modified from STEBI (Enochs & Riggs, 1990) which is a methodological contribution to knowledge. Cronbach's Alpha tested the reliability of T-TEBI based on pre-test data analysis. The outcome expectancy subscale consisted of 10 items (α=0.697, N=119). The self-efficacy subscale consisted of 12 items (α=0.880, N=119). T-TEBI is a useful instrument for others.

6.3.3 Contribution to Practice

This research contributed to the RALfie project by allowing PSTs to access RAL experiments. The RAL experiment was helpful for PSTs to learn about robotics. By playing and tinkering with the LEGO kits, PSTs had a hands-on experience to build experiments and connect their experiment to the system and program the LEGO EV3.

The scaffolding provided by professional engineers was important to motivate and engage PSTs to use RALfie. The professional engineers were able to provide technical scaffolding which was helpful to alleviate PSTs' anxiety and to improve their emotional status. Lecturers who taught Technology Curriculum with PSTs were important to encourage and persuade PSTs to use RALfie. The lecturer also built the

RALfie online experiment into his course and made some tasks for PSTs to learn which was helpful to engage PSTs to use RALfie.

Online activities were helpful for PSTs to have remote experiences which were valuable to improve PSTs' computational thinking and high order thinking skills. The RALfie project provides ready-made experiments for PSTs to use which save time. RALfie helped PSTs to broaden their understanding of the Australian Curriculum: Technologies.

6.3.4 Contribution to Personal Self-efficacy

After three years studying of self-efficacy theory, I think my self-efficacy increased much more. I firmly believe that I can complete my PhD study and I want to be a researcher to further explore self-efficacy theory. I gained some successful experience from using different theories and various approaches to tackle research questions. When there were tough times in my study, I tried my best to be positive and heathy. I met my supervisors more often on a regular weekly basis. I joined the research meeting group and doctor chat at USQ where I could learn from my peers. I met my mentors once a month which also helped me to learn from them. Supervisors, mentors, colleagues offered various experiences and verbal encouragement to me which was helpful. This research helped me to be a stronger person.

6.4 Limitations of This Research

A major limitation in the study was the small number of participants who participated in the RALfie activities and responded to both pre-test and post-test questionnaires. The low response rate reduced the potential power of the statistical analysis and required the use of non-parametric tests rather than the more conventional t-test. Hence the results of tests for pre-post differences in self-efficacy did not reach statistical significance. Additionally, the sample size for case study was quite small. The results discussed cannot be generalised to represent the PSTs in Australia. However, the case study shed light on how PSTs feel supported and encouraged through scaffolding in the maker and user activities.

Participants were limited to a short exposure to RALfie experiences. PSTs spent 4 hours on two sessions of hands-on activities and a few hours on online activities. Limited exposure to RALfie activities limited the potential for related changes in self-efficacy and contributed to the difficulty in detecting statistically significant differences.

Even at the time of the main study, the RALfie system was a prototype which was not stable and easy to navigate. When PSTs used the online system, there were many problems such as internet connection issues, frozen screens, and interruptions such as the detached ball on the pendulum. The technical difficulties and barriers caused PSTs' frustration and anxiety about using RALfie.

The T-TEBI instrument is confined to technology teaching efficacy belief which did not directly reflect their learning of RALfie skills. Technology is a broad term which may or may not be informed by RALfie. Self-efficacy is a specific construct (Bandura, 1997). It is important to understand PSTs' self-efficacy to construct an experiment, connect the experiment to a server to test networks, program the interface, and remote control the experiment. PSTs' self-efficacy for using RALfie should be directly and specifically linked to RALfie key skills. However, the T-TEBI instrument alone is not good enough to show the whole picture of PSTs' self-efficacy. Therefore, it is important to expand and enrich the T-TEBI instrument by adding specific RAL-related questions such as "I will be able to control an experiment remotely".

6.5 Recommendations for Future Research

It is recommended to explore the remote makers which is in line with the intent of RALfie. It can be identified from pilot and major data themes that hands-on learning is important. To start with hands-on experiences is consistent with PST's ZPD because they lack background knowledge of using RALfie (Vygotsky, 1978). Moving from concrete hands-on experience to more abstract online experience is in line with Piaget's learning stages (Piaget, 1973).

The cooperation between educators and engineers was important to impact on PSTs' self-efficacy. Professional engineers provided technical scaffolding which was of great significance to engage PSTs. For the future projects, there should be more collaborative projects which utilize strengths from different faculties.

On the technical side, professional engineers need to construct the RALfie system as robust and reliable as possible. The network connection should be reliable. The online interface need be more user friendly to limit confusion and frustration. The online technical scaffolding is important to alleviate users' anxiety using robotics at the far end. Perhaps there should be more online tutorials and regular meet-up session for remote users to ask questions and receive support.

On the pedagogical side, professional educators need to make the connection between RALfie activities and the Australian Curriculum: Technologies more apparently. Presenting RALfie activities to curriculum links and demonstrating appropriate teaching pedagogies will increase the likelihood for PSTs to use robotics or similar technologies in their own classroom practice when they become in-service teachers.

6.6 Conclusion

The purpose of this research was to explore the potential of RAL for enhancing PSTs' self-efficacy for teaching the Australian Curriculum: Technologies. The theoretical framework for the research was based on the four sources of self-efficacy information, namely successful experiences, vicarious experiences, verbal persuasion and physiological and emotional states (Bandura, 1997). A mixed methods approach was used to investigate changes in PSTs' self-efficacy. The pre-post T-TEBI and PANAS were used to measure the changes of self-efficacy associated with the RALfie experiences. Due to a small sample size, the quantitative data did not support more than minimal statistical analysis. Qualitative data were used to investigate the changes in self-efficacy.

In conclusion, this study confirmed that PSTs' successful experiences working with RALfie were the most influential information to develop their sense of self-efficacy.

Past successful experiences provide the most authentic evidence that one can succeed (Bandura, 1997). The hands-on activities were more powerful than the online activities because PSTs had more successful experiences working with concrete materials which is suitable for their ZPD. The social interactions with peers and professional engineers were powerful because of scaffolding.

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