Exploration of a Collaborative Non-Formal Science Education Program in Australian Secondary Schools

A thesis submitted for the degree of

Doctor of Philosophy

of

The Australian National University

by

Kathleen Emma Claire Hayes

Centre for the Public Awareness of Science

Faculty of Science

Canberra

February, 2018

This research is supported by an Australian Government Research Training Program (RTP) Scholarship.

Declaration

This thesis is an original work. None of the work has been previously submitted for the purpose of obtaining a degree or diploma in any university or other tertiary education institution. To the best of my knowledge, this thesis does not contain material previously published by another person, except where due reference is made in the text.

Kathleen Hayes

Kathleen Hayes

January 2018

Acknowledgements

First of all I would like to thank the teachers and students who gave up their time to participate in my research and shared with me their perspectives. I am very grateful also to KIOSC for letting me conduct my research and for the staff taking the time to answer my many questions.

I would like to acknowledge the considerable support and encouragement I have received through my PhD journey. I am very grateful for the advice and feedback provided by my supervisor Dr Merryn McKinnon at CPAS who was always ready with assistance despite the fact that we were in separate states for the entirety of my PhD. I am also very appreciative of the support and guidance given by my co-supervisor Dr John Cripps Clark at Deakin University both on my research as well as the quirks of academic life. In particular I'd like to thank John for alerting me to scholarship and grant opportunities with ESERA that enabled me to travel and present my research overseas. I am grateful for the many supportive and informative conversations I've had with colleagues at both Deakin and ANU. A special thank you to Dr Sue Stocklmayer, who gave much appreciated feedback on my work, and to Dr George Aranda who first connected me to Deakin and science communication academia initially.

I have been fortunate enough to receive considerable help from a wide network of overseas researchers through conferences and other opportunities. I am particularly grateful to the ASPIRES team who hosted me for a week at King's College London when I travelled there through the ESERA travel grant. This experience gave me valuable assistance in developing my ideas. In particular Dr Jennifer DeWitt's advice on my survey instrument was invaluable and much appreciated. The further feedback and support I found in the 2016 ESERA summer school for PhD students in Czech Budejovice was also helpful in developing my research and a great experience to meet other science education PhD students from around the world.

Outside of academia I am very grateful for all my friends putting up with my erratic scheduling and who all now probably know much more about science education than they ever wanted to. I must give special thanks to my sister Sophie and my roommate Rachel who each shared a house with me during my PhD and were much appreciated sources of rationally and needed breaks during those years.

Lastly, thanks also to my parents. Thank you Dad for consistently encouraging me to seek out and pursue further opportunities, and thanks Mum for your unwavering support as always.

Abstract

Declining student enrolment in post-compulsory science has prompted increasing use of non-formal science education programs to help motivate students to continue with post-compulsory STEM study. Non-formal programs are well acknowledged to have potential for engaging students in ways that schools cannot but there is a scarcity of data demonstrating this, particularly in Australia. As non-formal programs become more commonly used in schools it is important to understand the roles that they can have in schools and the opportunities within these roles for encouraging students to continue with post-compulsory STEM education. This research explores the perspectives of stakeholders regarding the ongoing implementation of a non-formal science education program in a specific local partnership. Over a year, non-formal staff, year seven and eight students and their teachers from two secondary schools were interviewed and observed during biannual visits to the centre. Students also completed a reflective survey at the year’s end. Results indicate that there is considerable potential for a non-formal program to help students develop post-compulsory STEM trajectories by providing a flexible, well-resourced and engaging learning environment. This environment was observed to support student participation and offered potential to extend students’ learning and increase their awareness and interest in STEM careers. Through these roles many students became more interested and confident in doing science and several developed interest in science careers. The program also affected teachers, prompting science teachers to reflect on their pedagogy and enthusing non-science teachers who attended as helpers. However full realisation of the potential of the non-formal programs was limited by students’ unrealistic expectations of the experience and a lack of efficient incorporation into their school learning. Most students were unaffected by their non-formal experiences as they were brief and scheduling limitations meant that they were not effectively linked to what students were learning at school. Often the non-formal program was seen as a day off school and students’ expectations centred around personal enjoyment and not learning. Difficulties in collaboration also occasionally disrupted students’ experiences which further diminished student expectations for their visits. As a result, some students developed a perception of the non-formal program as irrelevant to them or only worthwhile for people already interested in science which made it difficult for teachers to maintain student enthusiasm in the non-formal programs. This perception was exacerbated over time and amongst students who had poor pre-existing attitudes to science and who perceived limited support for their science learning. A further challenge to realising the potential roles of the non-formal programs lay in the collaboration between the centre and the schools which were each different communities with different agendas. Over time

however, teachers and non-formal educators were able to develop relationships and it was their collaboration that was the key to resolving issues and refining the programs. Going forward, realising the potential of ongoing non-formal programs in secondary science education requires attention to the challenges in stakeholder collaboration, maintaining student enthusiasm over time and incorporating students' experience into their school learning.

Table of Contents

List of Figures

List of Tables

Chapter 1. Introduction

1.1 Establishing a context

School inclusion of 'out-of-school' learning experiences in their teaching of science has long been a feature of science education in many countries and is becoming increasingly prevalent worldwide. Today it is common practice for schools to visit an external institution as part of their science curriculum, and many such institutions have evolved to specifically cater for school visits. These institutions include informal education organizations (libraries, youth programs), science-rich cultural institutions (science centres, museums, zoos, national parks etc), tertiary education institutes and a variety of science research centres. The market for providing these experiences in science education is growing as these external learning programs are proposed as a way to engage students in learning science and combat perceived flaws in school science teaching (Stocklmayer, Rennie, & Gilbert, 2010). However despite their avowed potential for engaging students in learning science, realizing this potential remains difficult and the evidence for their impact is elusive or contradictory (e.g. Banerjee, 2017b). As a hugely diverse and evolving phenomenon there is still much to be understood about how these programs are incorporated into students' science education.

Calls for the inclusion of out-of-school experiences in student science learning has historically been driven by dissatisfaction with traditional science teaching and the perceived deficiency of students who continue studying science, technology, engineering or mathematics (STEM) subjects at post compulsory levels (Sjøberg & Schreiner, 2010). Though there is debate over whether current enrolments represent a STEM employment crisis for society (Charette, 2013), it remains a fact that many countries worldwide have policies directed to engage students in learning STEM and studying it post-compulsorily. Many such programs are focused on engaging particular segments of the population which have considerable and continuous underrepresentation in post-compulsory STEM study and STEM related careers. The exclusivity of traditional science teaching for students from a particular gender or from ethnic minorities, low socio-economic backgrounds is seen as a problem which more diverse and inclusive out-of-school settings may solve (Barton & Osborne, 2001).

Many science educators are concerned that science in schools puts off otherwise able and interested students through disseminating a perception of science as a very rigid culture where a person needs to be 'brainy' and abnormally dedicated (DeWitt, Archer, & Osborne, 2013). Out-of-school learning experiences are proposed to provide students with a different experience of learning science that is more interesting, relevant or authentic than school science (Rennie, 2007). The settings for out-of-school learning are also suggested by Bevan et al. (2010) to be more flexible than school environments and more inclusive of different backgrounds which accommodate a diverse range of participation by students. Such inclusivity is now recognized as vital to students' engagement in learning science and heavily influential on whether they continue on to study STEM post-compulsory (Carlone & Johnson, 2007). This has led to a focus in science education research on student experience of learning science in out-of-school settings, and how students' interpretations of these experiences affect their development of a scientific identity and subsequent trajectory for post-compulsory STEM study. There is considerable research to suggest that students' experiences of science out-of-school have the potential to disrupt negative stereotypes and encourage them into trajectories for post-compulsory STEM study. However there is limited evidence published in the science education literature on consistent realization of this potential, in particular regarding students from disadvantaged populations.

Stocklmayer, Rennie, and Gilbert (2010) advocate that an effective science education for all students is achievable through collaboration between school teaching of science and the out-of-school science education sector. There is considerable support for this idea internationally with many countries implementing large scale programs that encourage collaboration between schools and external institutions, for example by making non-formal education a requirement of the national curriculum (Affeldt, Tolppanen, Aksela, & Eilks, 2017). In some countries, including Australia, this enthusiasm has manifested in government support for the establishment of specialist science centres dedicated to providing science education programs for schools. This emergence of top level support could lead to changes in the longevity of collaborations between schools and external institutions, potentially increasing their impact upon students. Typically collaborations between schools and external institutions have been hard to sustain as they are locally established and vulnerable to changes in leadership and funding (Bevan et al., 2010). The emergence of specially dedicated centres for science education programs and their collaboration with schools may help realise the potential of out-of-school learning programs for engaging students. Currently however there has been limited in-depth research conducted into these specialist science centres or into ongoing collaborative partnerships in general. As these science education programs become more formalized and incorporated into schools it is important that we understand how students are interpreting these experiences and what role these programs can fulfil in students' science education.

1.2 Clarification of terminology

Before discussing the focus of this research it is necessary to clarify the terminology used. Throughout the science education literature the terms out-of-school, informal and non-formal are all used inconsistently and on occasions interchangeably (Coll, Gilbert, Pilot, & Streller, 2013). These terms have been used to refer to students' learning as well as the setting in which learning occurs, which several researchers object to. Rennie (2007) advocates that classifying learning as informal or formal is senseless as learning is an ongoing, cumulative process built via experience in a range of settings. However different settings may afford different opportunities and limitations on student participation in learning science (Bevan et al., 2010) and hence it is useful to have a terminology distinguishing between different settings.

The categorization of 'formal' science education is widely accepted as an organized learning that has a specific structure, is located in formal institutions such as a school, and is connected to any kind of curriculum (OECD, 2012). In contrast to formal learning, informal learning is usually accepted to be driven by the learner's own interests and needs, taking place in students' leisure time and being voluntary and rarely measurable or assessable. Informal learning has often been defined as the opposite of formal learning and the OECD (2012) states that in order to be functional, the two definitions need to be mutually exclusive. References to formal or informal learning *sectors* describe institutions that are assumed to provide that kind of learning experience; schools, universities and other education bodies for formal learning and institutions such as zoos, centres, museums and after school clubs for informal. However the terms formal and informal fail to encompass the full range of student learning experiences, particularly those which span the formal and informal learning sectors.

To fill this terminology gap the terms 'non-formal' and 'out-of-school' have arisen. Non-formal learning is proposed to exist midway between formal and informal learning with characteristics of both (Eshach, 2007) (Table 1). Most researchers agree that non-formal learning is usually connected at least partially to a school curriculum (Coll et al., 2013), organized with objectives though less so than formal learning (Garner & Eilks, 2015; OECD, 2012)and that it takes place in less formal settings than school (Eshach, 2007). Often the distinction of non-formal learning activities from informal and formal ones isn't always clear (Garner, Hayes, & Eilks, 2014) and the term has been inconsistently applied to a wide range of programs (Coll et al., 2013). The structured, non-voluntary and non-school based programs described by Affeldt et al. (2017) and Garner and Eilks (2015) as non-formal have also been termed ‘structured informal learning’ (Dabney et al., 2012) and ‘out-of-school inquiry’ (Luehmann, 2009b). Likewise, the term ‘out-of-school’ has also frequently been used interchangeably with informal learning (Eshach, 2007). Going forward, this thesis will refer to out-of-school learning as per OECD (2012), as a general term for a learning activity that occurs outside the confines of school which can be either non-formal or informal learning. The focus in this thesis will be on non-formal programs that are run specifically for school students typically during school time. I define non-formal learning programs according to Affeldt et al. (2017, p. 15) as *organized science education that happens in out-of-school settings, whether or not it is tied to any structured curriculum.* As a result of this terminology, many examples I refer to in the following discussion as being non-formal may use different terms in the original publication. This strategy is necessary however to maintain clarity across an international field and avoid the term out-of-school becoming an inefficient ‘catch all term’ as informal learning is often claimed to be (Rennie, 2014). Further explanation of specific terms is included in Section 1.6, Glossary (Table 2).

Table 1. Characteristics of Formal, Non-formal and Informal Settings from Eshach (2007, p. 174).

Formal	**Non-formal**	**Informal**
Usually at school	At institution out of school	Everywhere
May be repressive	Usually supportive	Supportive
Structured	Structured	Unstructured
Usually prearranged	Usually prearranged	Spontaneous
Motivation is typically more extrinsic	Motivation is may be extrinsic but it is typically more intrinsic	Motivation is mainly intrinsic
Compulsory	Usually voluntary	Voluntary
Teacher-led	May be guide or teacher-led	Usually learner-led
Learning is evaluated	Learning is usually not evaluated	Learning is not evaluated
Sequential	Typically non-sequential	Non sequential

1.3 Problem statement

As a relatively new phenomenon, ongoing and institutionalized non-formal science education programs suffer from inconsistent data gathering and a lack of targeted research. A comprehensive review of informal and formal science education collaborations for non-formal science education by Bevan et al. (2010) found a substantial lack of documentation and evidence for student outcomes. Despite their prevalence in schools, non-formal programs seem to be rarely evaluated due to limited time for evaluation, use of inappropriate measures of impact (such as school tests) and inexperience in evaluation by either teachers or the external educators (Bevan et al., 2010).

Current research into school use of non-formal programs tends to involve short term experiences where the program is usually implemented as a short, one off experience. The findings regarding students' experiences of brief non-formal learning programs may not be applicable to the ongoing and collaborative programs which are now being established. Ongoing programs which are collaboratively developed by external institutions with schools can have a range of affordances not possible in short term experiences. This would provide students with quite different experiences of non-formal learning and the program could take on a variety of roles in their education. Additionally, the way schools use ongoing or long term non-formal programs in their science teaching can be quite different from the way they use short term ones. Consequently there is a substantial need for research specifically looking at long-term non-formal programs and not simply extrapolated from short term programs.

A key issue in what research that exists on non-formal learning in schools is the consistency and quality of data. There is considerable diversity of data due to the huge variability in the type of non-formal program and in the schools which use them. The inconsistent use of terminology to describe non-formal learning experiences also makes difficult to assess the field as a whole. These issues are emphasized by the common method of data gathering for research into student out-of-school learning experiences; the ethnographic case study. While this method is capable of gathering rich and in-depth data it does restrict what kind of evidence is available and the contexts to which it is applicable (Creswell, 2013b). For instance while there are several excellent case studies of short and ongoing non-formal programs in schools (e.g. Kisiel, 2010; Luehmann, 2009b; Robertson, 2007), these are often situated in American contexts and the development and implementation of the non-formal experience is often heavily intertwined with the local community. Consequently these results may not be easily generalizable to different cultures.

It is especially important to explore the implementation of non-formal science education programs amongst disadvantaged student populations who would be unlikely to otherwise participate in out-of-school science learning experiences. Youths from disadvantaged populations face considerable challenges in participating in science education in both informal (Dawson, 2014) and formal settings (Carlone & Johnson, 2007). Engaging and motivating these students to continue with post-compulsory STEM education is a significant problem in science education today and one which is often the focus of non-formal programs. However many non-formal programs involve highly selective youth populations, such as high achieving students who are already likely to pursue post-compulsory STEM education (Todd, 2016) or who are from particular ethnic minorities and not necessarily representative of a typical school population (Ash, Carlone, & Matthews, 2015). It is vital therefore to investigate non-formal science education programs in schools with disadvantaged student populations in order to ascertain the potential of non-formal learning for these students.

Another neglected aspect of non-formal education under-reported on in the literature is how the collaboration between teachers and non-formal staff affects the potential impacts of the program. Research has shown that communication between teachers and non-formal staff greatly influences how the non-formal program is implemented and incorporated into schools (Kisiel, 2010). Teachers who take on a more involved role in the program are thought to create a more meaningful and engaging experience for students (Tal & Steiner, 2006). However investigation into this has largely focused on the perspectives of teachers and non-formal staff (e.g. Bouillion & Gomez, 2001; Kisiel, 2010; Robertson, 2007). In the few reports on long term or ongoing non-formal science education programs there has been little direct examination of how the management of non-formal collaborations affects how students interpret and respond to non-formal education programs. Given the immense variation that can occur in collaboration size, desired outcomes and type of collaborative arrangement (Bevan et al., 2010; Tytler, Symington, & Clark, 2016) it is crucial to build understanding of collaborations in non-formal science education programs.

Globally there is limited evidence available on long-term non-formal learning programs; a mere handful have been reported on in the science education literature and very few of these have been based in Australia. There is a great need for context specific research into non-formal programs as both formal and non-formal science education can vary considerably between countries. The history of out-of-school science learning and its uptake in schools typically revolves around key innovators and the establishment of flagship informal education institutions (e.g. the Exploratorium in San Francisco described by Ogawa, Loomis, & Crain, 2009). With its isolation and relatively small population, the history of Australia's informal and non-formal science education sector can also be traced through a few particular innovators whose passion drove the establishment of the first science centres in Australia (Bryant, Gore, & Stocklmayer, 2015b). As shown in these cases the unique cultural and historical context of each country can greatly influence the form that non-formal science education takes. Hence understanding the role of non-formal learning programs in Australian science education would be best served by research conducted in Australian settings.

The current need for research into Australian ongoing and collaboratively developed non-formal learning programs has been highlighted by recent government funding into school-science centre collaborations in the Australian state of Victoria. This multi-million dollar program involves establishing 11 'Tech Schools' as specialist non-formal science education centres which will collaborate with local schools to specifically address local STEM employment and education issues. Research into this new model of non-formal science education would thus be highly relevant to the ongoing development and implementation of Australian science education, as well as useful to understanding current trends for ongoing non-formal science learning programs in schools worldwide.

1.4 Aim, Scope and Significance

The aim of this thesis is to explore the roles of an ongoing, collaboratively developed non-formal science education program in Australian secondary schools. Specifically, this research will investigate the implementation of an Australian non-formal science education program through the perspectives of attending students, teachers and centre staff. From this investigation this thesis will discuss the key opportunities that a non-formal science education program can have for encouraging Australian secondary students to continue with post-compulsory STEM. It will also examine the main limitations to achieving those opportunities in Australian secondary schools. In particular the effects of the ongoing and collaborative nature of the program on the opportunities available to students will be discussed.

To this aim the following research questions were proposed:

1. *How are students' experiences in an ongoing, non-formal science education program interpreted by students, their teachers and non-formal staff?*

2. *How do stakeholder interpretations of a non-formal science education program vary over time?*
3. *Is there an interaction between the collaborative nature of a non-formal science education program and stakeholder interpretation of it?*
4. *Is there an interaction between student background and students' interpretation of the non-formal science education program?*
5. *What opportunities are there in an ongoing non-formal science education program for students to develop trajectories into post-compulsory STEM education?*

As the focus of this research is on ongoing and collaborative non-formal science education programs in an Australian context, this study selected to investigate one of the few examples of such programs; an Australian specialist non-formal science education centre or 'Tech School' in suburban Melbourne, Victoria. The scope of this study was consequently limited to participants from two of its partnering secondary schools, specifically the year 7 and 8 students and teachers.

The findings from this thesis will contribute to current understanding of how ongoing non-formal science education programs are incorporated in schools and what roles they can fulfil in secondary students' science education. The main contribution of this thesis will be to provide insight into the current implementation of ongoing non-formal science education programs within schools, particularly in the Australian context where there are limited reports available. This will create a resource that will help guide future policy and assist in the development of further ongoing and collaborative non-formal science education programs in Australia and worldwide.

1.5 Overview of the study

Chapter 2 provides readers with the background necessary for understanding how students develop trajectories into post-compulsory STEM education. It outlines the debate regarding post-compulsory STEM enrolment and why it remains an issue for post-industrialized countries around the world. It then uses a socio-cultural perspective to illustrate the barriers facing students in continuing to study STEM post-compulsory. Through this discussion the chapter presents an argument that both the informal and formal science education sector can engage students in meaningful science learning that supports their continuation with post-compulsory science but each setting is limited on its own.

Chapter 3 is a literature review of current research into non-formal science education programs. It discusses the opportunities for students offered by non-formal programs which bridge formal and out-of-school settings. It then explores current challenges in realising the potential of non-formal science education programs in schools. From this, the literature review focuses more specifically on ongoing and collaborative non-formal science education programs and why there are increasing numbers being established worldwide. It discusses the lack of evidence available for the current claims made about non-formal programs and outlines a specific gap concerning Australian examples in particular. In light of this gap, a series of research questions are proposed.

The fourth chapter explains the setting for the research and outlines the methodology and method choice for answer the research questions. To begin it introduces the case study of this thesis and explains participant selection and recruitment. The study design is described along with a brief explanation of how it was adjusted and refined during the research in response to problems in recruitment. The chapter then describes the choice of methods and how instruments for these methods were developed and implemented. Subsequent sections outline the data analysis undertaken as well as the approach to generalizability and validity of the findings.

The results chapter provides the results of the data analysis from the interviews and survey responses. This chapter is outlined according to the research questions with each section discussing the main themes pertinent to each research question. Responses between participants (teacher, student and non-formal staff), schools and year levels are compared where relevant throughout the chapter.

The sixth chapter is the Discussion which explores the findings from the results in light of existing research into non-formal science education. It discusses key themes arising from the data and explains how they support, contrast or introduce a novel perspective to current understanding of non-formal science education. It describes the implications of the findings for the future establishment and development of ongoing and collaboratively developed non-formal science education programs in schools. Limitations of the generalizability of the findings are explained and future research priorities are also discussed. The main points made in this chapter are drawn together in a final concluding section in response to the research aims.

1.6 Glossary

Table 2. Glossary of Commonly Used Terms in the Existing Literature and their application within this Thesis.

Literature term	Definition	Use in this thesis
Formal Learning Setting/Formal Education	Organized learning that has a structure, a curriculum and is located in a dedicated learning institution such as a school.	As per definition
Informal Learning Setting/Informal science Institution	Settings where an individual's motivation to learn is primarily intrinsically driven. Typically used to refer to institutions like science centres, museums, zoos or similar which offer a range of activities and exhibits for individuals to interact without specific direction.	As per definition.
Informal Science Learning	Has been used to activities such as consuming science media or doing science related activities but has also been used to refer to any learning occurring in informal learning setting.	Used in this thesis to refer to free choice learning which is voluntary on an individual's behalf. Does not necessarily always occur in an informal learning setting.
Informal-Formal partnerships	Collaborations between informal and formal learning settings. Often for the provision of non-formal education.	Not used. Treated as equivalent to non-formal science education as explained in section 3.2.
Non-Formal learning sector	Not clearly defined in the literature.	A range of non-school institutions and organizations which provide non-formal science education programs to youths. These providers typically have a range of other functions such as an informal science learning institution, scientific research, or tertiary education.

Non-formal science education	organized science education that takes place out of a school setting.	As per definition.
Out-of-school	Any learning that occurs outside of school setting which can be informal or non-formal. Is especially used in American contexts to refer to school organized science education programs such as field trips or after school clubs	To refer generally to any science learning that occurs out of school.
Outreach	Another term for non-formal science education programs for students, often more used to refer to educational programs provided to secondary students by tertiary institutions and scientific research organizations or scientists.	Not used. Treated as equivalent to non-formal science education as explained in section 3.2. Usually used in the literature to refer to non-formal programs conducted by universities 'outreaching' to schools.
Science and Mathematics Specialist Centre	Used in Australian Governmental reports (e.g. Department of Education and Early Childhood Development, 2009) to refer specifically to non-formal science education centres which provide programs to students and teachers but not the general public.	These centres are referred to more generally as Specialist Non-Formal Science Education Centres.
Science Centre	A institution which provides a range of science exhibits and activities to the general public as well as to visiting schools.	As per definition
Tech School	Variously used to describe a variety of collaboratively developed non-formal science education models.	Specifically used in this thesis to refer to the centres established as part of the Victorian Government Tech School Initiative ("About Tech Schools," 2017).

Chapter 2: Student Trajectories into Post-Compulsory STEM Education

2.1 Chapter Introduction

This chapter outlines the concerns over declining student enrolment in post-compulsory STEM education and discusses why this is a problem for post-industrialized countries worldwide. The various factors affecting student development of trajectories into post-compulsory STEM education are discussed in light of current research. The chapter then highlights the difficulty of formal learning environments to encourage the participation of students from a wide range of backgrounds and the emergence of the informal science learning sector in response to this. The chapter concludes with a discussion of the opportunities and limitations of the informal learning sector for engaging students in meaningful science learning that supports their continuation with science.

2.2 The problems in student enrolment in post-compulsory STEM education

Today engaging students in learning science is seen as a major issue in countries around the world. Declining student enrolment in STEM (science, technology, engineering and mathematics) subjects after they are no longer compulsory at secondary school has been reported as a 'crisis' in many countries worldwide (Sjøberg & Schreiner, 2010). The continual decline in enrolments in the so called enabling sciences of physics, chemistry and mathematics (Office of the Chief Scientist, 2012) and engineering (UNESCO, 2010) are of particular concern as these are seen to open up career options for students. Additional alarm lies in the skewed demographics of post-compulsory STEM enrolment which is often unrepresentative of the larger population (Archer, Dewitt, & Osborne, 2015). Yet this 'crisis' in post-compulsory STEM enrolment has also been the subject of much contentious debate amongst academics and educators, which will be discussed in the following paragraphs. Further examination of the issue reveals a complicated tangle of diverse factors contributing to the drive to recruit more students into post-compulsory STEM education.

The problem of declining student enrolment in post-compulsory STEM education is prevalent worldwide but largely restricted to those countries which are post industrialization and moving away from a manufacturing based economy. The international ROSE study (Sjøberg & Schreiner, 2010) found that students from these wealthy, developed countries tended to be less interested in school science and less inclined to see it as beneficial for future careers. Sjøberg and Schreiner (2010) suggest that this may be the result of fundamental differences in how school is perceived, with youths from countries with a high level of development more likely to see school as a duty rather than a privilege. Bøe, Henriksen, Lyons, and Schreiner (2011) also favour this argument and argue that student enrolment in post-compulsory STEM education is associated with the socio-cultural characteristics of a generation rather than a nation's education systems. Consequently the issues of post-compulsory STEM enrolment and the drive to encourage more students to study STEM remains a post-industrialized world problem and the following discussion is based in this context.

On the face of the STEM enrolment 'crisis' in post-industrialized countries there is abundant data pointing to a consistent decline in post-compulsory STEM student enrolments worldwide including the UK (Hoyles, Reiss, & Tough, 2011; Smith, 2011) and wider Europe (OECD, 2006), the USA (Olson & Riordan, 2012) as well as Australia (Lyons & Quinn, 2010a). This evidence has contributed to government and industry apprehensions of a future shortage of STEM professionals and the economic prosperity that is seen to be linked to STEM research (Marginson, Tytler, Freeman, & Roberts, 2013). Consequently there has been, and continues to be, considerable emphasis in educational policy to recruit youth onto trajectories to post-compulsory STEM study and into the STEM professional pipeline (Office of the Chief Scientist, 2012).

However there has also been considerable criticism of this focus on recruitment with several reports casting doubt on the 'STEM crisis' and the data used to support it. An underlying issue when discussing post-compulsory enrolment in STEM is the lack of definite statistics due to conflicting definitions of what counts as a STEM profession (Charette, 2013). Many reports vary as to which professions they include and so report different conclusions, leading to inconsistent data regarding post-compulsory STEM enrolment at secondary and tertiary levels (Panizzon, Corrigan, Forgasz, & Hopkins, 2015). There is also immense variation in enrolment across the different fields of STEM with some areas such as engineering and technology facing a looming skills shortage (Tytler & Osborne, 2012) and offering better employment prospects than straight science degrees (Norton & Cakitaki, 2016). On the other hand, in the fields of health and life sciences there are more than sufficient numbers in most developed countries to meet demand (OECD, 2010). Osborne and Dillon (2008) also suggest that low STEM tertiary completion rates in local areas do not necessarily translate to a shortage in a particular scientific profession with the option of filling vacancies from overseas.

Charette (2013) and Norton and Cakitaki (2016) contend that there is in fact an oversupply of graduates in many STEM fields and limited evidence for a role shortage in many STEM professions. This has been further supported by thorough analysis in the UK (White, 2017). Charette (2013) goes so far as to claim that STEM industries have a vested interest in encouraging an oversupply of tertiary STEM graduates as this reduces average salaries, making the situation economically preferable for industry. Doubts over the value of post-compulsory STEM qualifications were also expressed in Australia by Andrew Norton, director of the Grattan Institute, who presented statistics which showed that a postgraduate STEM qualification did not make Australian tertiary graduates more employable (Norton, 2013). Conversely there is a reverse argument that claims STEM qualifications help graduate employability. Reports showing large numbers of science tertiary graduates employed outside of their field of study following graduation in the UK (Smith & Gorard, 2011), US (Charette, 2013) and Australia (Norton & Cakitaki, 2016; Panizzon et al., 2015) have been used to illustrate both the lack of employability for STEM graduates and to make the case for the value and wide ranging applicability of STEM degrees in employment. While acknowledging the absence of a general shortage of STEM professionals, Marginson et al. (2013) argue that there is shortage of STEM related competencies in the workforce overall. Support for post-compulsory STEM enrolment, particularly at tertiary levels, is based on the argument that STEM degrees equip students with adaptable skills which are seen as important for innovation and productivity across occupations (Council, 2015). Hence, despite the criticism, there remains widespread support for the idea that post-compulsory STEM study will benefit students in obtaining employment and be useful to their employers as well.

Support for increasing student enrolment in post-compulsory STEM study is further strengthened by a perception that participating in some form of post-compulsory STEM education will enhance students' scientific literacy, another issue of concern for many post-industrialized nations. The Programme for International Student Assessment (PISA) describes a scientifically literate person as *one who is willing to engage in reasoned discourse about science and technology, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically* (OECD, 2016, p. 20). There are concerns that upon graduating from school, students are not sufficiently scientifically literate and thus ill-equipped to make decisions on a range of complex socio-scientific issues that will affect their everyday life (Tytler & Osborne, 2012). This is of particular concern in Australia where only 61% of Australian students achieved the National Proficient Standard in scientific literacy and students who were Indigenous or from low socioeconomic backgrounds in particular fared poorly (Thomson, De Bortoli, & Underwood, 2017). Increasing student enrolment in post-compulsory STEM education is consequently commonly seen as necessary in order to raise student scientific literacy despite a lack of evidence to this effect.

The modern demands of scientific literacy for non-STEM professionals have prompted reflection on the current purpose of science education today (Smith & Gorard, 2011). The original purpose of science education in schools was to prepare a minority of students to become STEM professionals (Aikenhead, 2006), but today the majority of non-STEM aspiring students must also be prepared with the knowledge and skills needed to deal with the science and technology they will encounter in their future (Fensham, 2008; Stocklmayer, Rennie, & Gilbert, 2010). The difficulty faced by the current science education system in achieving the goals of adequately prepared citizens and future STEM professionals is highlighted by Tripney et al. (2010) who suggest that low ability students deciding not to continue with post-compulsory STEM education is desirable from the perspective of a system for training future scientists but a problem when considering the need to raise scientific literacy more generally. Osborne and Dillon (2007) are also critical of the notion of the 'leaky pipeline' process and suggest that the goal of science education must be '*to offer an education that develops students' understanding both of the canon of scientific knowledge and of how science functions*.' (Osborne & Dillon, 2007, p. 7). Thus while many schools encourage students to continue into post-compulsory STEM education with the aim of developing their scientific literacy, this goal does not align with the dominating view of post-compulsory STEM education as strictly a pathway to a STEM career.

While the debate continues over the value of post-compulsory STEM study for individuals and society it is well acknowledged that there is a strong need to address inequitable representation in post-compulsory STEM. Enrolment in post-compulsory science has long been seen to fall along racial, gendered and economic lines with students who are white, male or middle class more likely to choose to continue with post-compulsory STEM study (Archer, Osborne, et al., 2013). This is subsequently reflected in the population of STEM professionals, where the fields of physics, chemistry, mathematics and engineering fields show a continuous underrepresentation of women, those from ethnic minorities or low socio-economic backgrounds (Office of the Chief Scientist, 2012; Olson & Riordan, 2012). As a result of this inequitable participation, it is feared that large sections of the student population in many post-industrialized countries are disadvantaged in accessing potential careers and the general scientific knowledge required to navigate modern life, thus repeating a further cycle of disadvantage (Archer, Dewitt, & Osborne, 2015). It is proposed that understanding the inclination for students of under-represented populations to refrain from participating in post-compulsory STEM education will aid the development of science education which recruits and retains diverse populations (Carlone & Johnson, 2007).

To summarize, while there continues to be a debate over the extent of the STEM enrolment crisis there remains considerable support in post-industrialized countries for encouraging more students to study post-compulsory STEM. The arguments used to justify this call for increased post-compulsory STEM enrolment as means to improve economic prosperity, graduate employability and scientific literacy are more complicated and flawed than they first appear but neither are they easily dismissible. A more concerning argument for engaging students in learning science is the considerable evidence showing that current systems of science education are failing to appeal to students outside a particular background. Bøe et al. (2011) argue that researching student participation and trajectory into post-compulsory STEM education is important to ensure everyone has a legitimately free choice of education. DeWitt and Archer (2015) likewise argue that the STEM enrolment crisis is not merely an issue of economics but of social justice. Hence understanding how students can be encouraged to continue with post-compulsory STEM education remains an important avenue of research.

2.3 Factors that affect student post-compulsory trajectories

Over the years, considerable research effort has been invested into investigating why so many students choose not to continue with STEM education post-compulsory. This process has been extensively explored and modelled through a variety of theoretical frameworks. Increasingly it is apparent that understanding students' trajectories into post-compulsory STEM education requires consideration of a great many factors beyond simply interest and capability in science. In the following paragraphs I outline several factors which are considered to affect student trajectories into post-compulsory STEM education.

Interest in science has often been thought to be important to students' continuation with post-compulsory STEM education however research has revealed it is not enough on its own to support students' progression. While interest is one of the reasons students report choosing to continue with STEM in secondary school or at tertiary level (Lyons & Quinn, 2010a; Maltese & Tai, 2011; Tripney et al., 2010), considerable research now suggests that possessing intrinsic interest in science does not guarantee enrolment in post-compulsory STEM education. Simply having an interest in science is not enough to facilitate success in the science classroom (Barton et al., 2012), overcome negative social associations (Zimmerman, 2012), or a lack of awareness of STEM careers (Aschbacher, Li, & Roth, 2010) or a sense that science is 'not for me' (Archer, Dewitt, & Osborne, 2015). And in contrast to the common view that students grow less interested in science as they grow older there is research to suggest that students actually do like and enjoy school science in secondary school (Archer, Osborne, et al., 2013). Lyons and Quinn (2010b) in fact found that Australian year 10 students enjoyed learning science more than they did in primary school. These findings suggest that students from post-industrialized countries do, in fact, see science in general as important and interesting, but these perceptions do not translate into a wish to pursue it as a career or continue with post-compulsory STEM study (Jenkins & Nelson, 2005; Sjøberg & Schreiner, 2007).

A key factor in the choice to continue with post-compulsory STEM is its association as a conceptually difficult subject that requires intelligence. The societal perception of science as for 'clever' people leads students to class science aspirations as for the academic elite (Archer, DeWitt, & Willis, 2014). This perception is also prevalent amongst teachers and can lead to students with genuine interest in science being counselled by their teachers to choose 'easier' subjects (Aschbacher, Li, & Roth, 2010). This thinking is further entrenched by the culture of science in schools worldwide, where most schools require students to achieve a certain level of academic success to continue studying it post-compulsorily. Archer, Moote, Francis, DeWitt, and Yeomans (2016b) contend that in the UK this channelling process leaves students with little choice over their post-compulsory science study and leads to different provision of career resources which Archer, Dewitt, and Osborne (2015) accuse of leading to biased participation in post-compulsory science education. Likewise Marginson et al. (2013) attribute Australia's low enrolment problem as at least partially due to the fact that STEM disciplines are only accessible to students perceived as sufficiently talented. Archer, Moote, et al. (2016b) further argue that this 'channelling' of students through selective requirements reproduces societal inequalities and subsequently the under-representation of certain population groups in STEM professions.

There are concerns that the emphasis on academic achievement as a trait of successful science students may be misguided. Despite the continued association of STEM professions with intelligence and academic achievement in science, it is erroneous to assume that high achievement equates to intent to continue with post-compulsory STEM. Barton et al. (2012) and Tan, Barton, Kang and O'Neill's (2013) research reveals that motivation to be a 'good' school student often results in high achieving students with the correct answers but little intrinsic interest or intent to continue with science. This could explain Krapp and Prenzel's (2011) conclusion that there are weak or insignificant links between achievement and interest. Low academic achievement in school science is not necessarily reflective of disinterest in science or a lack of aspiration to a STEM career. Wong (2015) along with DeWitt et al. (2011) and Aschbacher, Li, and Roth (2010) found that students often aspire to science careers even with poor academic achievement in science. However without sufficient support students were unable to maintain their interest and aspirations in STEM.

Current literature suggests student continuation with STEM is not a matter of academic achievement or intrinsic interest, but whether they feel capable of doing science and see a science career as possible for them. Researchers have often used Bandura's (1997) construct of self-efficacy to measure this, defining it as individual's perceptions of their own ability to achieve a particular action. Self-efficacy in a STEM subject has been shown to play an important role in students' STEM career aspirations (Austin, 2010), and their commitment to pursuing a STEM career (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011). This has been further supported by research using the popular Expectancy Value Model of Behaviour Choice (EV-MBC) framework (Eccles, 2009) which shows that self-efficacy contributes heavily to students' expectations of success in an area and thus their motivation to continue with post-compulsory STEM education (Abraham & Barker, 2015; Ball, Huang, Cotten, Rikard, & Coleman, 2016). A pressing question for many researchers and educators then, is why so many students are not developing in schools as confident science learners who see themselves as capable of a STEM career.

Support for students' participation in learning science has been found to be critical for their post-compulsory involvement, especially support from meaningful authorities such as science teachers and family (Aschbacher, Li, & Roth, 2010). Recently the concept of 'science capital' has emerged as a construct to represent this support and illustrate how it contributes to current inequitable population representation in post-compulsory STEM enrolment. Science capital expands upon Bourdieu's notion of social reproduction and social capital, with science related resources as a new form of social capital that enables families to reproduce social advantages (Archer, Dawson, DeWitt, Seakins, & Wong, 2015). A students' level of science capital is largely dependent on their families and schools which influence what they know, how they think (attitudes), what they do (activities in and out of school) and who they know (friends, teachers, family) (Archer, Dewitt, & Osborne, 2015). Families with science capital are able to help their child build interest and confidence in science through providing extra activities, resources and connections that develop their skills, interest and identification with science (DeWitt & Archer, 2015; Gokpinar & Reiss, 2016). Families without this capital are often unaware of potential pathways for their child and having limited ability to navigate the education system on their behalf (Archer, Dewitt, & Osborne, 2015) even when highly involved (DeWitt et al., 2011). Consequently a students' level of science capital is strongly predictive of their self-efficacy in science, their post-compulsory study plans for science and their affiliation with an identity as a science learner (Archer et al., 2015).

Research into science capital has promoted concern that the system of science education in schools is only catering to a select group of students who are predisposed to identify with the current model of a science student. Students are alienated from science by negative connotations of a science student as 'brainy', anti-social and 'nerdy 'which makes an identity as a science learner undesirable for many (DeWitt, Archer, & Osborne, 2013) Archer, Dewitt, and Osborne (2015). Archer, DeWitt, et al. (2013) propose that working class and non-white students are further excluded by science's association with white, middle class masculinity. Students who do not fit into the socially accepted mould of a science student must invest considerable effort in negotiating their identity as a science learner with their race, class and gender (Carlone, Scott, & Lowder, 2014). Mitigating this cost can involve intense identity work and subsequently students who are not from favoured population groups are continually found to be less likely to continue with STEM studies post-compulsory.

Understanding the barriers to developing a positive identification with science is crucial as a science identity has been closely linked with post-compulsory STEM enrolment in the UK (Archer et al., 2010), US (Aschbacher, Li, & Roth, 2010) Europe (Holmegaard, Madsen, & Ulriksen, 2012) and Australia (Lyons & Quinn, 2010a). Bøe et al. (2011) argues that personal identification with science is a key requirement for student participation in post-industrialized societies where careers are emphasized as avenues for self-expression and individualization is prized. Studies done using the EV-MBC have also shown strong links between a student's continuation with post-compulsory STEM education and their identification with science (Andersen & Chen, 2016; Aschbacher, Ing, & Tsai, 2014). Within this framework an individual's perception of the fit of the science domain with their identity is constructed as their 'science attainment value', how well they see STEM further education and careers as affirming their identity (Andersen & Ward, 2014). Similarly, sociological researchers see the process of choosing to learn science as equivalent to that of developing an identity congruent with the culture and norms of science, as much about *becoming* scientific as about *knowing* science (Carlone & Johnson, 2007). As originally put by Barton (1998), a science identity is "*who we think we must be to engage in science"* (p.379). Currently many students see a science identity as overly rigid which puts off some students from studying post compulsory science but conversely appeals to others (Holmegaard, Madsen, & Ulriksen, 2012). This reinforces Abraham and Barker's (2015) conclusions and that of Archer, Moote, Francis, DeWitt, and Yeomans (2016a) that currently only students who fit the archetype of a science student are likely to continue with science in school.

Andersen and Ward (2014), Carlone, Scott, and Lowder (2014) and Archer, Dewitt, and Osborne (2015) all assert that conflict between students' culture and the culture of school science reduces the appeal of a science identity to many students. Indeed Aikenhead (2006) argued that the culture of school science was the most influential factor for students not continuing with post-compulsory STEM education. This view is supported by Carlone, Scott, and Lowder (2014) and Shanahan and Nieswandt (2011) who propose that the institutional and cultural narratives prevalent in school science manifest as classroom norms that can exclude the wider science related interests and activities of students. This reflects Aikenhead's (2006) argument that the culture of school science itself is the most powerful issue in student participation in science. All too often students' view of science is more closely reflective of the culture of school science rather than the culture of science itself (Shanahan & Nieswandt, 2011). To students, the role of a science learner is conflated with the role of a 'good' school student (Brickhouse & Potter, 2001) where getting good grades counts more than understanding the concepts (Tan et al., 2013). Consequently schools are seen to offer a much more rigid interpretation of science which offers restricted ways for students to be successful learners.

The institutional history of schools has led to rigid perceptions of what successful participation in learning science looks like (Aikenhead, 2006) and successfully learning science at school usually requires fitting into this characterisation (Barton & Tan, 2009;

Carlone, Scott, & Lowder, 2014). In a science classroom a good science student is expected to possess certain behaviours and characteristics (Shanahan & Nieswandt, 2011). This can exclude many students, especially those who have limited science capital and for whom accessing the identity of a science learner must involve considerable ‘boundary crossing’ which can be emotionally intense (Carlone et al., 2015). Research has shown that opportunities for students to establish positions as science learners within school science was made possible when their experiences and knowledge of science outside of school was included (Barton & Tan, 2009; Tan & Barton, 2010). This was illustrated by Gonsalves, Rahm, and Carvalho (2013) who saw students’ engagement in science depends on their ability to successfully navigate and engage with science across settings. Barton, Tan, and Rivet (2008) stresses that creating ‘hybrid’ spaces where students’ existing knowledge and interest are valued is key to making the identity of a science learner more flexible which facilitated their participation in science class. However including the non-traditional forms of science knowledge that students from ethnic minorities or low socioeconomic population groups requires considerable effort (Tan & Barton, 2010) and it is difficult to regularly achieve such flexibility in a school classroom (Barton & Tan, 2009; Carlone, Haun - Frank, & Webb, 2011). In response to these challenges many researchers and educators see external, non-school settings as places where the rigid expectations of school science are removed and students are free to meaningfully engage in learning science (Barton & Tan, 2017; Stocklmayer, Rennie, & Gilbert, 2010).

2.4 The capacity of the informal sector to support students into post-compulsory STEM

Science education in schools is frequently criticized for failing to support a sufficient proportion of its students into post-compulsory STEM education. This is broadly attributed to science being taught in ways that appear irrelevant and unengaging to students as well as inauthentic to the scientific profession (Stocklmayer, Rennie, & Gilbert, 2010). In many respects the informal science learning sector is seen as a possible solution to the flaws of formal science education but closer examination reveals that on its own the informal learning sector may not be enough to encourage students into post-compulsory STEM education.

The emergence of the informal science education sector occurred in the 20th century with the evolution of collection based museums into settings of interactivity and inquiry based learning (Friedman, 2010; Ogawa, Loomis, & Crain, 2009). In the late 20th century the social and economic conditions for western societies favoured a culture of enthusiasm for science education reform (Bryant, Gore, & Stocklmayer, 2015a; Ogawa, Loomis, & Crain, 2009). However successive initiatives and considerable investment of time and money has shown that large scale attempts of reforming science education in schools are incredibly difficult to do and not necessarily successful (Kahle, 2007). Ogawa, Loomis, and Crain (2009) suggest that schools are entrenched as a particular form of social institution and thus are very resistant to change. Stocklmayer, Rennie, and Gilbert (2010) also support this view, arguing that the very nature of school science resists change as it is weighed down by history and a need to cater for all students. Considerable dissatisfaction with school science has led to many educators and educational researchers turning their attention to an alternative way of teaching science, collectively known today as informal science education.

The increasing support for informal science learning over the past century has reflected a shift in educational research to a sociocultural perspective. From this viewpoint, learning is seen as situated meaning making; a product of the activity, context and culture in which it is developed and not simply the acquisition of new information (Brown, Collins, & Duguid, 1989). Alongside this perspective shift there has been increasing valuation of the many ways students can participate in learning science outside of the formal school environs (Rennie, 2014). These non-school experiences of science, such as family activities or leisure pursuits, have been shown to be hugely influential on youth attitudes towards science and also to affect their decision to continue with post-compulsory STEM education (Archer, DeWitt, & Wong, 2014). It is now suggested that encouraging more students into post-compulsory STEM education will require utilizing the many ways and settings in which youths can learn science (Stocklmayer, Rennie, & Gilbert, 2010). Consequently student learning of science in out-of-school settings has been the subject of much research and is being increasingly incorporated into schools.

Out-of-school settings are frequently seen as making science accessible through their ability to make the border of science ‘fuzzy’ and more inclusive (Barton, 1998). Providing a setting that is more inclusive of types of scientific knowledge is proposed to create a more flexible, and thus accessible, role of a science learner (Barton & Tan, 2009; Bevan et al., 2010). Rahm, Lachaine, and Mathura (2014) also suggest that these settings offer a flexible interpretation of what learning science involves, allowing students agency in their learning which empowers their sense of capability in science and can inspire further participation. Experiences in these settings thus provide students the opportunity to ‘refigure’ science in ways which challenge and break down the roles traditionally available in the science classroom (Barton & Tan, 2010). Correspondingly Bevan et al. (2010) argue that by providing a flexible environment that is inclusive of different ways of learning science, out-of-school settings are better able to facilitate youth participation in science learning experiences.

Another favourable aspect of out-of-school settings is that they often feature valuable resources that schools do not have, which can assist students in their ‘refiguring’ of science. Bevan et al. (2010) suggest that informal science institutions can present tactile, visual and kinaesthetic presentations through flexible use of space and technology that may allow students to engage differently with science, leading to new interpretations. Informal learning settings often also feature the historical and cultural context of science, which can facilitate a cultural understanding of science (Bevan et al., 2010) and help youth to make personal connections to the science (Archer, Dawson, Seakins, & Wong, 2016; Ash, Carlone, & Matthews, 2015). Learning experiences which blend students’ cultural and social worlds with that of science have been shown to help students to reinterpret science in ways that were personally relevant and empowering for them, thus encouraging their ongoing participation in science (Bouillion & Gomez, 2001; Carlone et al., 2015).

An additional affordance of out-of-school settings is that learning experiences can be constructed around students’ interest in ways that schools, limited by the curriculum, cannot. This can engage students in seeking out further opportunities to participate in science based on personal interests. There is evidence of youth clubs attracting youths into science based around other interests such as animal care (Zimmerman, 2012), cooking (Clegg & Kolodner, 2014), the environment (Barton & Tan, 2010) and feminism (Gonsalves, Rahm, & Carvalho, 2013). However this interest and engagement does not necessarily translate into successful participation in the school classroom if students do not recognise their activities as science (Zimmerman, 2012), or if the science in those activities is not recognized by authoritative others (e.g. teachers) (Gonsalves, Rahm, & Carvalho, 2013). Zimmerman (2012) makes the point that when youth are free to participate in science however they want, they will focus on what is enjoyable to them and may not engage in learning the scientific practices and content that is necessary for continuing with post-compulsory STEM education. This leads to the danger of youth not recognizing their participation as science and rejecting identification as a science learner (Zimmerman, 2012).

The flexible and supportive nature of out-of-school settings are often proposed as a way to facilitate students development of a science identity and a trajectory into post-compulsory STEM education (Carlone, Scott, & Lowder, 2014; Riedinger & McGinnis, 2016). Research into informal science learning has demonstrated that it is capable of being substantial and long lasting, providing emotional experiences that are can influence an individual's perceptions and ultimate career pathway (Bell, 2009; Rennie, 2014). The availability in out-of-school settings of multiple representations of science creates flexible norms for participation, making it more inclusive of students' varied interests and backgrounds (Carlone et al., 2015). This then gives students the opportunity to develop a science identity that includes their existing identities across their community and home, rather than the binary choice of either accepting the dominant science paradigm or rejecting it (Barton et al., 2012; Barton & Tan, 2009).

However research has shown that identity work in informal science learning may not be enough on its own to facilitate deep and persistent change in student perceptions of science. Gonsalves, Rahm, and Carvalho (2013) found that the cultural model of science as presented by school won out over non-school representations and Jensen and Bøe (2013) also observed that the motivation inspired by non-school learning experience decreased over time. Stake (2006) suggests that it is how the experience is interpreted and the social encouragement available once the student is back at school that could determine the impact of the out-of-school experience upon science motivation and confidence in learning science. Incorporating this out-of-school experience in students' science class can take considerable effort on behalf of the teacher and may not always be possible (Tan & Barton, 2010).

Further examination of many of the affordances of the informal science education sector reveals that like the formal education sector it is limited in engaging and supporting students to continue with post-compulsory science. The casual and relaxed nature of informal science learning allows multiple and flexible entry points but it also means sporadic and volitional participation is very common. Consequently many informal science education programs show minimal and fluctuating participation rates (Bevan et al., 2010).There is also evidence that these experiences only appeal to those youths already interested in science, thus limiting participation to students who are already strongly affiliated with science (Todd, 2016).

Research into student participation in informal science learning has further revealed that this participation is strongly linked to their family science capital (Archer et al., 2015).

Youth participation in informal science learning is generally associated with affluence, with families from working class or minority ethnic backgrounds often lacking the resources to facilitate their child's participation in extra-curricular activities (Francis & Archer, 2007). Dawson's (2014) research supported this and found that for certain population groups the cost of attending an informal science institution (ISI) was prohibitive, not just in the upfront cost of partaking in the activity itself but in the implicit financial costs of travel, food, souvenirs and the opportunity costs of the time spent. Dawson (2014) and Archer, Dawson, et al. (2016) also found that many exhibits and activities in ISIs assumed that the attendees were fluent in English and knew various western cultural and scientific background knowledge. Thus a high level of science capital is required for families to support their children in navigating and fully participating in informal science learning.

Despite their potential for engaging students in science, it is clear that informal science education in out-of-school settings is not enough to support students' transition into post-compulsory STEM education on their own. Formal science education has the advantage of mandated attendance as well as measured learning which allows a sequential and sustained approach to students' science education (Bevan et al., 2010). Bevan et al. (2010) claim that the nature of non-sequenced learning in informal science learning may not afford coherent understanding of processes and relationships across phenomena. Certainly Archer, Dawson, et al. (2016) found that despite enjoying the experience, youth who visited an ISI were unable to recall their learning afterwards, expect for one student who linked her experience to her science learning at school. Additionally informal science education programs can lack the educational expertise and bureaucratic reach of schools to facilitate ongoing and in-depth learning experiences which develop the knowledge and skills required for post-compulsory study. Lundh et al (2013) found that the lack of resources for several non-school settings, particularly regarding staff professional development, limited the effectiveness of the learning experience. Programs that were not well supported by education institutions were observed to have little inclusion of opportunities for students to reflect on their science learning, or to identify with science. These two categories are critical for students establishing an identity as science learners and encouraging ongoing participation in science education.

The immense variation in schools and out-of-school settings means it is erroneous to assume that all science classes are rigid and exclusive, or that all informal science learning is unstructured and without educational expertise. In general however the affordances of schools centre around their function as educational institutions, and out-of-school settings emphasize their flexible nature and relevance to youth. Both the informal and formal education sectors are limited in their ability to overcome the wider social structures and perceptions of science which dictate the way that students can participate in learning science. Instead many science educators and educational researchers are now arguing that drawing from both sectors is necessary to educate the STEM professionals and citizens needed for the future (Stocklmayer, Rennie, & Gilbert, 2010). This argument has brought increasing attention and support for an emerging third sector of science education; non-formal science education.

2.5 Chapter Summary

Across school and out-of-school settings student participation in learning science is dependent on their family's science capital. Those students whose families have the 'right' kind of knowledge and background are better able to access and then navigate the education setting. Consequently student participation in informal and formal science learning is consistently seen to be limited by individuals' sense of identification with science, their perceptions that such participation is not for 'people like me' (Aschbacher, Li, & Roth, 2010; Dawson, 2014). Opportunities for participation then arise when students are able to feel a sense of identification and inclusion in their science learning. Connecting a students' experiences of learning science out-of-school to their science learning in school can help with this. The next chapter will discuss how connecting students' experiences of learning science across settings can help to overcome the limitations of either setting. From this, the chapter will explore the growing role of non-formal science education in schools.

Chapter 3: Opportunities and Challenges in Non-Formal Science Education

3.1 Chapter Introduction

This chapter provides an overview of the emerging role of non-formal science education programs in schools. Section 3.2 introduces the non-formal sector, explaining how it has emerged through the collaboration of informal and formal science education. The next section (3.3) discusses the various roles of non-formal programs in schools, largely centring around their capacity to access, engage and empower students in meaningful learning experiences. Section 3.4 explores the current challenges to realising these roles. The chapter concludes with a section looking specifically at ongoing and collaboratively developed non-formal science education programs before outlining the research questions.

3.2 Introducing the non-formal sector

As discussed in the preceding chapter, the formal and informal sectors of science education each have advantages and disadvantages in supporting students to continue studying post-compulsory STEM. The different social and structural affordances of informal and formal learning settings create different learning experiences and thus provide students with different ways to participate in science (Bevan et al., 2010). Increasingly there are calls to draw from both sectors to provide students with accessible, inclusive and meaningful learning experiences within the school context and its pedagogical expertise (Bevan et al., 2010; Braund & Reiss, 2006; Stocklmayer, Rennie, & Gilbert, 2010). Consequently there is growing support in science education for providing students with learning experiences that arise from collaboration between the informal and formal sector.

As explained in Chapter 1, non-formal science education refers to organized science education activities that happen in out-of-school settings and are usually tied to a school's curriculum (Affeldt et al., 2017). These science education programs do not fit neatly into current categorizations of formal or informal science education and are increasingly, but not consistently, being referred to as 'non-formal' science education. Hence it is noted that while this thesis uses the terms 'non-formal' in summarizing findings from various studies, these terms are not the ones necessarily used by the authors of those works. For instance science education programs that fit within a non-formal definition have also been referred to as ‘cross sector’ collaborations (Traphagen & Traill, 2014), ‘formal-informal’ collaborations (Bevan et al., 2010; Weinstein, Whitesell, & Schwartz, 2012) or university outreach (Jensen & Bøe, 2013).

According to Bevan et al. (2010) ‘formal-informal’ collaborations take place between schools and informal education organizations (e.g. youth programs) and science rich cultural institutions (e.g. museums and zoos). However to provide their students with authentic and engaging science learning experiences many schools collaborate with other institutions beyond informal science institutions. It is common to see other organizations involved such as tertiary institutions (Henriksen, Jensen, & Sjaastad, 2015; Luehmann, 2009b), educational companies (Shuda, Butler, Vary, & Farber, 2016), industrial companies (Bryant, Gore, & Stocklmayer, 2015a), community groups (Bouillion & Gomez, 2001) and specially dedicated non-formal education institutions (Department of Education and Early Childhood Development, 2009). These programs represent a significant shift in how we conceptualize science education with increasing recognition that it is no longer the sole province of schools (Coll et al., 2013).

In many respects non-formal science education is a further evolution of the informal learning sector, which itself evolved largely out of dissatisfaction with western systems of science education (Ogawa, Loomis, & Crain, 2009). As highlighted in Chapter 2, the failure to achieve large scale reform of the formal science education sector, and growing appreciation of the capacity for youth science learning out-of-school, has led to the popularisation of collaborations between schools and external institutions. The past few decades have seen an increasing number of collaborations between schools and non-school organizations in developing and implementing non-formal science education programs (Bevan et al., 2010). Depending on the program, the desired outcome may be to encourage students as community minded and scientifically literature citizens (Bouillion & Gomez, 2001) or to encourage students into study pathways that lead to STEM careers (Jensen & Sjaastad, 2013) or a combination of the two. In general, teachers and schools seek out non-formal science education programs for their students which tend to centre around providing a more interesting, authentic and meaningful learning experience that is not possible at school (Anderson, Kisiel, & Storksdieck, 2006). Support for non-formal programs, particularly in science education, continues to grow worldwide and it is increasingly accepted as part of the educational landscape (Affeldt et al., 2017).

Non-formal science education programs can exist in a variety of forms with differences in the length and structure of the learning experience. This thesis will focus specifically on those programs run in collaboration with schools, which offer particular opportunities to students that non-school involved programs do not. Bevan et al. (2010) suggests that differences in the time and structure of non-formal programs can provide different opportunities to engage students in science. Unstructured and brief experiences may serve to stimulate student interest and introduce concepts while more structured and time intensive experiences provided by schools can facilitate deeper learning (Figure 1). Schools also possess utilise pedagogical expertise and long term teacher-student relationships which non-formal educators may not have (Bevan et al., 2010). As shown by Luehmann (2009b) and discussed by Tal and Steiner (2006), teachers can play an important role during the program by supporting their students and being involved in the non-formal program. The following sections will explore the possible roles of non-formal science education in more detail, specifically highlighting the opportunities these roles offer for helping students develop trajectories into post-compulsory STEM study.

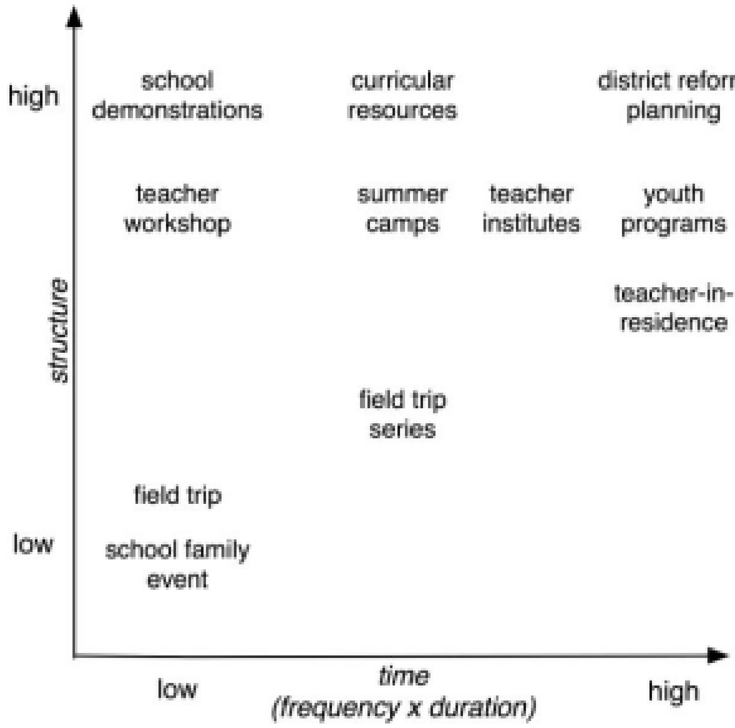

Figure 1. An example of types of non-formal science education programs; Formal-informal collaborations graphed by time investment and degree of program structure. Adapted from (Bevan et al., 2010, p. 28).

3.3 The roles and opportunities of non-formal science education programs.

An important role that non-formal science education programs can have in schools is that of engaging students, particularly those who would not normally take part in science related activities. Given that student attendance of non-formal programs in schools is typically compulsory this access is a key advantage that non-formal programs have over informal science learning. As described in Chapter 2, youth participation in informal science learning is highly variable (Bevan et al., 2010) and often reliant on their family's existing science capital (Dawson, 2014). Even non-formal programs that are not compulsory are often advertised through schools (e.g. Ahrenkiel & Worm-Leonhard, 2014) or made free specifically to school students (Kisiel, 2010) which can encourage attendance by students who would otherwise be unaware and unlikely to attend. Bevan et al. (2010) claims that non-formal science education programs run in schools can thus create equity and access for youth living in poverty. Further opportunities for informal and non-formal settings to inspire, inform and encourage under-represented students into post-compulsory STEM education can thus be made possible through non-formal school based programs.

Further to their role of student engagement, non-formal programs typically provide schools with resources for learning which may be more advanced, attractive, or otherwise inaccessible to schools. Such unique resources and overall novelty of the external setting can be highly engaging for students (Luehmann, 2009b) and are proposed to be the catalyst for a more deeper and sustaining interest (Rennie, 2014). Braund and Reiss (2006) claim that the resources available in out-of-school settings are more engaging to students as a result of having to attract attendance, particularly because as Bevan et al. (2010) highlight they are usually developed for general audiences of different levels of knowledge and interest. Certainly many non-formal and informal education providers aim to present science in a different and more engaging manner from school, making up for what they see as deficiencies in school representation of science (Ogawa, Loomis, & Crain, 2009). There are indications that schools do value non-formal programs as a source of resources that facilitate student engagement or learning (Luehmann & Markowitz, 2007). This is supported by Coll et al. (2013) who comment that formal science education often seeks out and adapts informal sector resources for their students. Hence there is a strong expectation that non-formal programs will utilise resources that will engage students in a science learning experience.

Often the purpose behind including non-formal science education programs in schools is to enable students to take part in learning experiences that are not possible at school or which are more authentic to scientific practice (Luehmann, 2009b). The importance of having authentic purposes and contexts for activities is stressed by Bevan et al. (2010) as key to facilitating purposeful and thus meaningful participation by students in STEM education. According to teachers this immersion of students in authentic science activities can help them develop confidence and affiliation with science (Luehmann & Markowitz, 2007). The capacity of authenticity in non-formal learning experiences to inspire student interest in science has been demonstrated throughout the science education literature; examples include an after school club (Clegg & Kolodner, 2014), a school-museum collaboration (Paris, Yambor, & Packard, 1998) or a collaborative non-formal program that involved university based laboratory experiments (Luehmann, 2009b). Non-formal and informal organizations recognize the value of this quality for students; Bryant, Gore, and Stocklmayer (2015b) describes how many Australian science centres were carefully established to take advantage of their location and the surrounding institutional or natural resources. Many non-formal programs are provided by, or arise from, collaboration with institutions such as science museums, natural parks or university laboratories which can provide students with a historical and cultural context to their learning experience that schools cannot (Bevan et al., 2010). Some non-formal programs go further and offer students the chance to try on authentic roles and engage in actual scientific practices (Burgin, McConnell, & Flowers, 2014). This allows students to explore potential STEM careers which can be empowering and enlightening for students as well as offering them future opportunities for study and work (Rahm, Lachaine, & Mathura, 2014; van Eijck & Roth, 2009). On the other hand interest inspired by a non-formal experience may only be temporary (Stern, Powell, & Ardoin, 2008) and there is considerable evidence to suggest that maintaining the changes catalysed by a non-formal learning experience requires students to be supported after program completion (Stake & Mares, 2005).

Non-formal programs can help students develop support for their interest in learning science by helping students' families to recognize student interest and capability in science. Student achievement or interest in science topics may not be understood by a family until it is shown as being helpful for academic success, which is highly valued (Fields & Enyedy, 2013). Alternatively, learning in a science class may not be meaningful in a student's and their family's everyday life but the activities offered in an informal or non-formal program can be a shared point of relevance (Barton et al., 2012). Linkage between settings and students' figured worlds also increases the overlap between a student's existing identities across their family, peer group and community, making it easier and less threatening for students to engage in science identity work (Carlone, Scott, & Lowder, 2014). Rajala et al (2016) propose that connecting science learning across settings is a way to deal with socio-cultural mismatches at the heart of many students' failure to develop a science identity and continue with post-compulsory STEM education. Non-formal programs are increasingly seen as a way to facilitate this connection between schools, students, local communities and the scientific community.

The focus of non-formal programs on the cultural and environmental aspects of science can create further points of connection and support for students which encourages them to learn science. Often a desired outcome of non-formal programs is to develop students' sense of 'place and connection' to their local environment (Carlone et al., 2015) or community (Bouillion & Gomez, 2001; Tytler, Symington, & Clark, 2016). For some of these programs, their main focus is not on encouraging students into specific STEM careers but on students as citizens whose awareness and future behaviour would affect the environment (Tytler, Symington, & Clark, 2016). Despite having an additional or even dominant focus that is not on students' post-compulsory study or careers, this program orientation can still offer students several opportunities for developing trajectories into STEM. Stevens, Andrade, and Page (2016) and Ash, Carlone, and Matthews (2015) showed that the emphasis on place and culture was critical to youth participating in the program and achieving a positive reform of the way students viewed science. Likewise Bouillion and Gomez (2001) observed that youth were empowered by their involvement in a community focused non-formal program. Students' participation in a community based non-formal program can also lead to recognition within a student's community which can support them to develop post-compulsory STEM trajectories (Polman & Hope, 2014). By being positioned where their background and community was valued and key to the success of the scientific endeavour, students are able to establish a comfortable position in science, making learning science possible and even attractive to them.

Non-formal science education programs can serve as a means to support and even empower students in their learning by providing opportunities for recognition and development of identities as science learners. The collaboration between schools and external institutions offers students the opportunity for teacher recognition of their ability in a different setting where they may be more successful in learning science. Teachers involved in non-formal programs report seeing their students participate in ways that showed them to be more capable or interested in science than they expected based on their behaviour in class (Luehmann, 2009b). When a teacher recognizes the interests and capabilities of a student in science outside of school, this opens up positions for those students back in the science classroom and can make it easier for students to participate in learning science (Barton & Tan, 2009; Fields & Enyedy, 2013). This transfer can be particularly beneficial to students who have been unsuccessful as science learners in a traditional classroom environment (Rahm, 2008). Teacher perception shift could be critical for students developing trajectories into post-compulsory STEM education as recognition from authoritative figures has been shown to be crucial for students developing a science identity and seeing science as possible for them (Carlone, Scott, & Lowder, 2014). Without school validation the impact from out-of-school experiences on student science identity development is limited and insufficient to disrupt the students pre-existing conceptions of science (Barton et al., 2012; Gonsalves, Rahm, & Carvalho, 2013). Hence it is a key advantage of non-formal programs that they can facilitate this recognition in a school setting.

Non-formal programs can further empower students by helping them access supportive networks and build science identities through the availability of role models. Many informal and non-formal settings recruit from the scientific community such as current undergraduates or retired professionals (Bryant, Gore, & Stocklmayer, 2015b). This enables students to get to know a wide range of people involved in science, other than their science teachers, who can serve as positive role models (Jensen & Sjaastad, 2013). Building relationships with instructors or other members of the non-formal setting can support students in their learning and make it fun and relaxing for them. It can also help students feel like they belong to the scientific community (Dowie, Barrow, & Nicholson, 2015). Some non-formal programs were specifically focused on mentoring, aiming to achieve student engagement through providing mentors from the same ethnicity as the students (Stevens, Andrade, & Page, 2016). Stevens, Andrade, and Page (2016) showed that this strategy helped make the learning experience culturally relevant to students and positively affected their interest and perceptions regarding science.

The capacity of non-formal science education programs to support students in their science learning also stems from the flexible participation made possible by the out-of-school setting. By providing a more flexible and inclusive environment for learning, out-of-school settings can give students more freedom to experiment with different roles and interpretations of science (Barton & Tan, 2009; Barton, Tan, & Rivet, 2008; Rahm, 2007; Tan & Barton, 2010). Affeldt et al. (2017) see this as a particular affordance of non-formal programs, where the flexibility of topic and pedagogical approach can offer students alternative ways of participating in learning science. Additionally within the non-formal program the teacher is often no longer positioned as the unquestionable authority but as a co-learner, which encourages student participation and experimentation with their roles as science learners (Riedinger, 2015; Riedinger & McGinnis, 2016). Hence non-formal programs can support students in crossing the invisible but ‘unthinkable’ boundaries to participation in science and open up new opportunities for student participation (Carlone et al., 2015). Taconis and Kessels (2009) claim making such boundary crossing easier is necessary in order to encourage more students to pursue post-compulsory STEM education.

While using non-formal programs to facilitate student engagement, connection and ultimately empowerment in learning science is highly valued in science education there is an expectation that non-formal programs will also support students’ achievement of learning outcomes. Teachers particularly value non-formal learning experiences for increasing their students’ skills and understanding of scientific content, as well as positively affecting student confidence and interest in learning science (Luehmann & Markowitz, 2007). Non-formal programs can further help students learn science by providing them with a meaningful and emotive learning experience. Strongly affective learning experiences in non-formal science education programs can be memorable and motivating for students who are then more interested and willing to participate in science class back at school (Luehmann, 2009b). This opportunity is recognized by teachers who desire social and affective experiences for their students in non-formal programs in addition to learning outcomes (Anderson, Kisiel, & Storksdieck, 2006; DeWitt & Storksdieck, 2008). Pursuit of this particular role for non-formal programs is however balanced with the need for schools to achieve learning outcomes for their students (Anderson, Kisiel, & Storksdieck, 2006). Currently evidence suggests that the potential of non-formal science education programs to extend student learning is not being fully realised (Banerjee, 2017a; Itzek-Greulich et al., 2016). This has implications for the ultimate aim of many non-formal programs, that of encouraging more students to continue with post-compulsory STEM education (Banerjee, 2017b). The following section will discuss current challenges to realising the potential roles of non-formal science education programs in schools.

3.4 Current challenges in realising the potential of non-formal programs

Throughout the science education literature many researchers have found that students' non-formal experiences need subsequent reinforcement back at school (Adelman & James, 2000; Stake & Mares, 2005) or risk losing out to the more consistent experiences at school and home (Gonsalves, Rahm, & Carvalho, 2013; Jarvis & Pell, 2005; Tytler, Symington, & Clark, 2016). School based preparation and post de-briefing can also extend out-of-school learning experiences and enable students to engage in the learning in more depth (Luehmann, 2009b). Ensuring that an external informal or non-formal experience is connected to the curriculum is consequently a high priority of teachers (Kisiel, 2005; Storksdieck, 2001; Tytler, Symington, & Clark, 2016) though one which is continually reported as not occurring (Anderson, Kisiel, & Storksdieck, 2006; DeWitt & Storksdieck, 2008; Stake & Mares, 2005). This is concerning as it is well established that learning experiences in informal or non-formal settings need to be connected to students' school learning in order to obtain the maximum impact from the experience (DeWitt & Osborne, 2007; Fallik, Rosenfeld, & Eylon, 2013). Subsequently a key challenge to realising the various roles of non-formal science education programs lies in ensuring students' experiences are incorporated back into their learning at school.

Another challenge to maximising student outcomes from non-formal learning experiences involves establishing appropriate expectations in the students and teachers involved. Students may have expectations of novelty and fun for their non-formal program, especially for programs run at informal science learning institutions. While initially encouraging attendance, if these expectations are not met this can affect student satisfaction with the experience (Appleton-Knapp & Krentler, 2006). Fun based expectations can also reduce the impact of the non-formal program (Garner & Eilks, 2015), particularly with regard to student learning (Orion & Hofstein, 1994). Ensuring students are aware of the learning outcomes for their non-formal learning experience is critical, as settings which are less structured and organized than those students are used to may leave students less able to recognize the learning outcomes (Stewart & Jordan, 2017). Storksdieck (2001) and Garner and Eilks (2015) further stress that this learning orientation of students is essential for the success of the non-formal program. However teachers are often unaware of the importance of setting student expectations and many do not consider it to be important when planning non-formal programs (Anderson, Kisiel, & Storksdieck, 2006; Storksdieck, 2001). Some teachers remain unaware of how to forge this connection effectively or face difficulties in doing so amidst time and curriculum constraints along with their own unfamiliarity with the program (Anderson, Kisiel, & Storksdieck, 2006). Storksdieck (2001) found that teachers often attended visits with vague or incorrect expectations themselves, which can affect the incorporation of the visit into a student's school learning (DeWitt & Storksdieck, 2008). Establishing appropriate expectations in both teachers and students therefore is needed in order to effectively implement the desired roles of the non-formal program in schools.

Further challenges arise when the expectations of schools and teachers do not align with those of the non-formal staff and their institution. While a non-formal education provider usually shares similar goals to schools for creating a meaningful science learning experience, what this looks like can differ between educators (Robertson, 2007). The external institution providing the non-formal program may also have additional goals for the program not shared by the school, such as an underlying mission to inspire environmental ideals (Robertson, 2007; Stern, Powell, & Ardoin, 2008), building student familiarity with an institution to aid in recruiting future tertiary students (Finkelstein, Mayhew, Henderson, Sabella, & Hsu, 2008; Jensen & Bøe, 2013) or increasing the number of visits from members of the public or schools themselves (Friedman, 2010; Irwin, Pegram, & Gay, 2013; Pedretti, 2002). Having different underlying goals for the experience results in different interpretations of what a successful experience looks like (Kisiel, 2014). For instance an external institution may measure the success of the program in terms of repeat business (Tytler, Symington, & Clark, 2016) and not the affective or learning outcomes desired by teachers (Anderson, Kisiel, & Storksdieck, 2006). Kisiel (2014) states this discontinuity can lead to different expectations and subsequent experiences for students. Resolving different or even conflicting priorities for the collaborative experience is critical to realising its opportunities for students but as Kisiel (2010), Tytler, Symington, and Clark (2016) and Bouillion and Gomez (2001) all highlight, achieving this resolution can be a challenging process of negotiation across different educator communities.

Anderson, Kisiel, and Storksdieck (2006) and Kisiel (2010) both argue that difficulties for teachers and non-formal educators in establishing shared expectations for a non-formal program stems from conflict between the two different cultures of formal and informal science learning. Even brief non-formal science education programs require teachers and external staff to be aware of cultural differences between their communities and to be prepared to navigate those differences (Bevan et al., 2010; Kisiel, 2010; Tytler, Symington, & Clark, 2016). Despite general teacher enthusiasm for non-formal education, the very different and often innovative experiences provided in non-formal learning can encounter resistance in schools (Tytler, Symington, & Clark, 2016). It is common therefore for non-formal programs to rely on the efforts of an individual who is particularly passionate (Bevan & Semper, 2006) and who has familiarity with the external community, thus being able to act as a boundary worker or culture broker between different communities (Tytler, Symington, & Clark, 2016). This boundary work is important as inefficient collaboration can result in the unique affordances and opportunities of a non-formal setting being lost. This can result in non-formal programs where classroom norms and positioning of students in such settings persist, limiting the opportunity for students to try out new roles as science learners (Tan et al., 2013). Resolving conflict between two different cultures and creating a shared purpose for non-formal programs is key to realising the desired roles of a non-formal program, however it takes time and commitment to develop such an understanding which can involve considerable effort (Kisiel, 2010; Robertson, 2007).

An overarching challenge to realising the roles of non-formal science education programs lies in their acquisition of sufficient funding. Non-formal programs may be able to draw on the resources and abilities of multiple settings to provide valuable resources however they are also vulnerable to their associated pressures (Tytler, Symington, & Clark, 2016). Both Robertson (2007) and Bouillion and Gomez (2001) describe collaborative non-formal programs as subject to the conflicting priorities of the stakeholders who must each cope with limited time and funding. In some respects non-formal programs can be more vulnerable to funding and organization problems as they may lie outside the typical funding set up for schools (Bevan et al., 2010) or be reliant on informal science institutions which themselves face considerable difficulties in obtaining and maintaining funding (Bryant, Gore, & Stocklmayer, 2015b). This is often the case for the many non-formal programs which tend to spring up from arrangements on a local level. The emergence of top level support for non-formal programs therefore may provide a more secure funding arrangement which could allow for more involved and long-term collaborations between schools and non-formal education providers. Facilitating such collaborations could provide the time and commitment needed to overcome the main challenges to implementing non-formal programs in schools. However as the next section will highlight, ongoing and collaborative non-formal programs are rarely studied and there are currently many unanswered questions about their operation and impact on students.

3.5 Looking specifically at ongoing and collaborative programs

Non-formal science education programs that are long term or ongoing are reported to have several benefits over short term programs. The time available and involvement of school teachers in developing the learning experience allows for targeted programs that are more effectively implemented and connected across settings (Bouillion & Gomez, 2001; Kisiel, 2010; Luehmann & Markowitz, 2007; Robertson, 2007). In addition to facilitating familiarity and connections between the communities of school and non-formal education, long term collaborations could potentially have a more significant role in students' science learning than short term efforts. There is some evidence in support of this, with a year-long collaborative partnership showing a substantial impact on students motivation to learn science (Luehmann, 2009b) while a program for a unit across several weeks resulted in temporary moderate increases in student motivation to learn science (Itzek-Greulich et al., 2016). There are also reports of increased student engagement and interest in science following involved and long term non-formal programs (Bouillion & Gomez, 2001; Garner & Eilks, 2015; Kisiel, 2014; Paris, Yambor, & Packard, 1998; Polman & Miller, 2010; Robertson, 2007). However these reports represent nearly all of the current known investigations into long term non-formal programs and there remains a lack of evidence illustrating the roles that ongoing and collaborative non-formal programs can fulfil in schools.

Kisiel (2010) highlights that while there are many examples of formal partnerships between schools and informal institutions, there is limited documentation of the outcomes of such partnerships. Bevan et al. (2010) agree with this, discussing the challenges in finding sufficiently documented programs for their review and commenting that many such collaborative programs undergo limited evaluation. This is suggested to be a result of program orchestrators not being trained researchers and a lack of funding and time to invest in in-depth evaluation (Bevan, 2010). The challenge of collecting and analysing data systematically and comprehensively is made more difficult by the small scale and insecure position of many non-formal programs. Current understanding of collaborative non-formal learning experiences is further limited by restricted or biased samples which offer poor generalization (Itzek-Greulich et al., 2016). Consequently despite a long history of ongoing and collaborative non-formal science education programs used by schools there is a lack of consistent and comprehensive documentation of outcomes and impact on students when compared to the wealth of information on formal science education or even informal learning (Affeldt et al., 2017; Bevan et al., 2010).

The need for further research into ongoing non-formal science education programs used by schools is emphasized by the increasing number of large scale collaborations being implemented across the world. Kisiel (2010) once reported that formal partnerships between informal institutions were more the exception than the rule but it is now becoming common for such partnerships to be initiated as a result of policy directives. Across the world in Europe (Affeldt et al., 2017), the US (Traphagen & Traill, 2014) and in Australia (Victorian Auditor General, 2012) there are large policy initiatives underway to support non-formal science education programs in schools. Further evidence of the incorporation of non-formal education into the formal sector comes from the emphasis placed on it in teacher training (Monteiro, Martins, de Souza Janerine, & de Carvalho, 2016). Altogether it is evident that non-formal science education is taking on increasingly more influential roles in the formal science education system. It is important then to ascertain whether such large scale programs are able to overcome the challenges faced by small scale and locally based non-formal programs, or whether there are new, unique challenges that require attention.

While there is much support for the potential of non-formal science education programs to address perceived problems in science education in schools (Affeldt et al., 2017; Stocklmayer, Rennie, & Gilbert, 2010) there has been little research into either their roles and the opportunities that they may offer or the challenges to realising those opportunities (Bevan et al., 2010). Tytler, Symington, and Clark (2016) argue that in order to improve the effectiveness of connecting students' learning experiences across settings a better understanding of collaborations between different educational organizations is needed. While the scale up of collaborative partnerships for non-formal science education is aimed to increase their effectiveness and impact there is currently no evidence demonstrating this. A recent study in the UK found the reverse, suggesting that numerous non-formal programs or interventions run at schools had no significant effect on student post-compulsory STEM subject choices (Banerjee, 2017b) or maths attainment (Banerjee, 2017a). It is not possible to say whether these trends may be replicated in Australian science education given the differences between the two education systems and, to the best of the researcher's knowledge, there has been no equivalent research conducted in Australia. The results of Banerjee (2017b) however emphasize the need for more research into non-formal science education programs in schools. As a quantitative examination of student datasets these reports do not explore potential reasons behind the trends observed nor do they examine what roles non-formal programs were trying, or failing, to fulfil in schools. Given the potential of non-formal science education programs to affect student trajectories into post-compulsory STEM education through various roles, it is crucial to understand what factors affect student experience of long term collaborative non-formal science education in the Australian context.

3.6. Research Questions

This research aims to contribute to current understanding of the roles that a collaborative and ongoing non-formal science education program can have in secondary science education. The primary aim of this research was to investigate the roles of the non-formal science education program through the perspectives of its stakeholders; teachers, students and non-formal staff. Research question 1 sought these perspectives in order to explore the variety of roles possible and ascertain any challenges or limitations to realizing those roles.

1. *How are students' experiences in a long term, non-formal science education program interpreted by students, their teachers and non-formal staff?*

A key motivation for this research was the lack of evidence available concerning the stakeholder experience of non-formal science education programs. In particular there is little reported about programs that are designed to be ongoing or that occur between schools and a dedicated non-formal education institution. Consequently two research questions were devised to examine these defining aspects of long term and collaborative implementation:

2. *How do stakeholder interpretations of a non-formal science education program vary over time?*
3. *Is there an interaction between the collaborative nature of a non-formal science education program and stakeholder interpretation of it?*

It has been well demonstrated that a students' background, particularly their family's science capital, greatly influences their choice to do post-compulsory STEM study. It has also been shown that student background has a critical influence on a student's participation in learning science in informal, non-formal and formal settings. Hence it was necessary to explore whether student background played a role in how students approached and interpreted their non-formal learning experiences:

4. *Is there an interaction between student background and students' interpretation of the non-formal science education program?*

The final research question of this thesis was written to direct exploration of a strongly desired outcome from non-formal science education programs, their capacity to develop student trajectories into post-compulsory STEM education.

5. *What opportunities are there in an ongoing non-formal science education program for students to develop trajectories into post-compulsory STEM education?*

The specific non-formal science education program chosen for the research was a newly established and possibly unique model in Victoria, Australia. This collaboration involved the partnership of six secondary schools with a dedicated non-formal science education centre; the Knox Innovation, Opportunity and Sustainability Centre (KIOSC). KIOSC was established in 2013 to support the secondary science education of the six schools through a range of non-formal learning experiences linked to their science curriculum. It is the flagship model for a series of similar non-formal specialist institutions called 'Tech Schools' currently being developed in the state of Victoria. This model is described in further detail in Chapter 4.

3.7 Chapter Summary

This chapter has given an overview of non-formal science education and illustrated the potential roles that non-formal programs can provide in schools. Subsequent sections discussed the challenges in realizing these roles and highlighted how effective collaboration between institutions was both a source of issues and a key to resolving them. From this the emergence of ongoing and collaborative non-formal programs was introduced while highlighting the current lack of knowledge concerning their impact upon students. The necessity of investigating ongoing and collaborative non-formal science education programs was argued, leading to the establishment of the research questions for this thesis. The next chapter will outline the study design and choice of methods undertaken in order to address those research questions.

Chapter 4: Research Design

4.1 Chapter Introduction

The preceding chapter discussed roles that non-formal science education programs could provide for schools and the opportunities they offered to encourage students to continue studying STEM post-compulsory. It then explored the challenges to effective implementation of non-formal programs and realisation of those opportunities. The chapter concluded with an overview of the increasing prominence of non-formal science education collaborations and highlighted the lack of research available about them. This combined to form an argument for the need to research such programs in Australia where several non-formal science education partnerships for schools are currently being directed by government policy.

This chapter explains how the study was designed in order to achieve the research aim; to explore the roles of an ongoing, collaboratively developed non-formal science education program in Australian secondary schools. This aim is broken down into 5 research questions which are repeated here:

1. *How are students' experiences in an ongoing, non-formal science education program interpreted by students, their teachers and non-formal staff?*
2. *How do stakeholder interpretations of a non-formal science education program vary over time?*
3. *Is there an interaction between the collaborative nature of a non-formal science education program and stakeholder interpretation of it?*
4. *Is there an interaction between student background and students' interpretation of the non-formal science education program?*
5. *What opportunities are there in an ongoing non-formal science education program for students to develop trajectories into post-compulsory STEM education?*

Section 4.2 looks at the research setting; the partnership under study and the participants involved. 4.3 discusses the methodology approach used in this research and outlines the study design. The development and implementation of the methods are then explored in more detail in Section 4.4 while Section 4.5 gives an overview of the data analysis. This chapter concludes with a discussion of the validation strategies used in this study in section 4.6.

4.2 Research setting: Case Description

4.2.1 A Case Study Framework

This investigation took the form of a case study into a specialist non-formal science education centre located in the suburb of Knox in Victoria, Australia. Given the lack of available research into ongoing collaborations for non-formal science education in the Australian context this research was intended as an exploratory venture for which a case study approach was needed (Yin, 2014).

Generally case studies are used to explore a particular program, event, activity or process and involve intensive data collection around a limited number of individuals over a sustained period of time (Stake, 1994). This makes case study a suitable approach for investigating complex social phenomena such as education where the events under study will be largely or entirely uncontrollable by the researcher. This framework is additionally suitable for the focus of this research which centre around 'how' and 'why' questions that seek to explore a new phenomenon (Yin, 2014).

4.2.2 Case Description: KIOSC

The Knox Innovation Opportunity Sustainability Centre (KIOSC) is located at the Wantirna campus of Swinburne University in the district of Knox, Victoria. Knox contains historically working class suburbs and is currently home to over 160,665 people. An established centre of manufacturing, Knox is seeing considerable change in many of its industries which are becoming more skills-intensive in response to globalization and increased specialisation (REMPLAN, 2018). It is in this environment that KIOSC was established "*to inspire and empower today's students to develop the skills, knowledge and behaviours which will equip them for their future careers*" ("KIOSC," 2017). KIOSC was specifically established in partnership with six local secondary schools, the local Knox council, local industry and Swinburne University on whose campus it is based. KIOSC is managed collectively by the partnership stakeholders represented by a board which meets four times a year along with an industry advisory group. This particular model of collaboration for non-formal science education is, as far as the researcher can establish, unique to Australia.

The overall stated goal of KIOSC is to educate attending students about sustainable futures and help them access further study and career opportunities ("KIOSC," 2017). As part of this goal KIOSC aims to build students' scientific literacy, critical thinking ability, employability skills and overall awareness of possible study and career paths in desirable fields, particularly STEM professions. It was designed and built specifically to create a learning environment that reflects innovative and sustainable engineering technologies. The centre was originally established under the Federal Government's Trade Training Centre in Schools Program and opened in April 2013. Since April 2016, KIOSC has been funded by the Victorian State Government as a model for their Tech School Program. This program involves establishing 10 similar institutions modelled on KIOSC which are due to be open by 2018. Like KIOSC, they will be hosted on the campuses of tertiary education institutions. While these tech schools all share the aim of supporting students in their transition from school to further study and employment, the programs on offer will be shaped by the local industry and employment needs.

KIOSC primarily provides programs to the secondary students from the six consortium schools. A few programs are also provided for primary school students and for schools who do not belong to the consortium but this is not the main focus of KIOSC. Students in years seven to ten from the consortium schools attend programs twice a year that span a broad range of science areas with an emphasis on environmental, economic and socio-cultural sustainability perspectives. Students in year nine can also attend 'Taster' days of VET (Vocational Education and Training in schools) courses, a showcase of potential courses which are run by Swinburne University staff. These VET courses are run by university staff and specifically address areas that have been identified as skills shortages in the local area. The courses available at KIOSC are laboratory work, printing and graphic arts, engineering and electrotechnology. More senior students (years ten to twelve) enrolled in post-compulsory STEM subjects attend programs specific to that subject (e.g. psychology) and have the option of doing a VET course at KISOC.

The programs offered at KIOSC to students from year seven to ten are called 'Discovery Programs'. They are designed to align with the Australian school curriculum and match outcomes of the Victorian Career Curriculum Framework. The aim of the programs is to build student understanding of the natural and built environment, innovation, technology and sustainability. At the time of this study the themes for programs included Energy, Water, Waste, Biodiversity, The Changing Earth (plate tectonics), Sustainable technologies, Robotics and Forensics. This focus reflects the tag line of KIOSC as *"An innovative learning centre that will give students the opportunity to develop the new "green" skills essential for success in the workplace of the future"* ("KIOSC," 2017).

These visits to KIOSC are not an optional excursion; all students are required to attend. For large year level groups the visits to KIOSC necessitate splitting up the students and running the program over a few days. Each class visit to KIOSC is accompanied by teachers, typically the science teacher but also teacher aides and other teachers who do not teach science who come along as helpers. Apart from a materials fee for some VET courses, all programs are at no cost to the students. In previous years however, schools which were not within walking distance had to charge students a nominal fee for bus transport. This fee is currently covered as part of KIOSC's funding under the Victorian Government Tech Schools program.

The schedule and selection of programs for students is organized between the school science teachers and KIOSC staff, typically at the beginning of the school year. Each program offered at KIOSC is designed to directly link in with a school's science curriculum but some programs are only available at KIOSC at certain times of the year. In 2016 schools were given a binder of resources with associated activities provided for the class to do before and after the visit. For the consortium schools participating in this research the organization of KIOSC visits was managed by a designated science specialist teacher.

When first entering KIOSC visitors walk across a short bridge over a sunken courtyard into a large, airy foyer on the upper floor. This space is bright and modern, with floor to ceiling glass windows on one side and a wall with posters and student projects on the other. Technology is integrated throughout KIOSC; most rooms have a smart board, several have multiple interactive screens and projectors on walls and in one case the ceiling and floor as well. These technological features of the building are incorporated into several programs for students on sustainability. There are numerous multipurpose workshops spread out over two levels; theory rooms, preparation rooms and an outdoor workshop. Programs for the junior students are held in the upper floor rooms which consists of two laboratory workspaces and two multipurpose spaces, as well as a set of staff offices and staff kitchen.

Programs typically run from 9:30 am to 2:30 pm and are divided up into three 75 minute sessions with breaks in between for morning tea and lunch. Often two or more classes would be running at the same time in separate rooms. Each session is devoted to an activity which relates to the overall theme of the day, e.g. Biodiversity or Robotics. The sessions vary in level of interaction, with some requiring students to be moving around the entire time and others involving working at tables. All sessions start and end with a short briefing by a staff member explaining or recapping the activity. To illustrate, I describe here activities from two different programs in which the students participating in this research took part; a biodiversity themed program with a single, self-contained activity per session and a forensics themed program which had one main activity for the whole day.

One session in the Biodiversity themed program was highly interactive and involved students taking on the role of an animal or plant with a bunch of tokens that increased or decreased depending whether they consumed energy (from the sun or other animals and plants) or were eaten themselves. The students had to move between different 'habitats' around the room as various events occurred, narrated by the staff member running the activity. Eventually all except one student went extinct and that one student was announced as the winner. The animals, plants and habitats involved in the activity were all based on a local reserve which students were familiar with. Another Biodiversity session was less active physically and involved students measuring the populations of animals and plants using quadrats. Laminated photos of animals and plants were strewn randomly on the floor and students had to count and also identify the species with an information booklet.

The Forensics program involved a series of stations throughout several rooms at KIOSC which students worked their way around in pairs over the three sessions. At each station students carried out an activity such as testing the pH levels of soil, measuring footprints or using UV light to detect 'blood' on clothes. Each student pair gathered data in order to determine the murderer in a scenario presented at the beginning of the day and had to argue their case against other pairs of students in a recap at the end of the day's final session.

The resources used by students varied between programs but included I-Pads, interactive screens on the walls, programmable robots, scientific equipment (e.g. beakers, scales, thermometers) and crafting materials (e.g. cardboard, textas). Depending on the activity the I-Pads could be used for measuring data, undertaking research, completing a game or series of activities or as a tool for visualizing augmented reality. The building itself and the surrounding grounds could also be counted as a resource; KIOSC was built to showcase sustainable technologies and was used in several activities, for example one requiring students to measure the temperature in different locations. Several pieces of equipment were also specifically constructed for use in particular activities, e.g. the series of laminated photos of different animals or plants used in the biodiversity session and the accompanying information booklet.

4.2.3 Participant Selection

The focus of this study is on the non-formal learning experiences of students in year seven and eight, the first two years of Australian secondary school. These years were chosen because this age group (12-15 years) is recognized as a key age where youth interest in science is established (Lindahl, 2007). Cultivating interest and awareness of science career pathways in this age group is important as youths who develop STEM career aspirations at this age are more likely to end up pursuing post-compulsory science education (Tai, Liu, Maltese, & Fan, 2006). Furthermore, encouraging student interest and enjoyment of junior science classes is overwhelmingly advocated by science teachers as the most effective way to get students enrolled in senior, post-compulsory science classes (Lyons & Quinn, 2010a). Thus students in years seven and eight are an important age group to examine the effects of interventions designed to encourage students post-compulsory STEM education, even though critical subject enrolment decisions are a few years away. Year nine students were approached, but insufficient numbers agreed to take part and subsequently were not included in this study.

Student participants were recruited for this study in order to understand the student experience of the non-formal programs at KIOSC and what affect this had on their perceptions and attitudes concerning science. The necessity of obtaining students' perspectives was made clear by research which shows that the way students perceive non-formal programs affects how they approach and participate during the experience (Garner & Eilks, 2015). A student perspective also affords in-depth investigation into the underlying reasons for the choices to engage or not with science education which are not always apparent in examining their end choices (e.g. Holmegaard, Madsen, & Ulriksen, 2012).

The teachers who attended the KIOSC programs alongside students were also recruited for this study. This included the students' science teachers, as well as non-science teachers attending as helpers. Including the teachers' perspectives of the non-formal program was important as they had valuable insight into their students' experiences. Teachers are able to observe their students in both the school and non-formal settings and are best positioned to pick up on any changes in students from their non-formal experiences. As shown in Luehmann (2009b) study, obtaining the perspectives of teachers and students of the same non-formal science learning experience can provide different but complementary insights and a more comprehensive view of students' experiences. Teachers are able to recognise the changes in students that are made possible by the non-formal program which students may not be aware of. Teachers' involvement in collaborating with the non-formal institution also makes them able to comment on the challenges and limitations present in the non-formal programs as well (Robertson, 2007). The effect on teachers themselves is another reason to gain their perspectives. Teachers are often critical influences on students' trajectories (Victorian Auditor General, 2012) and their involvement in non-formal science education programs can help develop their capability to teach science in innovative and relevant ways (Kisiel, 2010).

As Kisiel (2010) and Robertson (2007) highlight, the different communities involved in non-formal science education programs (such as museum educators, zoo staff or professional scientists) are a key source of information on the opportunities and challenges present in the programs. To fully explore a non-formal science education program it is necessary then to include the perspectives of the non-formal educators. Hence all four of the KIOSC staff who ran the programs for schools were recruited for this research. All staff were qualified secondary science teachers though not necessarily registered, as the teachers who accompanied students from school always included registered teachers. One staff member left mid-year, leaving three staff running the programs. These staff were directly involved with schools in organizing students visits while overall management of KIOSC was handled by the director.

4.2.4 Recruitment and ethics

At the time of research and writing other examples of this non-formal science education model were not yet established so they could not be included for comparison. Hence only the six schools that were members of the KIOSC consortium were contacted regarding this research.

Prior to recruiting participants, ethical clearance was obtained from the Australian National University and the Victorian Department of Education. Once this was obtained in late 2015 each school in the KIOSC consortium was sent an invitation to take part in the research by email (see Appendix A), and then a follow up phone call if there was no response. Of these six schools only two consented to take part. The two schools that participated in this study were suitably representative of the six schools partnered with KIOSC. These schools were designated 'School 1' and 'School 2'. These two schools both follow the same Australian secondary school curriculum, have similar population demographics and are based in the same suburb with only a 10 minute drive apart. Both schools had voluntary science clubs run by the science teachers and also had long term hands on projects with live animals (e.g. mice). However there is a number of differences between the two schools which are described here.

School 1 was very small with only one class each for year seven (24) and eight (28), while year nine and ten shared a combined science class in the year that the study was conducted. There were two science teachers responsible for both classes, one of whom was the head of science for the school and the main contact with KIOSC.

School 2 was of size more typical for an Australian secondary school with four classes per year level and six teachers involved in teaching years seven and eight science. One science teacher who taught a year seven and eight class was also the careers counsellor for the school. There were four separate classes for year nine science but in previous years there had been no year ten science class due to lack of demand. Students who were interested pursuing science had previously gone straight from year nine into year eleven level science units. The lack of a year ten science class is not typical of an Australian secondary school.

Treating the two schools as multiple cases and thus statistical replicates was thus not possible due to the low number of participating students. Instead the experiences of students and teachers from these two schools are treated as a whole, with any particular differences made clear where relevant.

Early in 2016 I visited year seven, eight and nine classes in both schools to explain my research to students and hand out information sheets and consent forms for participation (see Appendix B and C). Further reminders were provided by the science teachers and also a notice in each schools' newsletter. As the student participants were minors the information sheet was sent home with the student and consent was required from both the student and the parent. While all students from years seven, eight and nine in both schools were invited to take part only a small proportion of each year level returned the consent forms. Originally this research intended to explore student perspectives at years 7 and 9 only, but due to the lack of participating year 9 students this was changed early on to focus on students in years 7 and 8. Student participation in the study varied over the year as some students were not present at school when gathering data and one student moved schools mid-year. No incentives were offered to take part.

On their consent form (see Appendix C) all participants were offered the option of using their name, pseudonym or no attribution for their comments in any reports arising from the research. It was made clear to all participants that comments could be potentially linked to a particular school. In an effort to limit risks and protect the confidentiality of all participants, no data was reported verbally or in writing in a manner that could identify individuals without prior consent of these individuals. Responses were coded in a manner allowing re-identification only by the researcher.

4.3 Methodology

4.3.1 Study design development

Originally this research was planned as an explanatory mixed methods design (Creswell, 2013b) with a pre and post survey to measure changes in students' perceptions and attitudes regarding science. Once the initial survey provided an overview of the student population it would be used to guide sample selection for a series of interviews to explore student perspectives in depth. However an acceptable number of consent forms were not received from students. The research design was therefore subsequently refined to a more explorative focus which used a primarily qualitative case study approach (Figure 2.).

The final study design involved interviewing students, teachers and staff after each of their two visits to KIOSC. Students also completed a reflective survey after their second and final visit which asked students to reflect on their experiences at KIOSC. This kind of survey allowed extensive exploration of students' perceptions of their non-formal learning experiences; how they interpreted their experience and how they felt their experience had affected them.

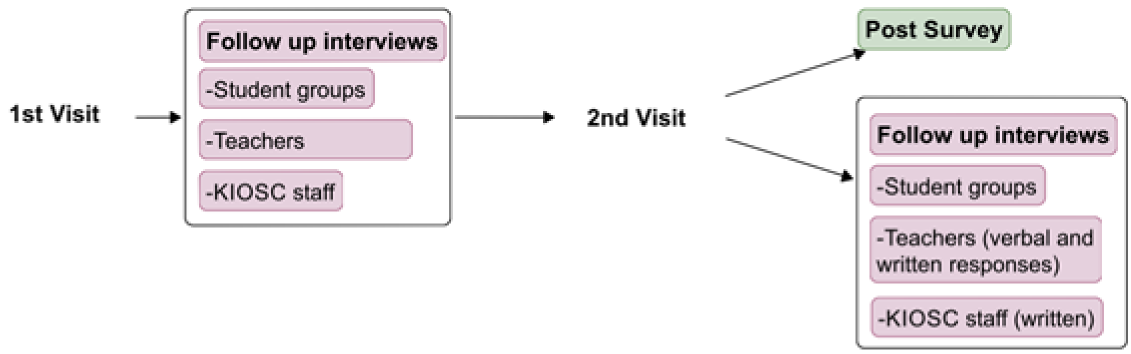

Figure 2. Final Study Design

4.3.2 A Qualitative Focus

Exploring the roles that non-formal programs can take on in schools and the opportunities for developing students' post-compulsory trajectories requires understanding how students' non-formal experiences affect their attitudes and perceptions regarding science. This research was not testing an objective theory as would be typical for a quantitative approach but was exploring what individuals think, a problem more suited to a qualitative perspective. Qualitative researchers are interested in understanding how individuals construct meaning from their experiences and their priority is interpreting and representing that meaning (Merriam & Tisdell, 2015). A qualitative methodology also fit well with this study's focus on exploring individual interpretations of particular experiences as it is a sensitive way of capturing the lived experiences of people in depth (Hesse-Biber, 2010). Hence qualitative methods were primarily used for the research questions which focused on elucidating individuals' perceptions of their experiences (as laid out in section 4.1)

While a qualitative approach dominated the research overall some additional quantitative data was also gathered from a post program student survey. Using mixed methods in this research enabled a flexible choice of methods that were most appropriate to answering the research questions, enabling a more complete comprehension of students' non-formal learning experiences than qualitative research alone (Creswell, 2013b). Using multiple methods also facilitated the collection of a more varied and stronger array of evidence than single methods alone would have (Yin, 2014). In this respect the main purpose of including a quantitative survey was to provide a broad perspective across the student sample for several independent demographic variables that are known to influence student trajectories into post-compulsory STEM education (e.g. family levels of education Archer et al., 2012). This data was especially needed to answer research question four which looked at the role that students' background played in their responses to KIOSC. The survey also looked at how students felt that their non-formal learning experiences had affected them which was used to answer research question 5 on opportunities. A series of Likert scale questions sought to quantify student perspectives on how their visits to KIOSC had affected their attitudes to, and perceptions of, science. It was initially intended that this data from the survey would also provide a means of generalizing the research findings to the wider population, but due to lower than expected numbers a statistical analysis was not possible. Instead this data is used as descriptive information about the sample population of the participating schools.

4.4 Instrument Development and Study Protocol

4.4.1 Program Attendance

I attended five of the eight visits to KIOSC that involved year seven and eight students from the two schools participating in the research. My attendance at these visits served primarily to build a familiarity with the students, teachers and staff prior to conducting interviews. Once this relationship was established it was not necessary to attend students' second visit to KIOSC for the year.

Those present were aware of my role as I had been previously introduced to the students and teachers from the two participating consortium schools when originally recruiting students for the study. This introduction was repeated on student visits to KIOSC when necessary, as these took place several weeks after my initial visit. During the visit I did not take part in the activities and my interactions with students and teachers were largely limited to pleasantries and discussion of the activity. My presence during the visits helped guide subsequent interviews with students, teachers and staff, for example by asking about a particular activity or event that had occurred to prompt reflection. A level of familiarity with individuals also assisted the flow of conversation during interviews and enabled me to probe in more depth on particular points.

A concern of observation research is that the presence of the observer affects what is being observed and that the researcher's own bias and subjectivity will affect their observation (Merriam & Tisdell, 2015). My presence may have modified participant behaviour, for instance by encouraging students to perform in a more socially acceptable manner. However after the initial introduction I believe my presence was minimally disruptive as throughout the day staff, teachers and students were all more concerned with proceeding in a timely fashion through the activities and in interaction amongst themselves. As the students were in a novel setting and in the presence of unfamiliar adults (KIOSC staff) it is likely that the addition of one more unfamiliar adult did not dramatically affect their participation or overall behaviour. I attempted to further minimise any impact of my presence by remaining to the back of the room during staff teaching and only interacting with students during the activities when it was clear that social interaction was taking place, e.g. a group of students and teachers gathered around a table discussing a particular activity.

4.4.2 Interviews

Interviews are key tools for exploring the internal motivations and perceptions of individuals; how they interpret or make meaning of their experiences (Rubin & Rubin, 2011). This makes them a common component of qualitative research (Ritchie, Lewis, Nicholls, & Ormston, 2013) and a necessary tool here in this research exploring stakeholder interpretations of a non-formal science education program. Consequently for this research the main data gathering was performed through a series of semi structured interviews.

Semi-structured interviews were used to elicit participant responses on particular topics which were of interest while also allowing freedom to explore certain responses in depth or to follow relevant tangents. The questions asked were specific to participant type, either staff, teacher or student (see Appendix D for a complete list of questions). Teachers, staff and students were interviewed in the weeks after each KIOSC visit that they were involved in. This meant that some teachers were only interviewed once while most of the staff were interviewed multiple times. Students were generally interviewed twice with very similar questions, however a few students were not present at school when interviews took place and so only took part in one interview. Repeated interviews usually took place months apart which was expected to minimise any priming effect from repeated exposure. Participants who were interviewed for a second time were also asked about any changes in their opinions since the previous interview.

The interviews took place in an empty classroom or office, and also occasionally outside in a quiet space at the school (teachers and students). All interviews were recorded with an audio recording device placed next to or between the researcher and the interviewee and this recording was later transcribed by the researcher. Notes of participant names were taken at the beginning of the session as well as occasional notes to track students' responses. On average the interviews with teachers and staff took around 30 minutes, while interviews with students ranged up to 20 minutes depending on the number participating and the general nature of the group.

Interviews with teachers and KIOSC staff were typically one-on-one, however due to time constraints towards the latter half of the year there was one group interview with all four staff and also several individual written responses to the interview questions. While this format reduced the amount of depth individuals went into in their responses, it still provided useful information on participant perspectives.

Students were interviewed in small groups of usually two or three, often within the same friendship group, in order to establish a comfortable environment for them. This arrangement provided students with a more natural setting which encouraged the sharing of ideas amongst peers that they might otherwise have been reluctant to share with the researcher, an unfamiliar adult stranger. With usually only two or three students present in each group interview it was possible to explore each student's interpretation of their

KIOSC experience in some depth and take the time to ensure each student had a chance to respond to each of the listed questions.

While there is criticism that this type of interview can affect the data obtained as individuals are pressured by the group to conform to a socially acceptable view point (Ritchie et al., 2013) it can also provide insight into the social negotiation of values and roles. Peer influence can be a strong influence on student perception of science (Riedinger, 2015) and so in this research, insight into the socially constructed perception of KIOSC amongst groups of students was useful for understanding student perspectives.

4.4.3 Survey

After students had completed their visits to KIOSC for the year they completed a reflective survey (see Appendix F for a copy of the survey). The survey was initially designed using the online software Survey Monkey and students completed a paper version of this and the responses recorded manually by the researcher into the Survey Monkey software. A total of 44 students took part in the survey however due to incomplete responses only 42 surveys were useable.

The survey included questions on student family background and other demographic data in order to place the research in a wider context and also to inform research question four: Is there an interaction between student background and students' interpretation of the non-formal science education program? This information is pertinent to understanding student interpretation of their non-formal learning experiences as student attitudes and expectations can affect their approach towards, and the subsequent impact of, external learning experiences (Falk & Storksdieck, 2005). Additionally student background, more specifically their science capital, heavily influences students' participation in science learning activities in and out of school as well as influencing their trajectories into post-compulsory STEM study (DeWitt & Archer, 2015). Hence several questions concerning student science participation and family background were adapted from the UK ASPIRES year eight survey (equivalent to Australian year seven) and also from the US 'Is Science Me?' study (Aschbacher, Li, & Roth, 2010) in order to ascertain whether student background had any effect on how they responded to non-formal learning experiences. Students were also asked about how they currently felt about their science teacher and how they thought their friends felt about science. These questions were included as science teachers have been shown to be an important school based factor in students' continuation into post-compulsory STEM education (Lyons & Quinn, 2010a) and the attitude of a students' friendship group can also affect student participation in science (Barton, Tan, & Rivet, 2008).

The survey also included a series of items based on the Expectancy Value of Motivated Behavioural Choice (EV-MBC) framework (Eccles, 2009) which measured students' current and changed attitudes towards learning science. The EV-MBC has been previously used as indicators of students' motivation to continue with post-compulsory STEM study and pursue a STEM related career (Andersen & Ward, 2014). Subsequently this research drew from several survey items used by Andersen and Ward (2014) which asked students to evaluate how they felt about science compared to their other subjects. These items included questions which assessed students' expectancies of success in science along with their subjective valuation of learning science (relative interest, cost, utility and attainment). The EV-MBC framework was also used for a series of evaluation questions asking students how they felt their KIOSC experiences had affected their perceptions or capability regarding science. These were presented in a similar manner to the post reflective surveys for out-of-school science learning experiences reported by Jensen and Sjaastad (2013) and Jensen and Bøe (2013). Comparison of change in students' opinions with their pre-existing support and attitudes towards science facilitated further investigation of research question four as well as contributing to answering research question five; What opportunities are there in an ongoing non-formal science education program for students to develop trajectories into post-compulsory STEM education? Research question five was also explored in more depth in the interviews but the survey components were included to aid in highlighting possible trends in student responses.

Using questions from multiple surveys ensured that this survey contained well-defined, previously validated questions that had already been tested on thousands of students across the world. However in many cases adaptation of questions in terms of rewording, removing or adding particular statements was necessary in order to place questions in the Australian context and accommodate the focus of this study.

4.5 Data Analysis

4.5.1 Data management

All audio files were transcribed using the inbuilt NVivo 10 transcription function by the researcher. Transcription included emotional expressions (hmm, laughing etc) and incomplete or grammatically incorrect sentences in order to obtain as accurate representation as possible of participants' responses (see Appendix E for an example transcript).

Most data including surveys, audio files and transcripts were stored in NVivo 10 and classified according to school and participant type (student, teacher, staff). NVivo also provides linkage between files and internal memos which allowed each data type (audio recording, transcript and document) to be linked to notes explaining how that data was gathered and any relevant notes stemming from observation of the program. For instance, interview recordings were linked to memos that described how the interview went, the environment it was conducted in, visual observations of the room and any other relevant factors that might affect participant responses.

4.5.2 Interview Analysis

The coding function in NVivo was used to carry out thematic analysis on the transcribed interviews. Thematic analysis was used for this research as is a powerful and flexible tool that enabled in-depth exploration of the research (Braun & Clarke, 2006). When carrying out the analysis I followed Braun and Clarke's (2006) procedure, the main points of which are:

1. Familiarising yourself with your data;

2. Generating initial codes from the data;

3. Searching for themes amongst codes;

4. Reviewing themes through coding new data;

5. Defining and naming themes, organising in a framework or map;

6. Producing the report, representing the themes.

The themes were further developed and subsequently structured according to the five research questions. This study uses Braun and Clarke's (2006) definition of a theme as *"capturing something important about the data in relation to the research question, and representing some level of patterned response or meaning within the data set"* (p. 80). Where relevant, themes were further refined and compared between year level (7, 8) participant type (teacher, staff and student) and individual school. This was made possible through the function of NVivo that allowed 'attributes' such as participant role, year level and school to be added to each interviewee response and their subsequent statements.

4.5.3 Survey Analysis

Due to the low number of completed surveys a statistical analysis was not conducted on the survey data. Instead Excel was used to sort, summarise and graph data to investigate student responses. Student responses were examined in terms of proportions (percentage of student group) out of 42 completed surveys. Responses to individual items were used directly but were also converted into a numerical format (Table 3). Response types 1-3 were used for variables looking at students' backgrounds and response type 4 was specifically used for items asking students to reflect on how their experiences at KIOSC had changed their perceptions or behaviours. Several related items were compiled to allocate students a general score for particular components but this only occurred for items with the same response format.

Table 3. Format of items with type 1, 2, 3 and 4 responses for student agreement with statements and their conversion to numerical weighting.

<table>
<tr><td>Response Type 1:</td><td>Strongly Disagree</td><td>Disagree</td><td>Neutral</td><td>Agree</td><td>Strongly Agree</td></tr>
<tr><td>Numerical Conversion</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>Response Type 2:</td><td>None</td><td>A few</td><td>Some</td><td colspan="2">Most</td></tr>
<tr><td>Numerical Conversion</td><td>0</td><td>1</td><td>2</td><td colspan="2">3</td></tr>
<tr><td>Response Type 3:</td><td>Never</td><td>Once a year</td><td>Once a term</td><td>Monthly</td><td>Weekly</td></tr>
<tr><td>Numerical Conversion</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>Response Type 4:</td><td colspan="2">Less likely to agree</td><td colspan="2">No change in agreement</td><td>More likely to agree</td></tr>
</table>

Numerical Conversion	-1	0	1

Student scores across the compiled background variables were compared to determine if there were any trends or associations of interest. Different levels of these variables were also compared with the variables assessing change in students following their visits to KIOSC. This was done in order to ascertain if students of different backgrounds responded differently to their non-formal learning experience. Findings from the survey analysis were compared with students' interview responses to determine if either type of response explained observed trends in the other.

Students' score for variables combined from several survey items (e.g. Parent Science Support) were sorted into Very Low, Low, Neutral, Moderate and High levels. These levels were determined by the histogram analysis in Excel which uses Scott's normal reference rule to calculate the histogram bin width. This formula was used as students' scores tended to follow a normal distribution. An example of this categorization process is provided in Appendix G. As the number of combined items for each variable varied (Table 4) the scores that determined the levels for a variable were usually different.

Students' scores for variables reflecting on their KIOSC experience (all Type 4 responses), were also combined from a series of related items (Table 5). The scores for response variables were divided into levels of negative change (-4 to -1), no change or neutral (=0), and positive change (1 to 4). Some response variables were calculated from multiple items and thus a further division between negative/positive scores (-2, -1 or 1, 2) and high negative/high positive scores (-4, -3 or 3, 4) was created for these items.

Items which asked students to compare science to other subjects or their ability in science to their classmates on a 5 point scale from 0 (worse/less preferred) to 4 (best/most preferred) were treated as individual scores and not compiled into a single variable.

Additional variables which were not compiled included whether students' immediate family members had a science related job, student gender, year level, and number of books in the family home. Survey items on family education and job level were not included due to incomplete responses.

Table 4. Student scores for compiled variables relating to perceived support for their learning and pre-existing attitudes towards science. Students were asked to mark their agreement with individual statements which were then compiled into larger related categories as listed. Items marked as FLIPPED had their scores reversed.

Background Variables	Items used
Parental Study Support (Response Type 1)	**1. They expect me to do further education or training after high school, such as university or TAFE 2. They know how well I am doing in my classes 3. They always attend parents' evenings at school**
Parental Science Support (Response Type 1)	**1. My family talks to me about how science and mathematics will help me in my life 2. They think it is important for me to learn science 3. They think science is interesting 4. They would be happy if I decided to pursue a career in science**
Friend Science Support (Response Type 3)	**How many of your friends: 1. Like science? 2. Think science is cool? 3. Get good grades in science? 4. FLIPPED Would think less of you if you did science activities?**
Friend Study Support (Response Type 3)	**How many of your friends: 1. Care about their grades in school? 2. Encourage you to do well in school? 3. Would be described as smart or 'brainy'?**
Teacher Support (Response Type 1)	**1. My teacher makes learning science interesting and fun 2. My teacher thinks I could be a good scientist one day**
Science Participation (Response Type 4)	**How many times a year do you? 1. Visit a science camp, club, received an award or done a university project 2. Go to a museum 3. Do science activities (e.g. science kits, nature walks, experiments) 4. Read a book or a magazine about science 5. Visit websites about science 6. Visit a science centre, science museum or zoo 7. Watch a TV program about science or nature 8. Talk with someone at home about what I've been learning in science class at school 9. Play games about science**
Science Aspiration (Response Type 1)	**1. I would like to study science more in the future 2. I would like to have a job that uses science**
Science Affiliation (Marked on a scale from 0 – 10)	**1. At the moment on a scale of 0 to 10, would you describe yourself as a science person?**

Table 5. Student scores for variables measuring change in student perception following their KIOSC visits. Students were asked to mark their agreement with individual statements (all response type 4) which were then compiled into the variables. Items marked as FLIPPED had their scores reversed.

Variables for change following KIOSC visit	Items Used
Change in science affiliation	1. I think I could be a good scientist one day 2. People who do science are like me 3. I see myself as a science person 4. Others see me as a science person
Change in perceived science utility	1. Studying science is useful for getting a good job in the future 2. FLIPPED Science is not that necessary to get into desirable courses at university or TAFE 3. Knowing science is useful in many different jobs
Change in science aspiration	1. I would like to study more science in the future 2. I would like to have a job that uses science
Change in science interest or enjoyment	1. Learning science is relevant to my life 2. I learn interesting things in science lessons 3. I look forward to my science lessons 4. FLIPPED Learning science is boring
Change in preference for learning science outside of school	1. I prefer learning about science outside of school
Change in science class participation	1. I often take part in science class discussions and ask questions
Change in confidence in science ability	1. I get good marks in science 2. I can do well in science tests and assignments 3. FLIPPED Science is difficult for me 4. FLIPPED I am just not good at science
Change in perceived expectations for success	1. I will be able to master the skills and concepts in next year's science class 2. I could do a job that involves science
Change in perceived cost to learn science	1. If I study science in the future I will have enough time for friends and hobbies 2. FLIPPED People will make fun of me if I work hard in science class

4.6 Data Generalisability and Reliability

4.6.1 Generalisability

The ability to generalize from a single case's findings is often criticized as a limitation of qualitative research and of case study research especially. This criticism however stems from assuming 'statistical generalization', where a single study is assumed to have been carefully chosen as a representative of a larger population by probabilistic estimates and to which the findings can be extrapolated to (Yin, 2015). The statistical generalization of this case study is advisedly limited but provided a more complete picture of students' interpretations through combining quantitative (survey) with qualitative (interviews) methods. It is still possible to generalize from the research findings using analytical generalization.

Analytic generalization involves inferring a study's findings to theoretical propositions and then taking that theory or concept in order to interpret other similar situations (Yin, 2015). This will take place in Chapter 6: Discussion, where there will be a through exploration of how the findings of this research reflect, support or contrast other studies concerning the development, implementation and impact of non-formal science education programs.

I have also earlier provided a 'rich, thick' description of KIOSC in the manner described by (Creswell, 2013a) in Section 4.2 to further aid in generalization. This detailed description is used to illustrate the particularities of school and KIOSC setting to give context to the findings of the research for future readers.

4.6.2 Data Validity and Reliability

To assure the validity and reliability of this study and the credibility of the findings presented, a number of strategies were undertaken. Consistency of the data gathering across settings was ensured by all data being gathered solely by the researcher, using the same instruments and protocol for each participant type. I documented the procedures undertaken and the data gathered in order to establish a chain of evidence as per Yin (2014) such that an observer would be able to repeat the study. These actions helped to ensure reliability of the data, i.e. that the research would produce the same results if repeated.

To help ensure validity or accuracy of findings towards the end of the study participants were given a summary of the main findings from the research. This facilitated member checking where participants are able to appraise finalized themes for accuracy (Creswell, 2013b; Yin, 2014). Additionally the use of multiple sources of data both by participant type (teacher, staff or student) and data type (interview and survey) allowed triangulation of themes (Creswell, 2013b). Via this method survey findings were validated by comparing with themes derived from the interviews. However the survey items themselves were not validated beyond the sample population due to the low number of completed surveys preventing statistical analysis. The additional change of item wording to the Australian context also meant that many statements were too different to rely on the statistical validation from the original, much larger surveys that they were adapted from. Interrater reliability of the interview coding was not an issue because only one person (the researcher) coded the data. To ensure that the codes were appropriate and valid for the data they were modelled (Example in Appendix I) and the coding was discussed extensively with fellow researchers in the field.

4.7 Chapter Summary

This chapter has outlined how this study was approached, designed and implemented in accordance with the research focus. It has described the case study under examination and explained the choice of methodology and methods. The final section covers how the data obtained in this research was analysed, with acknowledgement of the limitations placed upon this analysis by the study design and methods. It concludes with an explanation of how the findings from this research were assured to be reliable and how they can be generalizable to the wider context. The next chapter will now focus on the results from this data gathering and will explore the main themes obtained.

Chapter 5: Results

5.0 Introduction

This chapter presents the data gathered according to the procedures outlined in the Methods chapter and is structured according to the research questions outlined in Chapter 3 (Literature Review). Accordingly, after a brief overview of the study population and the coding prevalence amongst participant types (5.1) the remaining sections present the data relating to a particular research question. Section 5.2 focuses on the interpretation of the KIOSC programs by students, teachers and staff. Section 5.3 examines how the interpretation of KIOSC programs varies over time. Section 5.4 looks at the effect of the collaboration between KIOSC and the schools on student experience and their interpretation of the KIOSC programs. Section 5.5 examines what effect student background has on their response to KIOSC while section 5.6 outlines the opportunities present within the KIOSC program for students to develop trajectories into post-compulsory STEM education.

5.1 Results Overview

5.1.1 Study Population

A total of 49 students took part in this study but not all students completed the two rounds of interviews and the survey. Due to absences the number of participants varies across the year (Table 6). The student cohort for this research was largely Caucasian and reflective of the demographics of the local area. The students were evenly split between genders.

Table 6. Number of student participants across multiple rounds of interviews and a survey. Complete survey datasets were obtained from 42 students.

Students		1st Round of Interviews	2nd Round of Interviews	Post Visit Survey	Total Participants
School 1	Year 7	6	11	9	12
	Year 8	4	4	4	5
School 2	Year 7	20	16	19	20
	Year 8	12	12	12	12
	Total Student Participants	**42**	**43**	**44**	**49**

Nine teachers and four staff in total were recruited and participated in interviews after the KIOSC programs that they were involved in. Not all attending teachers were science specialists (Table 7). To maintain confidentiality teachers' positions within the school are not reported, however gender identification is maintained.

Table 7. The pseudonyms of teachers and staff participating in the research.

	School	Gender	Pseudonym	Science Specialist or Not
1.T1	School 1	F	Leslie	Non-Science
1.T2	School 1	F	Carol	Science Specialist
1.T3	School 1	M	Brian	Science Specialist
2.T1	School 2	M	Steve	Science Specialist
2.T2	School 2	M	Jim	Science Specialist
2.T3	School 2	M	Adrian	Non-Science
2.T4	School 2	M	George	Science Specialist
2.T5	School 2	F	Jane	Non-Science
2.T6	School 2	F	Emily	Science Specialist
S1	KIOSC	F	Bridgette	Staff
S2	KIOSC	F	Mary	Staff
S3	KIOSC	F	Helen	Staff
S4	KIOSC	F	Anne	Staff

5.1.2 Coding Prevalence

To give a sense of the data as a whole a list of the 10 most common codes for each participant type is provided here. A longer list of the 50 most common codes for all participant types is included in Appendix J. The counts for student codes are higher than other participant types due to the high number of students (49) relative to staff (4) and teachers (9 total).

As shown in Table 8, the codes most commonly used to code the student interviews were focused on the activities and students' experiences of the programs. For instance "Enjoyment" is the most commonly used code with 118 counts followed by "Satisfaction with activities" at 112. Another prominent code was "Lego, robots" which related to a particular activity students did but which was not used anywhere near as much for the interviews of other participants. The exception to this trend is the code for "Science jobs and people" which was prevalent because each student was asked about this and was not a reflection of student interest or awareness of scientific jobs.

Table 8. The 12 most common codes used for Student interviews

Codes	Student Interviews
Enjoyment	118
Satisfaction with activities	112
What students and teachers want from KIOSC visits	76
Dissatisfaction with activities	68
Different to learning at school	66
Lego, robots	64
Hands on	52
Science jobs and people	51
Memorable	50
Student self-perceived capability in science	47
Learning at KIOSC appealing	45
Boring	41

Tables 9 and 10 show the 12 most common codes used for staff and teacher interviews were more concerned with the overall program rather than the emotive aspects of an experience. Staff in particular (Table 9) talked a lot about changing student interest in or perceptions of science and about cultivating a sustainability mindset. Science specialist teachers (Table 10) were coded most for dissatisfaction with activities and a lack of curriculum connection. They were also more inclined to talk about the practicalities or programs; whether it was possible at school or not and the flexibility of scheduling. In contrast non-science teachers rarely talked about the program management and were more focused on the experience at KIOSC, seeing the activities much more positively then science specialist teachers.

Table 9. The 12 most common codes used for Staff interviews

Codes	KIOSC Staff Interviews
What students and teachers want from KIOSC visits	11
Different to learning at school	10
Affects students' perceptions, inspire interest	10
Sustainability mindset	9
General technology	8
Building awareness, desire and incidents	8
Engagement	8
Possible at school or not	7
Not necessarily seen as science	6
Staff role, efforts aims	6
Challenges, management	6
Student participation	6

Table 10. The 12 most common codes used for Teacher interviews, Science Specialist and Non-Science.

Codes	Science Specialist Teachers Interviews	Codes	Non-Science Teachers Interviews

Dissatisfaction with activities	53	Engagement	16
Lack of curriculum connection	40	Enjoyment	10
Engagement	36	Limitations of observing any impact	10
What students and teachers want from KIOSC visits	30	Satisfaction with activities	8
General technology	30	Hands on	8
Possible at school or not	29	Different to learning at school	6
Attitude over time	24	Affects student competency	6
Flexibility of usage, scheduling	23	Dissatisfaction with activities	5
Satisfaction with activities	22	Learning new things	5
Different to learning at school	20	Possible at school or not	5
Connecting experience between school and KIOSC	20	Active, interactive, competitive	5
Learning new things	19	General technology	5

5.2 Research Question 1: Interpretations of an ongoing and collaborative non-formal science education program

5.2.1 Section Overview

This section explores the themes relating to Research Question 1; *How are students' experiences in an ongoing, non-formal science education program interpreted by students, their teachers and non-formal staff?* Stakeholder interpretations of the non-formal science education programs at KIOSC are explored in the following sub-sections through four key themes:

5.2.2: A day out of school

5.2.3 A day off school

5.2.4 Extending and supporting student learning

5.2.5 Promoting awareness of sustainability and careers

Of these interpretations one in particular (a day off school) was not desired but was strongly prevalent amongst students. This interpretation also dominated over teacher and staff desired interpretations of the experience as a learning extension and as way to promote sustainability and career awareness. Notably school 1 students were more inclined to see their non-formal experiences as a learning extension, likely due to the preparation and follow up of the material in their classes which school 2 tended not to do.

5.2.2 A day out of school

A key theme from the interviews with all participants was the emphasis of KIOSC being a distinctly different setting to school. Staff proposed that the different learning experiences at KIOSC were made possible by resources not available at school, such as specialized equipment or the whole day period.

Helen (Staff): I think that's a real bonus about this place, sometimes we get more time with them, like when we run the whole day activities. There's a whole day for them to sit and digest information and work with it and problem solve and inquire and come to the end point.

Staff were also aware that students in the local area were not economically advantaged and saw part of KIOSC's role as providing students with experiences that they would otherwise be unable to access.

Bridgette (Staff): Given the economic status of the schools, I think that this does provide an experience that the students wouldn't receive if they weren't coming to KIOSC.

Staff strove to provide students with a different experience of learning science from what they would have at school. This was emphasized by multiple staff members and appeared to be a clear ethos for KIOSC. One statement in particular captures the aims of KIOSC staff:

Bridgette (Staff): I don't want KIOSC to be like school. I want it to be that amazing experience when they get to come and not see a show, but be wowed and excited and a little bit entertained and you know be able to actually grasp it and get involved and go hey, I really like this.

However staff also clarified that while a unique and engaging experience was a key goal, they also endeavoured to meet expected learning outcomes for students as well. Meeting learning outcomes was a key goal of teachers, though they also wanted students to enjoy their experiences at KIOSC.

Steve (Science Specialist): We have a look to see what fits in with our curriculum anyway but also what we know is going to get the kids and think "OK we're going to do a whole day of (topic) well that's pretty cool doing that". So hopefully [they] enjoy doing that.

Interestingly, teachers tended to have different perspectives on the KIOSC programs depending on their experience teaching science. Non-science specialist teachers who came along to help manage students were invariably very positive about the experiences at KIOSC. They saw the KIOSC setting as being very engaging for students and as being quite different from a regular science class.

Leslie (Non-Science): They do things there that they can't normally do here and that's why the students find it very interesting.

Science specialist teachers were also appreciative of the differences between settings but tended to be more conservative about the extent to which KIOSC was different from school. In interviews with the science teachers, there was much more detailed discussion about how exactly the learning experience was different for their students and concern over whether the activities were possible at school or not. Generally science teachers were pleased with the experience when it facilitated activities that they could not do at school and which drew on aspects that were a point of difference between the school and KIOSC settings. Commonly mentioned aspects were the physical layout of the building, including its location on a university campus and the resources available at KIOSC.

School 2 science teachers in particular appreciated that the program ran over a whole day and was managed by external educators. They felt that this offered students different opportunities to engage in learning even when the activities themselves were doable at school.

Steve (Science Specialist): I think that's what can help engage them when its someone else doing it….I know if we can go to KIOSC and do the activities there it's actually easier than running them at the school. Like we could set that [program] up but we don't have the space to do that … so you could break it up week by week [but] you couldn't do it as whole day activity.

One science teacher felt that the KIOSC staff taught the activities in such a different manner so as to be unrecognizable by students as science, which he felt would help engage those students who were resistant to science.

Jim (Science Specialist): The kids don't really know that they're doing science as such. They have a really good way of teaching it completely differently that I think will help them.

Teachers from School 1 likewise valued the opportunities facilitated by KIOSC resources but felt that several activities were quite similar to what they did at school:

Carol (Science Specialist): Although we don't do that kind of learning all the time in our classes we do it a fair bit. … We are already doing most of things that the junior students at least get to do at KIOSC.

Correspondingly, science teachers from both schools were dissatisfied with activities that they felt did not take advantage of the resources available at KIOSC. In particular the programs for junior school students were seen to be more restricted in resources then senior year levels and this was linked to a lack of interest by the students.

Steve (Science Specialist): Maybe bring some of those programs down, lower in the years [.] Then I think it would run better [and] there'd be more interest in it from the students as well, because that's where our problem is "oh we're off to KIOSC again are we" and there's sort of no real relevance [.]They don't see much relevance to it.

Similarly students from both schools found aspects of their day at KIOSC to be similar to their schooling in the activities they did and the way they interacted (e.g. sitting while staff member talked). Consequently the experience did not meet students' expectations and they tended to be very dissatisfied.

Student: I found it quite boring because there wasn't much fun to it, it was more like sit down class work kinda stuff.

Alternatively teachers also suggested that a disinclination to do work could explain why some students found the visit boring. Teachers from both schools commented that some of their students had an attitude of not wanting to engage in work that required mental effort or didn't have a clear answer.

Jane (Non-Science): I find that a lot of the reason why they find it boring is because they're actually required to do work and maybe think for themselves[.] They're not being spoon *fed so I don't know if it's a clear reflection on how the program actually works.*

Teachers often attributed student engagement to the different and novel aspects of the KIOSC experience. In particular they emphasised the appeal of technology and the outside setting.

George (Science Specialist): They just enjoyed the experience of getting out and walking around with funky devices.

Students also appreciated the expertise of the staff and that they were passionate about their subjects.

Student: Everyone was like really enjoying [it]. All the teachers - they didn't teach because they had to teach, they taught because they wanted to.

One particular aspect about KIOSC that students highly valued was the interactivity of the activities at KIOSC. These activities were frequently described as 'fun' and 'hands on' by students from both schools and across year levels.

Student: I think it's different to school because here we usually just sit down and do a task but there ….you can go around and do a lot of activities[. I]t's just really fun cause you actually do things.

Student perspectives on the hands on nature of activities at KIOSC differed between schools. All students enjoyed the hands on activities but School 2 students in particular saw KIOSC as providing more hands on activities then their regular science classes. A few students from School 1 thought that their science classes at school were more hands on then KIOSC.

Student: [Activity] was hands on, so it was good …but it just wasn't as good at KIOSC. I think we found the class ones better because we were actually finding animals, putting [them] in bottles and stuff.

5.2.3 A day off school

Making the KIOSC experience an enjoyable day out of school for students was a goal for both staff and teachers on its own but it was also part of achieving learning outcomes by engaging students in learning science. However students were generally inclined to see the visits as fun days *off* from school. Their reflections of KIOSC were dominated by personal enjoyment with less consideration of the educational focus. Generally students' recollection of their visits were focused on their enjoyment, or lack thereof, and this characterized KIOSC to them.

Student: Like at school we get to learn and stuff whereas there we just do fun stuff and just have fun. We learnt a bit but not a lot.

Students' interpretation of their experience as a fun day off school was picked up on by teachers.

Steve (Science Specialist): I think to them they see it as it's not actually work officially … because there's nothing then that they essentially bring back to school. It's done and that's it.

Science teachers from both schools expressed concern that students were not seeing the relevance of their day at KIOSC to their science learning. This appeared primarily due to scheduling issues which meant that students' experiences at KIOSC weren't well connected to what they were studying in class. Teachers from both schools strongly believed that linking and incorporating the KIOSC experience into their school curriculum would make it meaningful for students.

Steve (Science Specialist): I think when the students see the relevance of [the program] linked in to the curriculum more from our end then I think we would see more interest following on from KIOSC, because they can see the relevance to it. At the moment, that relevance isn't there and then by the time we get to that topic it could be lost or they've forgotten a little bit about what they've done at KIOSC.

Teachers from School 1 were less focused on the lack of a connection than teachers from School 2. This is likely due to the framing activities undertaken by the School 1 students at school, with teachers and students reporting that they'd spend time prior to the visit working on related activities provided by KIOSC as well as doing some follow up work.

Student: We do sometimes some stuff before to help with what we're going to learn in KIOSC…. Follow[ing] up we'll discuss what we did in KIOSC, but we'll also expand on what we learnt there sometimes.

In contrast School 2 students didn't seem to do any pre or post work related to the visit, and were vague or negative about the connection between their visit and their school learning.

Student: It's like a totally different subject to what we're doing.

However one science teacher commented that going in without prior knowledge in one case may have contributed to students' engagement in the activities, highlighting the value of KIOSC's novelty appeal for engaging students.

Jim (Science Specialist): Probably even coming back from it because it's good then going in not really knowing much about it, I think if we had done all that, if we had done a week on [topic] before they went they might have got a bit bored of it.

The perceived irrelevance of KIOSC programs led some students to see attendance at KIOSC as conditional upon having an interest in science. Without it the experience was not seen as valuable or worthwhile for a student. Notably this was not only expressed by dissatisfied students but also by their peers who were interested in science and did appreciate going to KIOSC.

Student (not interested in science): There's nothing that I'm going to do, they should just make people who want to do that stuff go. I think it would be good for some, but not for us.
Student (interested in science): I believe I think you probably make them optional…. [be]cause not lots of us want [it], not everybody has an interest in the subject as I do.

Science teachers and staff also observed this attitude and reflected it made it difficult for them to engage students in the KIOSC programs.

Steve (Science Specialist): [Two particular students] didn't come to KIOSC because both of them thought, " Well what's the point? I don't enjoy science, I'm not going to get anything out of that." So yeah, that does make it a little bit more difficult.

Not all students shared the view of KIOSC being only for certain people. There were some students who believed that the experience was suitable for all kids regardless of interest.

Student: We're not even very science based kids and we really enjoyed it so, yeah, I'd say tons of people would really love to do it.

5.2.4 Extending and supporting student learning

Teachers were eager to utilise KIOSC as a learning extender for their students. They wanted their students' visits to KIOSC to use the resources and other affordances of the KIOSC visit to support or extend student learning in ways that were not possible at school.

George (Science Specialist): I think it should just enhance what we're teaching. I don't [think] it should be a just a "Oh yeah I've got this really cool trip coming up, you'll learn stuff that we've kinda learnt in school and you'll just get to do fun stuff". I think it should be designed to enhance the units that we're teaching, when we're teaching.

Non-science teachers didn't necessarily disagree with this interpretation but in describing KIOSC they focused more on the engagement aspects and were less aware of how the experience affected students' science learning. One science teacher, who had attended KIOSC as a helper prior to taking on a science subject, reflected that his perception of the visit had changed with experience. As a science teacher he was now more cognisant of how well the visits fitted in or not with his students' science learning.

George (Science Specialist): This is the first year that I've taught science. So every other year I've gone, I've gone as like a helper. I haven't had the same sort of understanding of the science bit of it, whether it's tying in or not.

Staff also supported the teachers' vision for KIOSC programs to be supplementary learning experience for the students.

Mary (Staff): I suppose it's supplementary in some ways to their in school learning. So it's a supplement but also an enhancement of what they do in schools.

While students from both schools enjoyed learning new things at KIOSC and valued their learning there, only School 1 students explicitly commented on their learning as supporting or extending their school learning.

Student: They're teaching you about what we're doing so you get to know more things about the thing that you're doing at school…….. In class it helps to develop what you need to know about it. Like if we're doing a test or something we got a better score than we did before we went to KIOSC.

Students from both schools did enjoy learning new things at KIOSC and were positive about their learning there. Many students felt that it was easier to learn science at KIOSC.

They appreciated having a whole day to learn science and also felt that it offered a less pressured and more engaging learning environment which made learning easier.

Student: At school you're like pressured to do well…. but at KIOSC you can kinda like make mistakes and learn things.

The emphasis on flexible student participation at KIOSC was evident in the staff interviews. Staff spoke of multiple occasions where they adjusted their teaching approach to accommodate students who were having difficulty in engaging with the material and took pleasure in those students' eventual successful participation. They recognized students' interest and engagement with the learning material even if the activity wasn't completed in the usual manner.

Bridgette (Staff): One particular student who actually when everybody else had finished hadn't started and I let him continue doing it while I was talking, he probably came up with the best reasons as to why he put the things in the bin that they did. So he actually did think about what he was doing, he didn't just chuck [stuff] into particular bins because he didn't care.

Students also liked the social nature of the activities at KIOSC. This was also commented on by the teachers as an opportunity to develop student socialisation skills. Student ability to work in groups was seen as a key challenge both at school and at KIOSC by teachers from both schools.

Jim (Science Specialist): It's really important for these kids [be]cause [for] a lot of them socializing, they [don't have] the greatest social skills, especially with people outside their friendship groups. So it's good to expose them to that and learning at the same time.

School 1 teachers and students did however comment negatively on a difference in pedagogy between school teaching and KIOSC teaching which was seen to hinder student initial engagement slightly.

Brian (Science Specialist): Here we do a clear learning intention at the start of every session with success criteria, so that's something that they don't do over there. So some kids, it takes them a while to swing into "oh this is what it's all about".

5.2.5 Promoting awareness of sustainability and careers

Another interpretation of KIOSC was as a career guidance tool for raising students' awareness of and interest in STEM careers, particularly those relating to sustainability. Teachers from both schools were quite keen to use the visits to KISOC to inspire students to consider STEM careers and tertiary study.

Jane (Non-Science): I think it's more sort of like, whether or not it is a vocation that they'd like. It's kinda immersing them in 'this is what you can do if you take science right to the very end. These are the sorts of doors it will open up for you'. That's how I think it would actually benefit our kids.

One teacher from School 2 appreciated learning about careers around sustainability that he could introduce students to.

Steve (Science Specialist): Rather than just you know the traditional science related things, for me it's opened my mind as to what there is out there and sorta more looking at sustainability and those types of careers.

The focus on future careers and sustainability was a key aim for Staff.

Bridgette (Staff): The aim for KIOSC is to basically produce innovative ways to kinda teach sustainability and get them in interested in what sort of careers they'd like to do.

However while staff were wanting to broaden student awareness of science careers, it was seen as quite challenging.

Helen (Staff): But sometimes they don't want to be told it's science. When I tell you what do you want to do when you're older and they're like "Be a physiotherapist," and I'm like "You need science," and they look at me like "No I don't".

However as well as introducing students to careers in sustainability, staff also hoped to inspire changes in the personal behaviour of students.

Bridgette (Staff): You're sorta kinda hoping the kids take away that maybe if I shorten my shower I'm doing better for the environment. Or with waste if I recycle more efficiently or not throw something away.

Even though they were not specifically asked about their opinions on sustainability in this study, several students showed an increased awareness and valuation of the sustainability.

Student: Well to do with like the rubbish like, we just chuck it out or we don't know really yeah where it's going, what's doing and stuff and it makes you more aware about the environment.

Teachers were aware and supportive of the sustainability focus but were more concerned about using KIOSC programs to extend their students' learning or to build their awareness of careers and study pathways.

Brian (Science Specialist): [Regarding study pathways to STEM careers] that's probably not KIOSC's main aim. KIOSC's main aim is about that, innovation and sustainability, that's what they'd like to get across.

In interviews however students were generally vague about career opportunities related to the program they attended. This will be discussed further in section 5.6 Opportunities.

5.3 Research Question 2: Program Interpretation Over Time

5.3.1 Section Overview

The themes explored in this section relate to Research Question 2; *How do stakeholder interpretations of a non-formal science education program vary over time?* As staff members' interpretations were consistent over the study period there are only two themes discussed; the change in student interpretation (5.3.2) and the change in teacher interpretations (5.3.3) of their non-formal experiences at KIOSC over time. With time teachers became more familiar with the non-formal programs and built relationships with the KIOSC staff. This led to teachers developing a more positive and hopeful interpretation of the program over time. Students however tended to form more negative interpretations of the non-formal programs over time as the novelty of the experiences wore off. After a few visits students seemed to interpret the program as irrelevant to them and were disinclined to attend. The interpretations of teachers and students were strongly consistent across schools.

5.3.2 Change in student response over time

Staff interpretation of the role of KIOSC remained relatively constant over the year they were interviewed and in their recollections of previous years. The interpretations of teachers and students however was revealed to change over the years as they became more familiar with the centre and as the partnership with schools developed.

A few students in year 8 also felt that their visits to KIOSC were getting better over time. Some felt that the activities were more interactive and enjoyable. Others suggested that their KIOSC experiences got better because they became more familiar with KIOSC, making it easier to participate in the activities.

Student: Before like the first time I went thought it was like a bit hard but then it got easier because I was more used to it[.] [Be]cause usually at school we usually don't do hands on things.

From the students' perspective it is hard to discern whether this improvement is actually due to changes in the KIOSC programs, or reflective of the students' perspective changing as they grew and develop over the years. Insight into students' responses over a more extended period of time came from the teachers' observations who were able to observe their students over several years. Teachers reported that year 7s on their first visit tended to be excited about KIOSC, attracted by the novelty of the experience.

Steve (Science Specialist): *Year 7's really get into it because it is something new for them… so for them science is something new, something terrific and taking them to KIOSC is really good.*

However while the novelty of KIOSC did appeal to students, it also risked setting up unrealistic expectations. Fun based expectations were at risk of being unrealistic given that the activities also had to meet learning outcomes and align with the science curriculum. Some students thought that KIOSC would be like Scienceworks, an informal science centre with many hands on exhibits. This risked disappointing student expectations if the experience didn't live up to their idea of a 'fun' time.

Leslie (Non-Science): He wasn't engaged in the second activity because he thought it was going to be something different. He also was referring back to, he thought it was going to be more like Scienceworks, and that was disappointing for him.

Teachers were also unable to moderate student expectations for the visit when they were unfamiliar themselves with the program.

Adrian (Non-Science): *Generally yeah, pretty excited. Most of them didn't know what [the program] was so they kinda went in not knowing. I guess they knew it was this science* *excursion so [they were asking] "Is this like Scienceworks?" And I just said to them, "I don't actually know, I've never been there either. So we'll be discovering it together."*

Over time, students' interpretations of KIOSC programs were primarily shaped by their own experiences there and through sharing opinions with their peers.

Teachers in both schools saw that over time students' initial attitude changed as the novelty of the experience wore off. They reported that negative opinions were shared between students of different year levels which they felt affected students' attitude to subsequent KIOSC visits.

Steve (Science Specialist): But then they get to year eight and the year eight's talk to the year seven's "Oh, you know it's pretty boring, you know, you do this this and this." So then later on in the year some of the [students] are like "Look I don't really want to go now".

In contrast, in the interviews students reported sharing positive opinions about KIOSC, indicating that they were encouraging their peers to attend.

Student: Some of our friends didn't go so we told them what we did and stuff … some of them I guess kinda regretted that they didn't go.

However according to the teachers this was not common and instead teachers suspected that pressure from peers to 'look cool' resulted in students spreading dismissive opinions of their KIOSC experience.

Steve (Science Specialist): You see them during the day, "Oh this is really good." But they'll come back to school and say, "Oh that was boring." They don't want to be seen as actually enjoying [the programs] in front of their friends.

If students felt that they had had a boring experience at KIOSC, they expected more of the same in the future and didn't want to visit again.

Student: We weren't very excited coming this year because last year was a bit boring.

Teachers found it quite difficult to challenge this negative perception, especially when in previous years students were required to pay for the travel cost as well.

Brian (Science Specialist): We try to talk it up as much as we possible, we want it to work, we want them to come and be like this is awesome, [it's] a day off classes. And some years we maybe struggle to get maybe 14 kids because we had to pay for the buses, other *schools can walk but we're too far away. So we had to charge them about 23, 25 dollars to go, and they weren't really enjoying it that much, so once they did it once they were like, "Not doing that again."*

The senior science teachers from each school offered almost identical observations on students' enthusiasm for KIOSC decreasing from years 7 to 10.

Brian (Science Specialist): Year seven's no problem, year eight gets a bit more difficult. Pretty much by year ten they don't want to go even though it's free, even though everything is paid for, even though it's a day out of school, they don't want to go.

Teachers attributed this decline in enthusiasm to students perceiving the visits as irrelevant and boring, perceptions they believed arose from the programs not using the unique features of KIOSC and not connecting to students' learning at school.

Brian (Science Specialist): There's all these things that like if you could come up with the right tasks that they could access, but they tend to save it for the year nine's, tens or twelves. By that point as a teacher I'm struggling so far to get the kids to want to come back because they've been so bored by the first two years.

However teachers also felt that declines in attendance over time were not solely attributed to students' experiences at KIOSC but also reflective of student attitudes towards excursions more generally. This will be discussed further in section 5.5.

5.3.3 Change in teacher perceptions of non-formal programs over time

The responses of teachers to KIOSC from both schools changed over time as the program was developed from its conception and establishment in 2013. Teachers were disappointed in their initial expectations for KIOSC where a more flexible usage of KIOSC was initially proposed.

Steve (Science Specialist): The whole idea behind it was that it was meant to be stuff that we couldn't do at school and you know we'd go to KIOSC and utilize their facilities but it hasn't actually come that way. A lot of, some of the stuff and you would have seen that as well, you could actually do at school.

Over time in light of curriculum connection issues and concern over declining student enthusiasm teachers adjusted how they approached KIOSC experiences.

Steve (Science Specialist): I think getting the permission slips done earlier in the year has helped with that because we're not then chasing round permission slips the week before the excursion.

Teachers from School 2 also described how in light of declining student interest as they became more senior, they were choosing programs specifically to address student engagement.

Steve (Science Specialist): By the time you get to year nine, they feel that they've already done all the programs, and as I said there's no benefit to them. [This] is why now with the year nine's we're trying to do things like [program x] or a day long program like [program y] or something like that where they're not actually going to have done that before[.] We've got to try and keep that motivation up.

However a comment from staff revealed that this approach also made things a bit difficult as students were not necessarily matched to the right learning level.

Anne (Staff): When the school selected this activity it was strongly advised that it was not appropriate as the material covered was too complex. The staff booking the excursion said they understood but just wanted the kids to have fun [doing the program] and weren't too concerned with the theory behind it. This did make teaching and engaging the students at the start difficult.

The interviews with the teachers revealed that a shift from disappointment to hope. Over time they reported observing adaptation and improvement of their programs as well as a growing relationship with staff. As a result of the ongoing nature of the KIOSC partnership, teachers and staff were able to exchange ideas about the programs and increasingly work together to resolve issues.

Brian (Science Specialist): Looks like it's becoming better, it looks like they're really focused on improving it specially[in] the last six months. There's now more constant emails between us, so that seems to have improved. And the thing with the government putting that money [in], there's free bus costs now… and they are trying new things.

Teachers from both schools were positive about the programs going into the future and hopeful that their desires for flexible usage would be met.

Brian (Science Specialist): The last meeting with Helen (Staff) was really positive. She was just saying if you want to run stuff at KIOSC, like book a lab out for two weeks and actually *do your stuff at KIOSC for two weeks.*

Staff strongly emphasized their commitment to refining and improving the KISOC programs over time to accommodate the needs of schools. They reflected that as they got to know the schools, they were better able to understand the KIOSC role and improve the KIOSC experience for teachers and students.

Helen (Staff): [KIOSC programs are] a really unique opportunity and it's one that's going to get better and better the more that we understand what our role is within the schools. And that's starting to play in the last couple of years and this year we're trying to look at getting the VCE components in there as well. So it'll be a really interesting process I think.

Further findings on the difficulties and benefits of collaboration will be discussed in more depth in the next section.

5.4 Research Question 3: The interaction of collaboration with stakeholder interpretation of non-formal science education programs.

5.4.1 Section Overview

This section examines the findings relating to Research Question 3; *Is there an interaction between the collaborative nature of a non-formal science education program and stakeholder interpretation of it?* The first theme which emerged in answering this question was ‘Collaboration: difficult but valuable’ (sub-section 5.4.2), which explores the challenges staff and teachers faced in collaborating to implement the programs. These challenges and whether staff and teachers successfully overcame them affected how they interpreted the KIOSC programs. This discussion then feeds into the second theme in sub-section 5.4.3 which looks at the effects of collaboration on students’ interpretation of their KIOSC experience. While not directly involved in the collaboration behind the non-formal programs, students’ experiences at KIOSC were affected by it both positively and negatively. This subsequently affected student interpretation of their experiences and of the non-formal programs.

5.4.2 Collaboration: difficult but valuable

Discussions with staff and teachers revealed that while collaboration was at times tricky it was highly valuable. A key issue for collaboration was highlighted previously in section 5.2; the scheduling of student visits to align the program they attended with their current learning at school. The times programs were offered at KIOSC did not necessarily match up with the school curriculum and this made it hard for teachers to incorporate the programs into their science classes.

Brian (Science Specialist): Last year [organizing] for this year it was basically," This is the two week block we're offering energy in. Could you pick a date in that two week block?" Which doesn't really tie in with our curriculum.

As mentioned in sections 5.2 and 5.3, the lack of connection to students' school learning was attributed as a key cause for students' perceiving the programs to be irrelevant to them.

Steve (Science Specialist): Again it comes back to I think if its planned into the curriculum what we're doing at that time then yeah, I think there would be a bit more motivation and that there.

Scheduling issues were partially attributed to the need for KIOSC staff to cater to multiple schools. The different teaching practices of schools was also another challenge for staff who had to adapt for each cohort.

Mary (Staff): It's then how the schools implement [pre/post activities] back at school. And both the schools you're studying do different things.

It was not possible therefore for staff to rely upon the assumption that all students would visit KIOSC with sufficient prior knowledge, or that they would be working on the topic further afterwards. This was acknowledged by one of the teachers from School 1.

Brian (Science Specialist): We did a bit of work based on what KIOSC wanted us to do made sure the kids had a basic knowledge in these six things or five things or two things or whatever it is. And we work from there. So I suppose it's the teachers, like it's not just us if the teachers aren't doing that at other schools it creates a bit of an issue.

Another challenge for collaboration was ascertaining what roles teachers should play during the visits to KIOSC. All programs were run by the KIOSC staff with science and non-science teachers usually, but not always, in the background or with students. Occasionally the science teachers took on a more active role and worked with staff to run an activity. One teacher mentioned that at times they were unsure of their role during the KIOSC visit, which was run by KIOSC staff, and of wanting to clarify expectations for teachers.

Brian (Science Specialist): We need to have these conversations before we go in there as to what they expect from us. Is there a code word that they want us to take a student for, where do we step in [etc]. We don't like to usurp their authority but at some stage, we don't like the students to impact on the programs.

There was occasionally conflict in the roles teachers wanted to assume, and what was desired by staff.

Mary (Staff): The visiting teacher was engaged in doing the task but could have interacted more with the students.

Mostly teachers' participation during a visit to KIOSC consisted of behaviour management while staff ran the activities. Many teachers made comments about managing students' behaviour during the experience and this was put down as the main reason for any observations of improved student behaviour at KIOSC.

Carol (Science Specialist): I think what helps though is that it's not us presenting so we're able to crowd control which we don't get in a normal classroom [where] we're presenting and crowd controlling. So that helps a lot.

While collaboration was hard to do it was also very valuable. Communication between staff and teachers was key to addressing issues that arose in program implementation. For instance, when describing difficulty in accessing digital links for pre/post activities in a resource provided by KIOSC:

Brian (Science Specialist): We'll keep doing the same thing, like I'll ring Bridgette (Staff) up and see if we can actually get the digital stuff so we can actually link to whatever they're talking about.

5.4.3 Effects of collaboration on students' interpretation of their KIOSC experience

While not directly involved in the collaboration between school and KIOSC, students' experiences at KIOSC were often affected by successful or unsuccessful collaborative efforts. The focus of teachers on behavioural management meant that they were able to interact with students closely. This enabled teachers to support student participation and keep students on task when they observed students having difficulty or getting distracted.

Brian (Science Specialist): I sat with a group that has difficulty forming [and] working in teams, so I sat with them particularly to try - in the first activity - to try and get them to *discuss and encourage [them].*

For a few students in particular, having the teachers available as support made a big difference for them being able to participate in the experience.

Student: [at school there's] only one teacher, and sometime it's one session [so] he can't help everybody but at KIOSC they can help.

Teachers also revealed that in the past, organizational issues amid communication failures had affected smooth implementation of some visits.

Brian (Science Specialist): Last year became a schmozzle because they didn't know we were going there. I reckon probably every year level had an experience of that.

Disorganized visits affected students' experience which shaped their opinions of KIOSC as being disappointing and a bit unreliable. This fed into lowered student expectations for their next visit as described by their teacher.

Brian (Science Specialist): I think that was a really big thing this time, even on the bus it was a bit of a joke. Are you sure they know we're coming, laugh, laugh, laugh sort of thing. But that always plays in the back of their minds… once you start letting kids down it starts lacking, well it does lack credibility.

In converse, a positive example of effective communication between staff and teachers saw a video of student work sent to the school. In this case students hadn't completed an activity due to faulty equipment and being able to view the fixed version sent by staff resolved a potentially disappointing and negative experience into a successful and positive one.

Steve (Science Specialist): Helen (Staff) actually fixed it and then filmed it and sent it to me. So the boys actually got to see [and] they were quite happy about that to see the end product done.

5.5 Research Question 4: The effects of student background on student interpretation of non-formal science education programs.

5.5.1 Section Overview

The themes discussed in this section came about in response to Research Question 4: *Is there an interaction between student background and students' interpretation of the non-formal science education program?* This question was split into two key themes; pre-existing student attitudes (sub-section 5.5.2) and family involvement and support (sub-section 5.5.3). Students who already had pre-existing positive attitudes towards science were more likely to interpret the non-formal science education programs positively and saw it as a valuable learning experience. Likewise, students with family who were supportive of science were also more inclined to positive interpretations of the programs. One key finding that emerged however was that students' tended to perceive science as more useful following their experiences at KIOSC irrespective of prior attitudes or family support.

5.5.2 Pre-Existing Student Attitudes

A recurring theme was how students' background affected their response to KIOSC visits. Teachers from both schools mentioned that they had difficulty in motivating the attendance of students who had already decided that science wasn't for them, or who had disengaged from school entirely.

Steve (Science Specialist): Some of them are just disengaged about school anyways. So, anything you try and do with some of these kids [it] just isn't going to help.

Students with existing behavioural issues and difficulty participating in class at school were observed to have difficulty participating at KIOSC.

Jane (Non-Science): Most of them, well obviously they were quite behaved. Some of them you know the kids that tend to play up a little bit obviously weren't. But the 'extreme kids' as I like to call [them], it doesn't matter where you take them. They've just got it in them [and] they can't help themselves.

Teachers also felt that many of their students had a poor attitude to excursions in general, not just the programs at KIOSC.

Brian (Science Specialist): Some of our year nine and ten students' free excursions, they still don't go. Even if they're back at school with five people they'd prefer to do that than, it doesn't matter whatever the excursion is yeah. Even if it's free, [even if] they don't have to pay for this thing.

One teacher felt that his students had very poor awareness of the study and career pathways open to them, attributing this as characteristic of the local area.

Brian (Science Specialist): You're fighting, I think you're fighting a real history. Very few of *our kids go onto university pathways and that's a history of the [local] area… Our students have a really poor understanding of what options are available to them post year ten.*

Survey responses also revealed that students' pre-existing attitudes towards learning science affected whether they felt their experiences at KIOSC had positively or negatively changed their perspectives on learning science. Invariably students who reported positive changes in affiliation with science, science aspirations, confidence, success expectations, interest and cost were those who already had high evaluations of science. In particular, students who already evaluated science as more interesting or easier compared to their other subjects reported highly positive changes in their interest following their visit to KIOSC. This trend was also seen in students who already felt strongly affiliated with a science identity and who were interested in further study or work involving science. Students who evaluated science poorly or who had low levels of affiliation or aspiration in science showed the reverse pattern.

Two students were notable exceptions to these patterns; in year eight from both schools there was a male student who had very positive attitudes towards science and high levels of science affiliation and aspiration but who reported no change whatsoever in their perceptions (Student codes:1.8E, 2.8G).

5.5.3 Family Involvement and Support

Overall parents seemed to have limited involvement or even awareness of their child's experiences at KIOSC. One teacher believed that when parents didn't understand the value of the KIOSC experience as a learning opportunity it hindered student attendance.

Jim (Science Specialist): In some things we don't have that support of parents … I mean the parents probably don't have a clue about it.

According to the survey, 38% of students reported that they talked with someone at home about what they did in science class. However, when talking with students in the interviews only a few students mentioned talking to their parents about their KIOSC visit in any depth.

Student: I told my Mum that how [sic] long it took for stuff to break down and that, like all the facts that we figured out.

In the interviews not many students described family involvement and support for science.

Student: I sometimes do like science things, sometimes my dad explains to me how the wind is like, how the clouds and stuff [work].

Parental response, as reported by the students, tended to consist of positive but vague encouragement.

Student: They said it's good that you're into it.

Some students described their parents as being interested in science or having a science related job. Again these students were in the minority.

Student: My Mum kinda is [into science] yeah, she loved experiments and doing like dissecting the bull's heart and stuff.

In general students reported moderate to high levels of support from their parents for their education (Figure 3). 52% of students either agreed or strongly agreed that their parents expected them to go to university or TAFE. Only 12% of students disagreed with this statement completely.

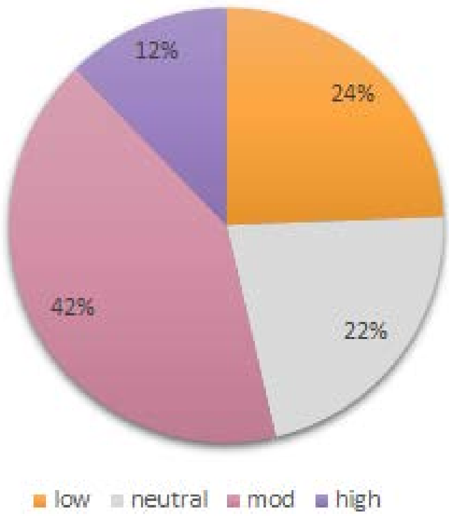

Figure 3. The proportions of students with low, neutral, moderate or high Parental Study Support; students' perception of their parents support for their general education. This variable is combined from several related survey items.

However, a much smaller proportion of students reported parental support for learning science specifically (Figure 4). Examination of the specific items comprising this variable revealed that only 31% agreed their parents thought it was important that they learned science and only 33% thought that their parents found science interesting.

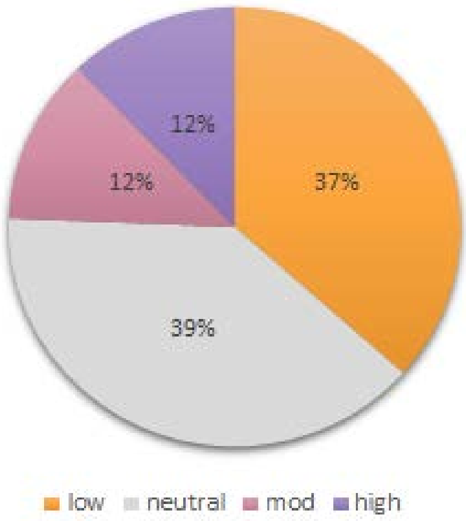

Figure 4. The proportions of students with low, neutral, moderate or high Parental Science Support; students' perception of their parents support for their science education. This variable is combined from several related survey items

Overall, students who felt well or poorly supported by their teachers and their parents in their science education tended to report positive or negative changes respectively in their interest, confidence, success expectancies in science, aspirations in science and their perception of the cost of doing science following their visits to KIOSC (Table 8). These students also tended to have either high-moderate or low levels of pre-existing affiliation and aspiration in science as well. Whether students felt that their friends were supportive of them learning science did seem to correlate with positive (or negative) changes in perceptions but this relationship did not appear as strong. More general support from students' friends or parents for overall studying did not correspond to changes in students' perceptions.

Table 11. Association between students' perception changes for those students who expressed either a positive (+) or negative change (-) in their science aspirations. Highly positive or negative changes are indicated by (++) and (--) respectively. Students are ranked by the level of change in their science aspiration following their visits to KIOSC. Change in student preference for learning in out-of-school settings and class participation are not included.

Student Code	Perceived Parental Science Support	Perceived Teacher Support	Student Science Aspiration Levels	Student Science Affiliation Levels	Change in Student Confidence	Change in Student Success Expectations	Change in Student Interest	Change in Perceived Cost	Change in Perceived Utility	Change in Student Affiliation	Change in Student Aspiration
1.7J	High	High	High	Neutral	++	+	++	No change	++	-	++
2.7L	Moderate	Moderate	Moderate	Neutral	++	++	++	+	++	-	++
2.8F	Neutral	Moderate	High	High	++	+	++	++	++	++	++
2.8L	Moderate	Moderate	High	High	No change	No change	++	No change	+	No change	++
2.7A	High	High	Moderate	Low	+	+	++	+	++	No change	++
2.7F	High	High	High	Moderate	++	++	++	++	++	++	++
2.7O	Neutral	Moderate	Moderate	Moderate	+	++	++	No change	++	++	++
2.8B	Neutral	Moderate	Neutral	Moderate	+	+	++	No change	++	No change	++
1.7K	Neutral	Moderate	Neutral	Neutral	++	No change	++	+	++	-	+
2.7Q	High	Moderate	Moderate	Neutral	+	No change	++	+	++	No change	+
2.8D	Neutral	Moderate	Neutral	Neutral	++	+	No change	+	+	+	+
2.7N	Moderate	Moderate	Neutral	Neutral	No change	No change	++	+	++	+	+
2.7E	Low	Low	Neutral	Low	--	-	-	No change	No change	++	+
1.7E	Low	Neutral	Neutral	Neutral	-	-	No change	No change	No change	-	-
1.8A	Neutral	Neutral	Low	Low	No change	+	No change	No change	+	No change	-
1.7F	Low	Low	Neutral	Neutral	+	No change	+	No change	+	--	-
2.8E	Low	Neutral	Neutral	Low	+	-	+	+	++	-	-

2.8H	Low	Moderate	High	Low	-	-	-	-	-	--	-
1.7I	Low	High	Low	Neutral	+	No change	No change	No change	+	-	-
2.7D	Low	Very Low	Moderate	Low	-	-	-	+	+	No change	-
2.7H	High	Moderate	Neutral	Neutral	++	-	-	No change	+	-	-
2.7T	Neutral	Low	Low	Low	No change	No change	-	No change	+	--	-
2.8K	Low	Low	Low	Low	No change	No change	-	No change	-	--	-
1.7A	Neutral	Moderate	Neutral	Neutral	-	-	++	No change	No change	--	-
1.8D	Neutral	Neutral	Low	Low	No change	No change	No change	No change	No change	No change	-
1.7G	Neutral	Moderate	Moderate	Neutral	-	-	++	No change	++	--	-

5.6 Research Question 5: Opportunities in non-formal science programs for students to develop trajectories into post-compulsory STEM education.

5.6.1 Section Overview

Several themes emerged in response to Research Question 5: *What opportunities are there in an ongoing non-formal science education program for students to develop trajectories into post-compulsory STEM education?* Four themes looked at the opportunities available to students to inspire interest and awareness of science utility (sub-section 5.6.2); to empower students' confidence in learning science (sub-section 5.6.3); for recognition of students as science learners (sub-section 5.6.4); and through changing teacher practice (sub-section 5.6.5). The final theme (sub-section 5.6.6) examined staff and teacher observation of opportunities, detailing the challenges in recognizing and capitalizing on these opportunities.

5.6.2 Opportunities to inspire interest and awareness of science utility

The programs at KIOSC offered students some opportunities to develop trajectories for further participation in learning science. However, opportunities for changing students' perceptions of science, their capability in science or aspirations for a science career were limited. The majority of students interviewed expressed no or little change in the way they thought about science over the time period of this study. However a few students did express that their experiences at KIOSC had inspired a change in their perception of science. This was primarily due to their realisation that there were different ways to learn science then what they had previously experienced at school.

Student: I thought science might be like just about writing, then just doing kinda like, just bookwork stuff …but it was actually doing things outside.

Other students reported changes in their perception of who could do science.

Student: I used to think science was mainly just men in lab coats working with biology and stuff like that but now I've learnt that there are different types of science.

In the survey a substantial group of students (43% calculated from 18 students out of a total of 42) marked their interest in science as having increased following their visits to KIOSC (Figure 5). The variable of change in science interest or enjoyment (combined from several related items see Table 5) recorded 43% of students expressing a positive change following their visits to KIOSC compared to 23% expressing a negative change in interest. Examination of specific items on interest showed that some students (38%) were more likely to see science less boring and others (36%) felt that their science lessons were more interesting following their visit to KIOSC.

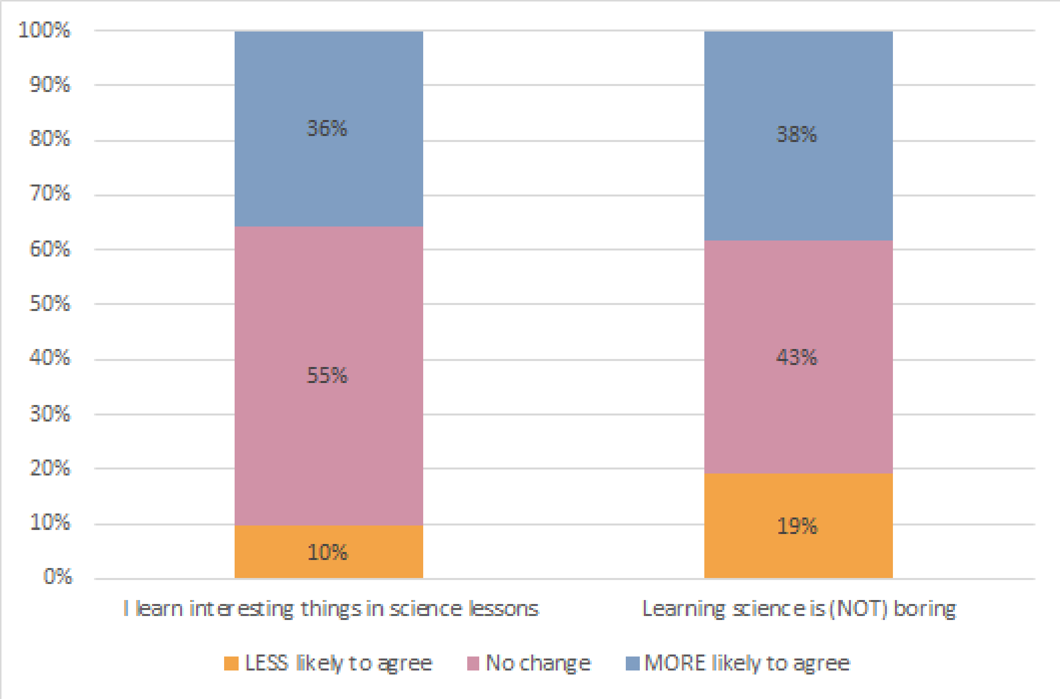

Figure 5. The proportions of students agreeing with a statement regarding their interest in learning science following a year of visits to KIOSC; more likely to agree, no change in agreement or less likely to agree (n=42).

From the teachers' perspective there was little observable change in students' interest and perceptions of science following the KIOSC experiences. Teachers did acknowledge that there was potential to stimulate student interest. Overall however teachers felt that the lack of connection between the KIOSC experience and their curriculum stymied opportunities to capitalize on any interest sparked by the experience.

Jim (Science Specialist): If we were doing [the unit] around that time I think there was heaps that we could have followed up on but other than that not a massive change.

Interviews revealed that for some students participating in the KIOSC programs had changed their perception of the utility of science.

Student: It was eye opening …it's like what we learn at school we learn a small part of it and then KIOSC shows more and it shows that there's a whole other side to it.

This was supported by the survey responses where 60% of students saw science as more useful following their KIOSC experiences (specifically referring to the change in perceived science utility value, collated from individual items which are detailed in Table 5 and graphed in Figure 6).

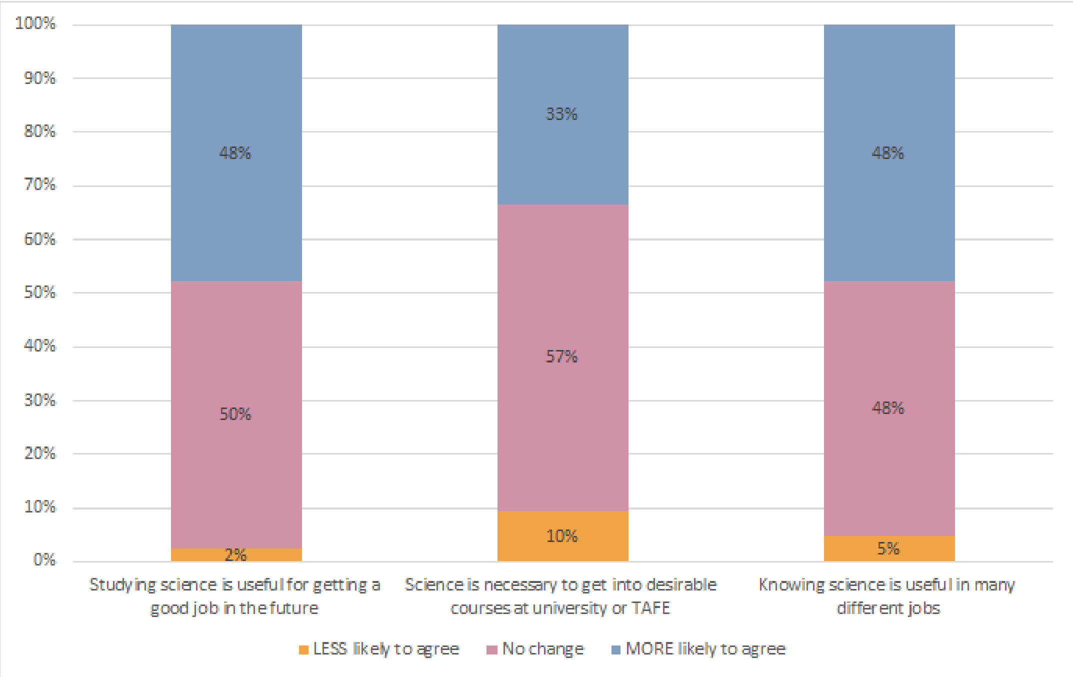

Figure 6. The proportions of students agreeing with statements regarding their perception change of the usefulness of science following a year of visits to KIOSC; more likely to agree, no change in agreement or less likely to agree (n=42).

Through the interviews the influence of KIOSC programs on students' perceptions and attitudes regarding STEM careers was revealed in more depth. A program that was on a topic students found interesting or enjoyable opened up opportunities to develop students' awareness of potential STEM careers.

Student: With the forensic science [program], [be]cause yeah, that definitely opened up my mind to forensic science and the different possibilities you can do with just simple chemicals.

Roughly equal proportions of the student sample expressed a positive or negative change in their desire to study science or to do a job that involved science (Figure 7). Overall student aspiration to study science or pursue a science career was not high (19% and 24%) respectively with most students expressing no change in their science aspirations. Despite STEM career awareness being one of the main goals of the KIOSC experience, very few of the students who attended the year 7 and 8 programs could talk about specific careers or study pathways following their visits to KIOSC.

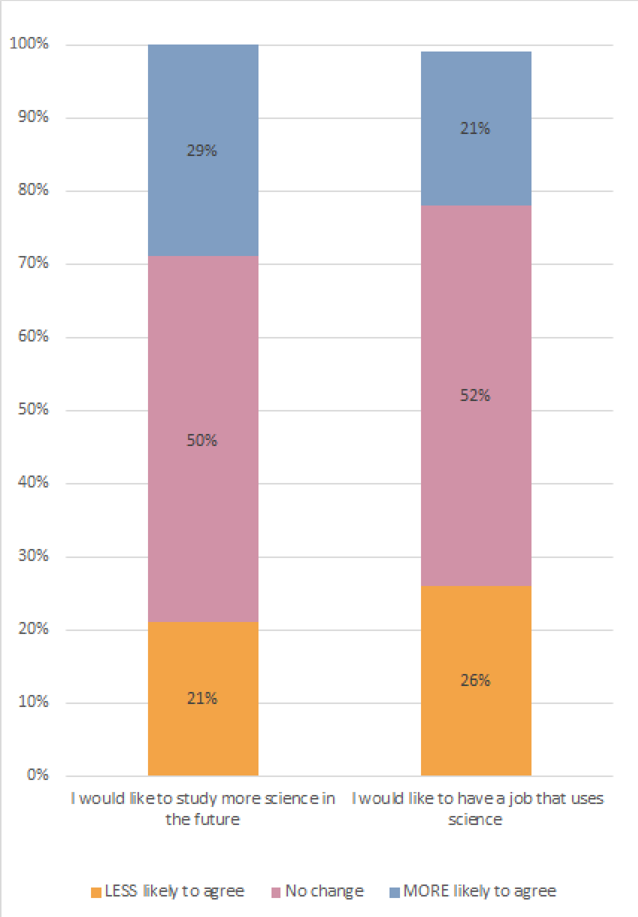

Figure 7. Student agreement with statements concerning their desire to study or use science in the future following their visits to KIOSC. (n = 42)

5.6.3 Opportunities to empower students' confidence in learning science

Crucially there were a few students who expressed that following their participation in programs at KIOSC they had changed their minds on how they fit into science. Several talked about realising that they were more capable than they had thought.

Student 1: Just the thought that even someone with,

Student 2: No experience even,

Student 1: Yeah even someone with no experience can go and do something so difficult and work it out….. I used to think, I would never be able to do anything like that.

Teachers and students both felt that the activities at KIOSC gave students opportunities to build confidence in doing science. Several teachers felt that the KIOSC programs gave students a chance to feel competence in doing science by allowing them opportunities for independence and agency in their learning.

Leslie (Non-Science): They had to think to themselves and then make decisions for themselves. I think a lot of the students more than anything else enjoy that sort of thing.

Students appreciated this agency in their learning and wanted similar activities in their future visits to KIOSC where they had more choices and more control over what they did.

Student: I like lots of hands on things like, and like you can take your own like part of it just, take control like you just taking control, instead of like the teachers coming round we could just like, go around by yourself or something with a group of friends and like do the activity…you get to take control of your work.

Forging a stronger connection to students' current work at school was also seen as a way to extend students' confidence in their learning. Teachers felt that when students had prior knowledge in the topic, they had more of a chance to feel competent in the activities.

George (Science Specialist): They seemed like they understood it because they had a bit of the background knowledge. So they started to get a bit more into that.

Survey responses also showed that students gained confidence in learning science from participating in the non-formal learning experiences at KIOSC. Half the student cohort felt that their confidence had positively changed after their KIOSC visits with only 19% reporting a negative change in confidence (Figure 8).

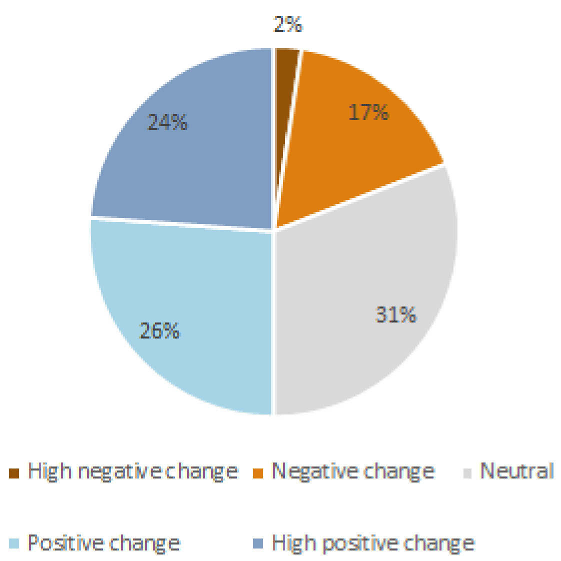

Figure 8. The proportions of students expressing an overall change in their confidence in learning science following their visits to KIOSC (n= 42).

Despite many students reporting that their confidence in doing science had increased after visiting KIOSC very few students reported a positive change to their affiliation with a science identity (Figure 9). Notably there were more students (42%) who expressed an overall negative change in their affiliations with a science identity then there were positive (15%). This may be associated with a lack of recognition by students of what doing science can involve. In the initial interviews students overwhelmingly associated a science identity with being smart and good at science at school. Statements by some students revealed that they did not recognize science in professions outside the stereotype, e.g. a student with an electrician brother reported that no members in his family did science or were interested in science.

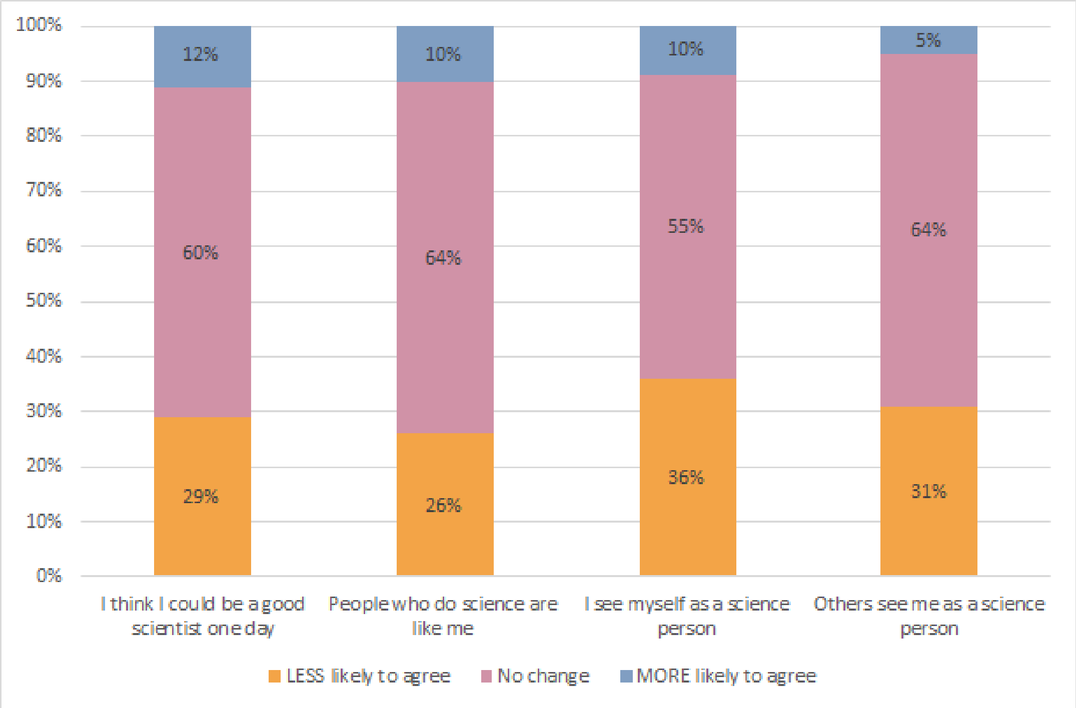

Figure 9. The proportions of students agreeing with statements related to their level of affiliation with science following their visits to KIOSC (n= 42).

Despite the low proportion of students with a high or moderate level of a science identity, some students seemed to consider that identification with science was flexible. They suggested that being a science person was possible in certain situations when they were particularly excited or passionate about a topic. Students agreed that KIOSC offered some opportunities for this to occur due to the more relaxed environment and more flexible nature of participation.

Student: They told us what to do and we weren't really restricted in what we were allowed to do and not allowed to do. We were allowed to like whatever.

5.6.4 Opportunities for recognition of students as science learners

Visits to KIOSC proved to be an opportunity for some students to gain recognition as legitimate science learners from their science teachers and the KIOSC staff. There were several instances when teachers reported being surprized with a student's participation in the activities at KIOSC which was very different to the student's typical behaviour.

Carol (Science Specialist): To be honest that was like 150% better than he would have been in a normal classroom, like sometimes we can't even get him in the door. So everything he'd done throughout the day and up unto that point I was like wow, I've never seen any of that.

This led to the teacher re-evaluating their assessment of the students' capability and interest in science and inspired them to follow up on these revelations back at school.

There was also evidence that attending KIOSC with their class groups gave students opportunity to gain recognition from their peers.

Students: To me, seeing people at school, there's a lot of different people that you wouldn't expect to do science and seeing mostly everyone go to KIOSC and really enjoying it.

KIOSC staff proved to be a valuable source of recognition for students as well. The connection between the school and KIOSC meant that this recognition was then able to be transferred back to the school setting, for instance through sharing with teachers.

Emily (Science Specialist): On the day two students who are normally disengaged and requiring behaviour management strategies blossomed under Helen's (Staff) compliment: "That they should be an electrician because they did such a good job".

5.6.5 Opportunities for students through changing teacher practice

Indirect opportunities for developing student trajectories were also available through the effect of the visit on teachers. As mentioned in section 5.2.1, the non-science teachers who attended were quite enthused about their visit and had changed perceptions or even renewed interest in science following the visit.

Leslie (Non-Science): I'm enjoying it so much more! No it gives me a totally different outlook as to what you can actually do and what these students could actually achieve. They could actually be some person or anything else making robots or making different *things.*

Science teachers didn't report changes in their interest or enthusiasm for science, one reflecting that she was already passionate about science.

Carol (Science Specialist): I love science a lot so I was already pretty excited about it. I think sometimes I get to see a bit more of the technology that I would get to see in everyday life. So that's pretty cool.

However science and non-science teachers did reflect that attending KIOSC alongside their students had given them ideas for their science teaching and inspired change in their teaching practice.

Jim (Science Specialist): It opens your [mind] to different ways of teaching… I'm very interactive and hands on and things like that and KIOSC just extends that and gives you little ideas. I think technology, I want to try and incorporate technology a little bit more.

Another science teacher felt that visiting KIOSC had given him a wider awareness of possible careers and courses in STEM which he could then use to help guide potential students.

Steve (Science Specialist): It's actually given me a bit more insight into what careers there are available to students as well rather than just you know the traditional science related things. So for me, it's you know opened my mind as to what there is out there…. Also I'm more aware now of what VET courses are run there as well. So when we're talking to the year nine students about doing a VET course in year ten, we can say hang on, there's these ones at KIOSC, have a think about those ones as well.

5.6.6 Observation of opportunities

A common theme in both teachers and staff interviews was the difficulty of observing any apparent changes, particularly over the long term. Staff only saw students for two days a year and didn't know the students well enough to judge if there were any changes in students' study trajectories over time.

Helen (Staff): *You look at the room, and you realise that you know five to six of the kids doing that VET course. And you think oh, I had them upstairs for a few years and then they're down here and I wonder if that's because they came to KIOSC and they liked what they did? Or they were just given an opportunity to see somewhere like this and go yep!*

Staff felt that classroom teachers would be better positioned to observe any changes in student perceptions of science. However the science teachers also found this difficult, explaining that it was hard to pin down changes specifically to the KIOSC experience when they were doing other topics.

Steve (Science Specialist): I don't know again, if some of the confidence has come from KIOSC or if it's just you know they're enjoying [current school project] or what it is.

It was reiterated that having more of a link between the curriculum and the KIOSC program would more easily reveal any changes in students.

Steve (Science Specialist): I think when it's embedded more into the curriculum then it will be easier to sort of get those ideas from the students and whether it has worked or hasn't worked will be able to be seen straight away rather than later on.

Both staff and teachers expressed that the KIOSC programs were just one component of students' long-term science education and unlikely by themselves to cause significant changes.

Carol (Science Specialist): So if anything has changed in their perception of science in the last two years it's been slow process and KIOSC is just another thing like what we're doing already. So we're hoping to do that all the time.

Teachers did see potential for change in the long term, not just from one KIOSC experience but from the combined effort of school and KIOSC with multiple visits over time.

Steve (Science Specialist): If we can link in like a little bit more science, and that you know further on down the track then yes [to affecting students' trajectories into post-compulsory STEM study]. Especially with VCE subjects I think we get a little bit more in, in fact for a couple of years we never had chemistry running. In the past couple of years we've actually got chemistry running as a VCE subject, so obviously doing some stuff at KIOSC has helped with that as well.

5.7 Summary of Main Findings

This chapter has presented the findings of this research project, structured according to the research questions. In general, KIOSC staff, teachers and students valued KIOSC for being different from school and saw the programs as engaging learning experiences.

However difficulties in connecting the programs to the school curriculum led to a lack of incorporation into students' science learning at school. As a result, many students treated visiting KIOSC as a day off school and some felt attendance was conditional on being already interested in science.

According to teachers these interpretations were accentuated over time as the novelty of KIOSC wore off and students saw the programs as increasingly irrelevant to them. However the ongoing nature of the KIOSC-school partnership also facilitated relationship building between staff and teachers and the ongoing development of programs. This collaboration was shown to be occasionally challenging but ultimately offered hope for resolving issues and refining the programs in future. This is important as the effectiveness of the school-KIOSC collaboration affected student experiences at KIOSC and the incorporation of those experiences into students' learning back at school.

There emerged a need to refine programs to accommodate the local context which saw teachers battling a lack of student enthusiasm for further education. Teachers often observed these pre-existing attitudes in students affecting their interpretation of KIOSC programs. This was supported by the survey which revealed that students more likely to express positive changes in their perceptions of science from their KIOSC visits were those who evaluated science highly in comparison to their other subjects and who already had a science identity and aspirations for further study or work involving science. The extent of support from teachers and family for students' science learning was also shown to relate to whether students reported positive or negative changes in their science perceptions. Notably however, students with varying backgrounds and attitudes towards science reported a positive change in their perception of the usefulness of science following their visit to KIOSC. Many students also felt more interested and more confident in learning science after their visits to KIOSC, but very few expressed a positive change in their affiliation with a science identity.

Overall there was a variety of opportunities within the KIOSC programs for affecting students' trajectories into post-compulsory STEM education. The non-formal setting offered several ways to engage and support students in learning science, particularly students who were reported as underperforming in the school science classroom. The connection between KIOSC and school also offered opportunities for teachers to recognize these students as successful science learners. Another indirect opportunity to affect students' trajectories into post-compulsory STEM education lay in how the programs enthused the teachers about science or broadened their awareness of STEM careers. The next chapter will explore these findings in more depth and explain how they relate to current research into non-formal science education in secondary schools.

Chapter 6: Discussion

6.0 Chapter Introduction

This chapter explores the results presented in the previous chapter, discussing them within the context of the literature. It will synthesise the results to answer the research questions this thesis aimed to address. Section 6.1 addresses the first research question looking at the general interpretations of the non-formal programs in four broad roles and highlights differences in interpretations between students, staff and teachers. The following section (6.2) focuses on how these interpretations change over time and explores the implications of this for realising the desired roles of the non-formal program. The effects of collaboration on student experience and their subsequent interpretations of the non-formal programs is examined in section 6.3. The next section (6.4) looks at the fourth research question where the influence of student background on their interpretation of non-formal programs is discussed. The final research question is explored in section 6.5 which explores the opportunities available in ongoing non-formal science education programs for encouraging students on trajectories into post-compulsory STEM education. Section 6.6 then details the limitations of this research and section 6.7 provides a conclusion for the key findings of this study.

6.1 How are ongoing non-formal science education programs interpreted by students, teachers and staff?

6.1.1 Engaging students in learning science

The non-formal programs at KIOSC were predominantly seen by teachers, students and staff as providing students with engaging learning experiences that were different from their science learning at school. This interpretation is congruent with the perspectives of teachers and non-formal educators reported in the literature (Bevan et al., 2010; Garner & Eilks, 2015). Similar to what was described by Luehmann and Markowitz (2007) the teachers in this study saw the non-formal setting as offering a valuable opportunity for their students to experience science differently. This perspective was also supported by the students themselves who found the unique aspects of KIOSC enjoyable and appealing. An interesting finding of this research however was that there was variation in the extent to which the non-formal programs were perceived as different from school science and subsequently how engaging they were believed to be for students. While non-science teachers and the KIOSC staff were highly enthusiastic about the programs being very different from school science the science specialist teachers were more conservative in their opinions. With more experience teaching science they were more attuned to aspects of the programs which they felt made the programs too similar to school. This contrasts the finding of Luehmann and Markowitz (2007) who found no difference in responses between groups of teachers. In this study, science specialist teachers' concerns over the similarity to school science echoed their criticism of not fully utilising the resources of the non-formal programs. Given the value placed by teachers on the uniqueness and authenticity of an external context demonstrated here and in other studies (Anderson, Kisiel, & Storksdieck, 2006; DeWitt & Storksdieck, 2008; Luehmann & Markowitz, 2007) this should be a high priority for non-formal programs.

Student engagement in the non-formal learning experiences was facilitated by the hands on and highly interactive nature of many of the activities at KIOSC. This finding is not surprising given the amount of literature attesting to student engagement with hands on activities (Garner & Eilks, 2015; Luehmann, 2009a). This study found that in particular the advanced technology, external educators and outside environment was very engaging for students. The engagement appeal of these features to students has also been reported in other studies on non-formal science education programs (Bevan et al., 2010; Dunkley, 2016; Garner & Eilks, 2015; Luehmann, 2009a). However, the opportunities provided by the unique affordances of the non-formal setting at KIOSC were often limited, possibly due to insufficient utilization of these affordances or students' experiences being too similar to school. Some of the advanced and unique technology of KIOSC was not always included in the programs for junior year level students and this negatively affected student engagement in the programs over time (discussed further in Section 6.2). This strategy and the consequences for student engagement has not been widely reported on. Though the disappointment of teachers in this study with programs they felt they could have done at school has been found in previous research into non-formal science education programs (Kisiel, 2010) the perspective of students has been lacking. This research shows that not fully using the non-formal resources, particularly when it results in experiences similar to school science, can have serious implications for realising the potential of non-formal programs to engage students in learning science. Development of long term or ongoing non-formal programs therefore should carefully consider how students' experiences make use of the unique features of the external setting.

Student expectations for novel and different experiences in the non-formal setting further shaped their interpretations of non-formal programs in ways which were not always positive. Instead of seeing the visits to KIOSC as a day out of school for experiencing a different way to learn science as the teachers and staff did, most students saw the programs as a day *off* school. Students' reflections of the experience were thus based around personal enjoyment and they typically did not see it as linked to their science learning at school. Archer, DeWitt, and Dillon (2014) also showed this compartmentalization in students in a class based science enrichment program which involved teachers delivering externally developed material. . This research supports their claim that an exciting learning experience which is very different from school can lead students to compartmentalize the activities and their subsequent enjoyment from school science. The personal enjoyment orientated interpretation had implications for student engagement across the student cohort. Students who did not find the activities interesting and enjoyable developed a perspective of conditional attendance which was amplified by the similarity of the non-formal programs to school science. This 'not for people like me' perspective of science has been reported in formal (DeWitt, Archer, & Osborne, 2013) and informal settings (Dawson, 2014) but not in an ongoing non-formal program like this one. In general the enjoyment based interpretation of KIOSC seemed difficult to maintain in students as their expectations for fun and novel experiences were often unrealistic, leading to disappointment and negative interpretations of KIOSC. Garner and Eilks (2015) also highlight the danger of this for student learning from non-formal experiences and stress that student expectations need to be moderated by teachers to avoid this. Therefore shaping students' expectations appropriately remains a critical challenge for ongoing non-formal programs as it does for short term or one off experiences.

6.1.2 Extending student learning

A key interpretation of the non-formal programs at KIOSC was as a learning extension for students. Staff and non-science teachers accepted this interpretation and assumed that through the non-formal setting and the activities which were aligned with the curriculum, students' learning was extended. This focus is not surprizing considering the value placed on aligning non-formal programs with the school curriculum (Tytler, Symington, & Clark, 2016). The desire of teachers expressed in this research for non-formal programs to extend their students' learning is a typical response frequently observed in non-formal science education (Anderson, Kisiel, & Storksdieck, 2006). However this research also concurs with Luehmann (2009a) in that providing curriculum-framed programs did not automatically equate to a meaningful learning experience for students. It was apparent in this research that realising non-formal programs in their role as learning extenders for students required careful consideration of how the experiences were actually incorporated into students' school learning.

This research found that it was very challenging for teachers to capitalize on students' non-formal learning experiences as the topic usually was not connected to what students were doing in class. This was an unexpected finding as all the programs on offer at KIOSC were carefully designed to fit into the Australian science curricula (which all schools followed) and had associated activities and resources provided to schools. The difficulty of connecting out-of-school learning experiences to school curriculum is well known and has been identified as one of the biggest challenges in collaborations for non-formal science education (Garner & Eilks, 2015; Tytler, Symington, & Clark, 2016). Here, the primary challenge to connecting students' learning across settings was from the difficulties in aligning the program schedule at KIOSC with the curricula of the individual schools. While drawing from the same national curriculum each school went through the topics on their own schedule which did not always align with the periods that particular programs were run. This challenge of organizing conflicting schedules in non-formal science education programs was also described by Kisiel (2014). However the extent to which my research revealed this to be an issue is surprising in a model which was established in such close connection with schools and where teachers had access to supporting materials. It is also surprising considering that there are only six schools involved. This thesis is not equipped to comment on initial set up of KIOSC however it seems that current staffing levels restricts KIOSC's ability to offer a more flexible schedule to schools. Given the impact of scheduling on incorporating non-formal experiences into students' school learning, facilitating this flexibility may be a worthwhile investment.

The findings from this research showed that students were unclear about the learning focus for the KIOSC non-formal programs and often did not perceive their visits as valuable learning experiences. While each program at KIOSC was developed with clear learning outcomes, these were not necessarily made clear to the students who were often not prepared for their visits. Hence this research supports the argument of Anderson, Kisiel, and Storksdieck (2006) who likewise found that without clear expectations and aims for the non-formal program teachers were less likely to use supporting materials productively. The necessity of students being well prepared for their learning experiences in non-formal settings has been previously emphasized (Garner & Eilks, 2015; Stewart & Jordan, 2017). The importance of preparation is further illustrated in this research which shows a clear difference in the interpretations of students from a school which did do preparation and students from a school that didn't. Students without the preparation were less cognisant of a connection to their school learning and more inclined to focus on the engagement aspects of the experience. As mentioned in the previous section this led to many students not feeling engaged and seeing KIOSC as 'not for me'.

Furthermore this research also saw that as Garner and Eilks (2015) found, students did not automatically expect a connection to their school learning. Their awareness of the learning outcomes for the program was further hindered by the different structure and pedagogy of KIOSC learning experiences which was unfamiliar to them. This finding reflects the claims of Stewart and Jordan (2017) and Peacock and Pratt (2011) that the less structured program and novel settings can make it difficult for students to recognize the learning outcomes in non-formal programs without explicit instruction. This makes it clear that in order to realise the potential of non-formal programs as learning extenders, it is vital to shape student expectations appropriately for their non-formal learning experiences. A simple way to do help establish appropriate expectations is by briefing the students before and after the program and doing some of the linked activities (provided by KIOSC) in class at school. As discussed in later sections (e.g. 6.3.2) this strategy was already in place, but difficult to achieve amidst the time constraints of both schools and KIOSC.

6.1.3 Flexible setting supports student participation

Another interpretation of the non-formal programs often expressed by staff and students in this study was that they facilitated student participation in learning science. According to the staff and students KIOSC had a relaxed learning environment which allowed flexibility in the way students participated in the activities. The staff focus on ensuring this flexibility in student participation is characteristic of the non-formal environment, where there is often a underlying intention to facilitate the participation of students from population groups underrepresented in STEM or otherwise disadvantaged groups (Bevan et al., 2010). While teachers, both science specialist and non-science, did not express this interpretation as clearly as students and staff, they were still cognisant of the KIOSC setting facilitating the participation of students who were typically disengaged or had behavioural issues at school. This finding is congruent with other research showing that non-formal environments have less rigid norms than schools which allows them to more flexibly accommodate students (Barton & Tan, 2010; Barton, Tan, & Rivet, 2008; Carlone et al., 2015; Riedinger, 2015). The social setting and emphasis on group activities was also appreciated by students, a feature likewise mentioned by (Digweed, 2015). A notable finding of this research was that several students specifically stated that they found it less stressful for them to learn science in the non-formal setting at KIOSC which made learning science more appealing to them. This supports the claims of Rahm, Lachaine, and Mathura (2014), who argue that a flexible learning setting supports student confidence and subsequent participation in learning science. This finding has implications for the way that non-formal programs can support students to continue studying post-compulsory STEM. Further development of this role by schools and centres could provide students typically disengaged in the science classroom with alternative avenues to STEM careers.

6.1.4 Increasing awareness and interest in STEM careers and sustainability

The interpretation of non-formal learning experiences as a career guidance tool is another commonly desired role for non-formal science education programs. In this study staff and teachers were of the opinion that the non-formal programs at KIOSC had the potential to broaden student awareness and interest in STEM careers in ways schools could not. Teachers and non-formal educators usually see non-formal programs as having a clear role in developing student interest and awareness of STEM careers and post-compulsory STEM education (Anderson, Kisiel, & Storksdieck, 2006) despite a lack of evidence for this (Banerjee, 2017b). Many non-formal science education programs have a clear goal to increase student interest in STEM careers (e.g. Allner et al., 2010; Crawford & Huscroft-D'Angelo, 2015; Dougherty, Oliver, & Fergusson, 2014). However, non-formal programs that do report increased awareness and aspiration for STEM careers, along with success directing students onto particular study pathways, tend to be highly focused on that specific pathway as the sole focus of the program (Arora, Schneider, Thal, & Meltzer, 2011; Burgin, McConnell, & Flowers, 2014; van Eijck & Roth, 2009). But such programs are not typical of secondary non-formal science education and restricted to small numbers of typically high achieving students. Persistence of the perception of non-formal programs as career guidance tools is not surprising given that non-formal settings are seen to offer students valuable exposure to scientific professions (Bevan et al., 2010) but as this research shows it can be difficult to realise non-formal programs in this role.

The capacity of KIOSC non-formal programs for increasing student awareness and aspiration for STEM careers was shown to be limited in this study. While the experiences at KIOSC did inspire several students to change their minds on the usefulness of science for careers, they were less well informed on specific career and study pathways that linked to the program they attended. Consequently students did not appear to interpret the non-formal programs as a career guidance tool and again were more focused on the affective components of their experiences. This was recognized by specialist science teachers and the KIOSC staff who while advocating for the non-formal programs as a career guidance tool also acknowledged that there was little actualization of this for students. The limited detail available in programs regarding career and study programs is also described by Tytler, Symington, and Clark (2016) who found that despite a strong desire for various career and study related goals from educators, non-formal programs tended to have little coherent view of specific career related outcomes for their students. Not providing students with clear links to STEM careers related to their experiences in the non-formal program is likely to result in poor awareness of students as is seen with learning outcomes (Stewart & Jordan, 2017). Further development of non-formal programs for the purpose of increasing student awareness and interest in STEM careers should take note of the need to make the career linkages apparent to students. It cannot be simply assumed that introducing them to a context or topic will be sufficient for them to make these connections. Given that junior secondary students are at a critical age for forming career aspirations (Tai et al., 2006) providing them with more explicit information regarding possible career and study pathways is an important role that non-formal programs can fulfil and identification of the most effective means of doing this should be a future avenue of research.

Another interpretation of non-formal programs related to their role as career guidance tools was their ability to inspire awareness and behavioural change regarding sustainability. This interpretation was most strongly expressed by the KIOSC staff, but it was also recognized by the teachers. The desire for non-formal programs to inspire sustainability awareness and behavioural change is typical of many collaboratively developed non-formal science education programs (Tytler, Symington, & Clark, 2016). However, this study demonstrated that there can be differing uptake of this role amongst teachers and non-formal educators. Unlike the ongoing collaborative non-formal programs described in Bouillion and Gomez (2001) and Robertson (2007), the sustainability focus of the programs was not a high priority for teachers in this study. It also showed only sporadic uptake amongst students. Peacock and Pratt (2011) suggested that student learning in environmentally focused non-formal settings (e.g. national park) was limited by the novelty of the structures which distracted from the learning purposes. These claims are reflected in this study which showed limited awareness of sustainability in students but an intense focus on the novelty and technology of the non-formal setting. As with the use of non-formal roles as career guidance tools, the ability of non-formal learning experiences to expand students' awareness may be limited by students not being prepared appropriately. There is currently no other research available directly examining student or teacher interpretation of non-formal programs in a role of sustainability awareness. Considering many non-formal programs aim to educate students about sustainability in addition to engagement and learning goals, investigating the capacity of non-formal science education programs in this role would be prudent. It would also be useful to clarify the role amongst attending teachers; while the specialist science teachers in this study recognized staff desire to promote sustainability awareness this was not a role they directly supported, and it might even conflict with their preferred roles of engager and learning extender for their students. Bouillion and Gomez (2001) and Robertson (2007) showed student engagement with the sustainable focus of their collaborative non-formal programs when there was intense investment by their teachers in the environmental ethos but this was not present in the teachers involved at KIOSC. Hence, realising the role of non-formal programs for increasing student sustainability awareness and promoting behavioural change requires consistent and clear interpretation of the role amongst the educators involved. Potentially this issue could be addressed by program development sessions where teachers could discuss programs and priorities with staff. It is noted however that staff and teachers already have regular meetings to plan KIOSC visits so perhaps an expansion of such meetings from scheduling to program development would assist in this regard.

6.2 How do stakeholder interpretations of a non-formal science education program vary over time?

6.2.1 Student Interpretation Over Time

Insight into the change in students' interpretations of non-formal learning over time is a novel finding which has been previously unreported. Current research into student perspectives of non-formal science education programs highlights the importance of shaping students' expectations for learning and maintaining their learning experience across settings (Garner & Eilks, 2015; Luehmann, 2009b) but this research shows the consequences of inappropriate student expectations over time. This study showed that in the long term, some of the students developed more negative interpretations of the non-formal science education programs they attended. Conversely a few students interviewed claimed that increasing familiarity enabled them to better participate and make the most of their non-formal experiences but in general teachers reported a marked decline in enthusiasm over years seven to ten. This was attributed by teachers as a key factor behind students' declining enthusiasm for the programs over time as many of the student cohort apparently saw the non-formal programs as not interesting or relevant to them. As detailed in section 6.1, it was common for students' non-formal experiences to be poorly connected or not incorporated at all into their school science learning. The need for connection is supported by Luehmann and Markowitz (2007) who found that connecting students' school learning to their non-formal experience helped to develop realistic expectations in students. McCreedy and Dierking (2013) and Stake (2006) also highlight that continuity of experience is important in supporting students' continuing participation in science following their non-formal program. Subsequently this research demonstrates that a lack of connection makes it challenging to maintaining student enthusiasm for non-formal programs over time.

Students' declining enthusiasm over time may also be due to their disappointed expectations for novel experiences. Students' interpretation of their experience centred on their personal enjoyment, a large part of which came from the novelty appeal which naturally reduced over time. While it is established that the novelty of external learning settings can distract students from the learning objectives of the program (Orion & Hofstein, 1994; Peacock & Pratt, 2011) no other study has shown that a reduction in novelty can negatively influence student interpretation of their non-formal learning experiences over time. Other reports into long term or ongoing non-formal science education programs have not raised novelty as an issue, however these programs were typically structured around a particular scientific unit (e.g. Luehmann, 2009b) or community issue (e.g. Bouillion & Gomez, 2001). In contrast, the model of non-formal programs at KIOSC involves regular visits to the same setting but on individual scientific topics. Hence these findings indicate that maintaining student enthusiasm over time is an important consideration for this kind of model of a non-formal science education program. Further development of an ongoing model of non-formal science education programs in schools to this effect could consider including long term projects (e.g. Bouillion & Gomez, 2001) which build upon each visit and encourages student investment over time. Alternatively informing students about later year programs, perhaps even by senior students themselves, could help students develop clearer expectations and anticipation for subsequent experiences.

6.2.2 Teacher Interpretation Over Time

This study showed that science specialist teachers' interpretation of the non-formal programs changed over the years as the program was established. Initially science teachers were disappointed when the non-formal programs did not fulfil the desired roles in the school, e.g. engaging students or extending their learning. As teachers grew familiar with, and adapted to, using the non-formal programs their outlook changed to cautious optimism. This process of adjusting expectations and perceptions in science teachers appears to be typical of the collaborative process of an ongoing non-formal science education program (Robertson, 2007). The time available for teachers to adapt to using a non-formal program for their students has been shown to be one of the advantages of an ongoing non-formal program (Kisiel, 2010). Facilitating this adaption should be a priority for non-formal programs as teacher familiarity and expectations concerning a non-formal program can affect their students' experiences and eventual outcomes (DeWitt & Storksdieck, 2008). In this research teachers' unfamiliar with KIOSC were not able to effectively prepare students for the visit, affecting students' own expectations and possibly contributing to student focus on the novelty of the experience rather than the learning goals. Kisiel (2010) also described how, with a greater awareness of the learning opportunities possible in the non-formal programs, science teachers could use it to reinforce concepts that they taught in class or introduce new ones they weren't able to cover. There was some evidence that this was also occurring at KIOSC, such as how one teacher was incorporating the career information of KIOSC into his teaching. Further research into teacher familiarisation with non-formal programs would help develop this process further.

The changing interpretations of the science specialist teachers became more positive as the non-formal programs were adapted over time. This included changing up the activities within particular programs, modifying programs to suit different year levels and altering the timing of programs throughout the year. Addressing various issues, particularly logistical ones, in consultation with the KIOSC staff contributed to teachers' positive outlook for the future. As with Kisiel (2010) and Robertson (2007), teachers grew more enthusiastic about the non-formal program as it was refined and they could use it more effectively as a learning experience for their students. This capacity for adaptation was made possible by the relationship building between the school and KIOSC communities. Collaboration over time helped to improve communication between staff and teachers which helped them to resolve issues and refine programs to suit the needs of both communities. Unlike Robertson (2007) however, this study did not observe teachers developing a sense of ownership or dedication to the non-formal programs. Robertson (2007) saw that teachers who were heavily involved in creating the program become very committed to using it and spreading its use amongst other teachers. But the teachers who took part in this study were not heavily involved in the program development. Fostering teacher involvement in the development of ongoing non-formal science education programs therefore should be a consideration when establishing these programs in schools. Positive teacher interpretation of non-formal programs is critical to program uptake in schools (Robertson, 2007) and to ensuring that the programs are appropriately adapted to suit the needs of a school (Kisiel, 2010).

6.3 Is there an interaction between the collaborative nature of a non-formal science education program and stakeholder interpretation of it?

6.3.1 The impact of effective and ineffective collaboration on students

This research reflects previous studies showing that collaboration between teachers and external educators had a major impact on students' non-formal experiences and how they interpreted those experiences. Effective collaboration between teachers and educators was shown to contribute to the development and implementation of non-formal programs which were enjoyable and meaningful learning experiences for students. This finding echoes that of Robertson (2007), Kisiel (2010) and Luehmann (2009b) who all observed the positive benefits from teachers and external educators or professionals working together. However this research also showed the negative consequences stemming from ineffective collaboration which few studies have described in depth. The difficulties of communication observed in this study are also described by Kisiel (2010) and Tytler, Symington, and Clark (2016), but there is limited information available on how this affects students' interpretations of their non-formal learning experiences. In this study there is a clear example of how ineffective collaboration (specifically a miscommunication of visit dates) disrupted students' visits leading to negative student and teacher interpretations of the non-formal institution credibility. As discussed in the previous section these initial interpretations influence student expectations and attitudes concerning future visits, potentially amplifying the effects of one negative experience. These findings further support the conclusion of Kisiel (2010) and Tytler, Symington, and Clark (2016) that effective collaboration between science teachers and non-formal staff is the key to a successful non-formal science education program.

Collaboration concerning logistics and organization of the programs at KIOSC were shown in this study to have a large influence on student experience of the non-formal programs. Managing these practicalities also affected teacher and staff interpretation of the programs as the logistics took a lot of effort on both sides. This research concurs with Anderson, Kisiel, and Storksdieck (2006) and DeWitt and Storksdieck (2008) that the practicalities of getting students to and from the non-formal program along with the cost involved influence teacher perception of the experience. The difficulties and effort required for logistics in non-formal science education programs have also been previously reported in Australia (Dougherty, Oliver, & Fergusson, 2014) and highlighted as key challenges to the success of non-formal science education programs (Kisiel, 2010; Tytler, Symington, & Clark, 2016). But the findings here go further to show that these factors also coloured student interpretation of their experiences which has not been previously shown. As reported by the teachers, the cost of the program was off putting to students when they felt the experience was not satisfactory. In this study and in others (e.g. Kisiel, 2010) communication between teachers and non-formal educators helped to resolve logistical issues. Consequently ensuring teachers and their non-formal partners have the time to work together is vital to the realisation of the potential of non-formal science education programs for secondary students.

6.3.2 Challenges to effective collaboration in non-formal science education programs

A key challenge for collaboration was the negotiation of different agendas and ways of operating between the KIOSC staff and the specialist science teachers. While sharing similar goals that students had an engaging, meaningful learning experiences, it was evident that there were different priorities for the staff and the science teachers. For instance the specialist science teachers focused on curriculum fit and realising the role of KIOSC as a learning extender and a career tool, while the staff valued the experiences as ways to develop student awareness of sustainability. The presence of different agendas and expectations for the non-formal learning experience reflects the general findings of the non-formal education literature (Anderson, Kisiel, & Storksdieck, 2006). Likewise, previously reported challenges of communication (Dougherty, Oliver, & Fergusson, 2014) and the necessity of spending time to negotiate different goals and cultures (Kisiel, 2010; Tytler, Symington, & Clark, 2016) reflect what was observed at KIOSC. This study also observed the tendency of teachers to focus on behavioural management while staff expected a more involved role which reflects the findings of Alon and Tal (2017). A process of negotiation between two communities has been shown to be a natural and required part of developing a successful ongoing non-formal science education program (Alon & Tal, 2017; Bouillion & Gomez, 2001; Kisiel, 2010; Robertson, 2007). Previously however this negotiation process has been described as occurring between distinctly different communities of teachers and scientific professionals (Tytler, Symington, & Clark, 2016) or informal educators (Kisiel, 2010).

This research shows here that extensive negotiation is required even when the external partner consists of qualified and experienced science teachers as the KIOSC staff all were. This research also found that there were also differences in school operation and agenda between the different schools involved. One school was sometimes focused more on engaging their students, getting them interested and involved in the experience regardless of the topic. The other was more attuned to extending student learning from school and helping them achieve learning outcomes. While this has been previously alluded to by research looking at teacher perspectives from a range of schools (e.g. Anderson, Kisiel, & Storksdieck, 2006) this research highlights how having to negotiate a range of different schools in a partnership affects staff implementation of a non-formal science education program. Further development of similar models of ongoing non-formal programs in schools should include consideration of the work needed to establish effective collaborations between non-formal staff and teachers. In particular there needs to be awareness that similarity of educator background or of school locality does not equate to similar communities nor remove the need to invest in time for understanding and adapting to different agendas and ways of operating.

6.4 Is there an interaction between student background and students' interpretation of the non-formal science education program?

6.4.1 Pre-existing attitudes affects student interpretation of program

It was apparent in this study that students' pre-existing attitudes to learning science affected their expectations and interpretations of their non-formal learning experience. However, as will be further discussed in section 6.6: Limitations, insufficient numbers of student participants prevented statistical analysis of the survey which was originally designed to explore student background. What can be concluded from the survey is that students who were positively disposed to science prior to their visit tended to report positive change in their perceptions of science while negatively inclined students reported the reverse. Positive changes in student attitude stemming from non-formal science learning experiences have been previously found (Şentürk & Özdemir, 2012; Stavrova & Urhahne, 2010). Yet as mentioned by Archer, DeWitt, and Dillon (2014) in regards to an in-class science enrichment program there is a concern that such programs are failing to connect with students who are not already enthusiastic about science. However, the tendency for students who have a poor opinion of learning science to report negative changes in their perceptions following a non-formal science education program has not been previously demonstrated. Considering students with negative perceptions of science are often the ones whose change in opinion is most desired, an important focus of future research should be on specifically examining students' negative responses to non-formal learning. Understanding how students with different pre-existing attitudes respond to non-formal learning experiences would be useful for refining non-formal programs that cater to school classes. School use of non-formal science education programs often creates the challenge of catering to a variety of demographics with different understanding and attitudes towards science (Archer, DeWitt, & Dillon, 2014). Yet this is a problem non-formal programs must be aware of and prepared to address in order to realise the potential of non-formal learning for reaching and engaging students in science.

Another finding of this research was that students who found that their non-formal learning experiences confirmed their negative perceptions of learning science were disengaged and resisted further participation in the activities at KIOSC. Negative attitudes towards science have been repeatedly shown to affect student participation in learning science across settings (Archer, DeWitt, et al., 2013) but this study appears to be the first to demonstrate how student attitudes in an ongoing non-formal science education program affect their attendance. Students' pre-existing negative attitudes about science seemed to be too often reinforced by their dissatisfaction with the non-formal learning experiences. Reinforcement of pre-existing opinions about science by a non-formal program was also demonstrated in similar albeit school-based program by Archer, DeWitt, and Dillon (2014), which along with this study illustrates the difficulty external programs have in overcoming dominant school stereotypes about science (e.g. science is hard). In contrast another study into non-formal programs showed that students with initially negative attitudes can be reformed positively, however this was an intensive unit and did not take place over multiple years (Carlone et al., 2015). Situating the non-formal program in the local context is also an important consideration as the general attitudes and ideas prevalent in the local community were reported by the teachers to affect student participation in the non-formal programs. The importance of adapting non-formal programs in light of the social and cultural aspects of the community is also emphasised in Barton and Osborne (2001). The possibility of non-formal learning experiences reinforcing students' negative perceptions and stereotypes about science should be something that teachers and non-formal educators are attuned to and actively working against. Consequently further reflection into how the non-formal programs can overcome these pre-existing biases is something that schools and non-formal educators should take into account. As section 6.5 will highlight, the non-formal setting held particular opportunities for engaging students who were disengaged from school science, which will be missed if students do not attend the programs in the first place.

6.4.2 Pre-existing support affects students' interpretation of program

An effect of student background, especially parental support for their science learning, was also seen in this research. This finding is not surprising given the strong influence of family (Archer, DeWitt, & Wong, 2014; Dawson, 2014; Sha, Schunn, Bathgate, & Ben‐Eliyahu, 2015) on students' experiences of science learning extensively reported throughout the literature. This research shows that the influence of parental support for students' science learning in formal and informal science settings also extends to non-formal learning. Further research in this area would be useful to the development of non-formal programs as many are specifically aimed to promote participation of students from underrepresented population groups (Thiry, Archie, Arreola-Pena, & Laursen, 2017) and who are likely to have poor familial support and low levels of science capital (Archer, DeWitt, & Wong, 2014). Understanding how to provide non-formal science education learning experiences that are accessible to students with low familial support should be a priority for those implementing such programs.

This research also highlighted the importance of science teachers to students' interpretation of their non-formal learning experiences. As has been shown by many studies (e.g. Lyons & Quinn, 2010a; Tytler & Osborne, 2012), teachers hold considerable influence over students' attitudes and perceptions of science in school and everyday life. The findings of this research indicate that this influence is likewise present in the way students interpret and respond to non-formal learning experiences. Given the extensive involvement required of teachers for effectively using non-formal science education programs shown here and in other research (e.g. Kisiel, 2010) it would have been unusual to not find a relationship. Subsequently this thesis joins in the calls for supporting the development of specialized science teachers (Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008) with the further appeal that training in using non-formal science education programs be also included. Many teachers both new (Redman, Dawborn-Gundlach, & Symons, 2017) and experienced (Anderson, Kisiel, & Storksdieck, 2006) lack familiarity and understanding of non-formal learning or settings which leads to unrealistic expectations and inappropriate use of the non-formal program. Teachers that are ill-prepared for non-formal learning experiences are one of the key hindrances to realising the opportunities therein for student learning (Anderson, Kisiel, & Storksdieck, 2006). Thus focusing on this challenge and encouraging teacher professional development in non-formal science education may represent a practical way to improve the effectiveness of non-formal science education programs and achieve the desired outcomes for students.

6.5 What opportunities are there in ongoing non-formal science education programs for students to develop trajectories into post-compulsory STEM education?

6.5.1 Opportunity to change student perspectives of science

Several aspects of the KIOSC program provided opportunities to spark students' interest in learning science. A particular affordance of the long-term nature of the KIOSC model of non-formal science education was that students were able to experience a variety of topics over time, increasing the likelihood that students will find a scientific topic that appeals to them. The engagement made possible through exposing students to a diversity of scientific topics is purported to be a strength of the informal sector (Bevan et al., 2010) but is less well reported on for non-formal science education programs. This may be partially due to many long term, non-formal science education programs being designed around a specific unit (Luehmann, 2009b) or a particular area of science (Kisiel, 2010; Robertson, 2007). Further opportunities observed in this study for developing student interest lies in the length of time they spend on a program. This was also reported by Luehmann and Markowitz (2007) where the teachers involved expressed similar opinions to the teachers in this study; that the longer learning experiences allowed students to take part in longer and more involved activities than would be possible at school. The increased interest reported by some students as measured by the reflective post survey aligns with a previous study which reported increases in interest shortly after student completion of non-formal programs (Stern, Powell, & Ardoin, 2008). This research also concurs however with the considerable amount of research demonstrating that student changes in interest, along with other impacts from the experience, is not sustained without support and social encouragement (Gonsalves, Rahm, & Carvalho, 2013; Stake, 2006; Stern, Powell, & Ardoin, 2008). Capitalizing on opportunities in non-formal programs for fostering student interest in science therefore relies as much on the environment at school as it does on the non-formal setting.

There was also potential in the KIOSC non-formal programs to change student perspective of how useful they thought science was for their future careers. This finding concurs with the findings from other non-formal science education programs which like KIOSC were based in a tertiary education setting (Jensen & Bøe, 2013; Jensen & Sjaastad, 2013). However the extent of change in student aspirations into STEM careers was limited in this study, affirming research that non-formal science education programs may not be capable of greatly influencing students' continuation in post-compulsory STEM (Banerjee, 2017b).

Despite the limited extent to which students' perspectives of science were affected these findings still support the argument that non-formal programs offer opportunities to affect student understanding of where science can lead (Archer, DeWitt, & Dillon, 2014). This study showed that several students saw science as more relevant due to their non-formal learning experience and there was a marked increase in student utility value of learning science. Programs which encourage students to see the relevance of science and increase their science utility values have been reported to increase student interest and performance in science (Hulleman, Godes, Hendricks, & Harackiewicz, 2010; Hulleman & Harackiewicz, 2009). Hulleman and Harackiewicz (2009) further demonstrated that a program focused on relevance is especially valuable for students with a history of performance and low success expectations. This could be seen in the findings reported here as well where students previously characterised as poor performers successfully participated in practically orientated activities. Altogether there is a strong argument that non-formal science education programs have considerable capacity to positively affect students who have disengaged from school science (Barton & Tan, 2010). To capitalize on this opportunity for encouraging disengaged and poor performing students to continue into post-compulsory STEM, non-formal programs should focus on increasing student utility value of science through topics that are highly relevant to them. Educators looking to address these student populations specifically may then benefit from incorporating such non-formal programs in schools.

This research showed that the flexible setting of a non-formal environment helped several students feel more confident about participating in the non-formal learning experiences. Presenting students with a culture of science in which they feel more welcome represents a significant opportunity to change students' trajectories towards science, as the perceived rigidity of science culture is a key barrier to students' ongoing participation (Taconis & Kessels, 2009). This study also showed that the flexible setting contributed to a few students undergoing substantial change in their refiguring of science. The potential for this refiguring of science has been repeatedly presented as a key advantage of learning in non-formal settings (Barton & Tan, 2010; Gonsalves, Rahm, & Carvalho, 2013). In this case it was apparent that most students did not engage in this refiguring of science. The total of two day visits out of the whole school year was regarded by teachers and staff to be too short to enact much change in students' perceptions of science. This limited time period could explain why the substantial change in students' science related perceptions or aspirations reported in other ongoing non-formal science education programs such as Luehmann (2009b) and Riedinger (2015) are not reflected in this study. Similar reports of limited change in students perspectives following non-formal programs have likewise been attributed to the programs being too brief to sustain substantial disruption of the dominance of the school cultural model of science (Archer, DeWitt, & Dillon, 2014; Gonsalves, Rahm, & Carvalho, 2013). Facilitating intense, weeks long non-formal learning experiences is difficult and likely impractical to implement in many schools. Hence stakeholders of non-formal programs should strive to support and reinforce the changes in students made possible by non-formal learning experiences once students are back at school. This would be facilitated by continuing students' learning through associated classroom material, or providing a space for students' to gain recognition of their experiences (e.g. displaying students' non-formal work (Paris, Yambor, & Packard, 1998). Ultimately, as is repeatedly stressed in the school literature, incorporation of students' non-formal learning experiences into their school learning is needed to realise the impact of non-formal science education (Anderson, Kisiel, & Storksdieck, 2006).

Challenges to realising the opportunities for positively affecting student interest and perceptions of science stemmed largely from the lack of incorporation of the non-formal programs into students' school learning. It was evident in this study that without alignment between students' non-formal learning experiences and their science class work there was little opportunity for teachers to support and extend the changes in students' perceptions. This reflects a common consensus in the science education literature on the importance of continuing and supporting the process of students' changing beliefs and attitudes back at school (Luehmann, 2009b). Similar examples showing the necessity of following up on students' non-formal learning experiences are described by Stake (2006) and Stern, Powell, and Ardoin (2008). Both studies highlight that without support and encouragement following the completion of a non-formal science education program the impact on students can be lost. Hence ensuring that non-formal learning experiences are tightly connected to students' learning back at school is a vital consideration for realising the opportunities of non-formal science education programs to affect student interest and perspectives of science.

6.5.2 Opportunity for empowering students

This study showed that the flexibility of the non-formal environment helped to develop students' confidence and expectations of success in science. These findings affirm the claims of Riedinger (2015) that a non-formal learning environment which allows various forms of participation can help students reassess their capability in science and build expectations of success in STEM professions. Conversations with students and teachers revealed that the opportunities of non-formal programs may be particularly relevant to students who are unsuccessful in a typical science class. However, it is interesting to note that changes observed in students in this study were not restricted to students already predisposed to liking science. In fact some strongly affiliated science students reported no change at all. Similar findings have been reported by Todd (2016) who concluded that there was a 'ceiling effect' for students already positively disposed towards learning science. Hence while the opportunities to change students' confidence in science may restricted to a few students, those opportunities may still be very valuable and important for students and schools.

The focus on sustainability issues which were directly relevant to students represented another opportunity to empower students in learning science and to consider STEM careers. This research showed that a few students found the programs on sustainability personally meaningful and something that they could potentially share with their families. This kind of impact of students has also been demonstrated in other studies on non-formal programs of various lengths and school involvement (Ash, Carlone, & Matthews, 2015; Barton, Birmingham, Sato, Tan, & Calabrese Barton, 2013; Barton & Tan, 2010; Stern, Powell, & Ardoin, 2008). Ash, Carlone, and Matthews (2015) and Carlone et al. (2015) both argue that non-formal programs which provide students with meaningful connection to their environment can help students develop a sense of confidence and capability in science which encourages further participation. It is possible that sustainability focus of KIOSC may also provide this opportunity for students and could be a worthwhile focus of further research looking to develop the role of non-formal programs for sustainability awareness in schools.

Increasing student confidence and finding meaningful connection with learning science was shown to have the potential to help a few students in this study develop identities as science learners. Seeds for this identity work can be seen to be taking place in students' changed perceptions of science, refiguring it as something that is useful and that they can be successful in. Similar observations have been made in other studies of non-formal programs (Ash, Carlone, & Matthews, 2015; Riedinger, 2015). A vital component of the non-formal setting for facilitating students' science identity development was the availability of recognition for this identity from the KIOSC staff and from their teachers which could be then be carried back to the school setting. This finding affirms previous studies of non-formal programs where the presence of teachers in the experience allowed them to witness and legitimize students' capability and interest in science (Luehmann, 2009b; Luehmann & Markowitz, 2007). My research also concurs with the conclusion of Luehmann (2009b) that this opportunity was made possible through the connection between the school and the non-formal setting. Having an identity as a science learner is crucial for students choosing to continue with post-compulsory STEM education (Lyons & Quinn, 2010a). Thus the capacity of non-formal settings to build students' identities as a science learner could greatly affect their trajectories into post-compulsory STEM education.

Despite the potential for students to develop science identities in the non-formal setting the survey showed that there was very limited occurrence of positive changes in student affiliation with a science identity. Previous studies into non-formal science education programs have reported little or no effect on students' identification with science (Archer, DeWitt, & Dillon, 2014) as well as a great positive effect (Luehmann, 2009b). Closer examination of the literature reveals that the KIOSC programs shared similarities with the class based science enrichment program described by Archer, DeWitt, and Dillon (2014) where there were difficulties in implementation and students tended to compartmentalize the very different and fun experience as separate to school science. In contrast, Luehmann (2009b) describes a program which was extensively incorporated into students' school learning and where teachers were heavily involved and supported to make use of the program how they wished. This study suggests then that encouraging student science identity development may be assisted by involving the teachers more extensively and improving the connection between students' school and non-formal learning, thus extending the impact of the non-formal program. Alternatively, the limited change in student affiliation with science may be explained by students not recognizing what they did at KIOSC as science. As Zimmerman (2012) describes, a student can be engaged in scientific practices yet still reject identification with science. Potentially then, non-formal programs may be more successful at empowering students and encouraging identification with science if they focus on destabilising existing stereotypes of science and broadening students' perception of who can be a science person. The incongruence of this research's findings on students perceiving themselves to grow more confident but less affiliated with science requires further investigation to illustrate fully. Potentially an in-depth case study focused on the opinions and experiences of a few students (e.g. as in Riedinger, 2015) would facilitate exploration of student science identity development in non-formal settings.

Teacher involvement in the program as co-learners alongside their students also represented another opportunity to help students build confidence and feel empowered. Not being responsible for delivering the material allowed teachers to focus in on students who needed additional help, thus facilitating their participation in the experience. The more flexible setting also afforded more opportunities for social interaction between students and teachers. This has also been demonstrated by Riedinger and McGinnis (2016) and Luehmann (2009a) who both noted that teacher-student interactions in a non-formal setting facilitated relationship building and helped students participate in the activities. It is further claimed that teacher involvement alongside their students can improve students' learning outcomes from the program (Alon & Tal, 2017; DeWitt & Hohenstein, 2010). Thus the freedom to engage in these social interactions presents a valuable opportunity to help students develop trajectories into post-compulsory STEM education as students feel more comfortable and empowered to try out new identities as science learners.

Facilitating the process of student empowerment and refiguring of science in non-formal programs was assisted at KIOSC by the involvement of the KIOSC staff but this was also a limiting factor. The brief and periodic time of the non-formal programs meant that relationships between staff and students were not able to be built. This is a significant limitation of the non-formal programs as previous studies have shown that the strong relationships developed between students and external educators helped to support students in refiguring science (Barton & Tan, 2010; Gonsalves, Rahm, & Carvalho, 2013) and to develop trajectories into post-compulsory STEM education (Jensen & Sjaastad, 2013; Luehmann, 2009b). This finding highlights an important feature of the programs at KIOSC, that despite operating over the long term the non-formal programs at KIOSC are structurally more similar to short term experiences. As commented by Bevan et al. (2010), the short term nature of learning experiences results in a different capacity of the program for student learning and this can affect the possible roles of non-formal programs in schools.

Further implementation of ongoing non-formal science education programs should consider what program structure would best serve the desired program outcomes of schools and non-formal institutions. Short and intensely engaging experiences may serve as catalysts for student interest in learning science (Rennie, 2014) while longer, more formally structured experiences may be more appropriate for facilitating in-depth learning experiences that are not possible at school (Luehmann, 2009b). Given that students' experience of the KIOSC program is only two days a year, it may have more impact on students if treated as a short, stand-alone intervention. Alternatively, increasing staff and teacher involvement at schools and KIOSC respectively may forge the connections required to integrate KIOSC as a school resource and extend its impact upon students (e.g. Kisiel, 2010). Hence, this thesis suggests that realising the potential for non-formal programs to empower students would be facilitated by ensuring teachers work closely with staff to determine the most appropriate form that is not only desired, but feasible for the school.

6.5.3 Opportunities for affecting teachers

Another opportunity presented by non-formal science education programs was how they could help teachers develop their pedagogy and interest in science. Attendance at non-formal programs prompted reflection on pedagogy for both science and non-science teachers. These findings support extensive research showing the capability of ongoing non-formal programs to influence teacher science pedagogy (Kisiel, 2010; Luehmann, 2009b; Robertson, 2007). Within the scope of this study it was not possible to determine whether teachers' pedagogy was in fact changed after a visit but it is possible to show that multiple teachers were positively affected by their experience. Non-formal science education programs have great potential to serve as an additional source of professional development for teachers. Unlike traditional workshops or lectures, attending non-formal programs alongside their students can give teachers the opportunity to see the techniques in action and as relevant to their students (Garner & Eilks, 2015). This has further implications for future development of non-formal science education programs for providing a valuable service to schools.

Alongside the opportunity to affect teacher pedagogy this study showed that the non-formal programs were able to help increase teachers' awareness of STEM careers and tertiary courses. Other non-formal science education programs have also shown that teacher collaboration with external partners has helped teachers become more aware of STEM professions while simultaneously increasing the external partners' knowledge of the school sector (Robertson, 2007; Tytler, Symington, & Clark, 2016). This could potentially translate into further support for students' trajectories into post-compulsory STEM education as teachers are often the main source of information for students about STEM careers (Lyons & Quinn, 2010a) and currently there is considerable concern that many teachers are ill-equipped in this regard (Archer, Dewitt, & Osborne, 2015). Increasing teacher capability is particularly important in Australia where there is a shortage of qualified maths and science teachers in secondary schools (Office of the Chief Scientist, 2014). Hence setting up programs to encourage this awareness in teachers could be a fruitful development of non-formal science education programs.

An unexpected finding of this study was how the non-formal science education programs inspired interest and enthusiasm for science in non-science teachers. This finding is significant as the capability of non-formal science education programs for positively affecting non-science teachers' attitudes has not been previously reported in the literature. While investigating the implications of this positive attitude was beyond the scope of this project, it is proposed that the formation of positive opinions in non-science teachers could have numerous benefits for supporting the non-formal science education programs and science teaching in general in their schools. The support of enthusiastic teachers has been previously shown to be critical to the uptake of a non-formal program in schools (Robertson, 2007). Luehmann and Markowitz (2007) also found that a non-formal science program was valuable for specialist science teachers as it validated their science teaching to their colleagues. Changing the perspectives of non-science teachers is thus a worthwhile endeavour which could have indirect effects on the post-compulsory trajectories of students.

6.6 Limitations and recommendations for further research

The scope of this study was limited to two of the six schools that were partnered with KIOSC. However considering the similarity of the findings from the two schools in this study it is reasonable to assume that interpretations of the non-formal programs could be similar across the non-participating schools which were all of sufficiently similar demographics. Additionally the KIOSC programs were offered in a similar arrangement to all schools, further adding to the consistency.

Due to time restrictions the non-formal programs at KIOSC were only able to be observed over one year. Evidence for stakeholder interpretations and perceptions over time was drawn from participant reflections, however the similarity of these across the cohort lent legitimacy to the observations. Further research into the ongoing nature of the non-formal program, either through the reflections of senior students or through following students over a number of years, would provide more detail on the effect of the ongoing nature of the non-formal program than the broad conclusions offered here.

Due to the unexpected low number of student participants, the findings from the survey were not able to be statistically analysed. Obtaining high numbers of student participation is a common difficulty in education research, particularly when the researcher involved is not associated with the school community as was the case here. The low numbers of student participants particularly affected the extent to which claims could be made when answering research question 4; Is there an interaction between student background and students' interpretation of the non-formal science education program? Consequently this study was unable to determine the extent to which students' family background affected student interpretation of non-formal programs. Further investigation which could include interviewing or surveying students' families or a more thorough recruitment effort to boost student numbers could help to illustrate familial influence on students' interpretations of non-formal science education programs.

Further claims regarding the collaboration of stakeholders in a non-formal education is limited as not all collaborators took part in the study. The KIOSC partnership operates on several levels, some of which - like the collaboration between council, schools, industry and KIOSC on the management board - are beyond the scope of this research. However much of students' non-formal experiences is affected directly by the everyday collaboration between KIOSC staff and school teachers which was able to be illustrated through the interviews in this study. Investigating stakeholder collaboration in more depth in future studies would be facilitated by increasing the number of interviews with stakeholders or by conducting an ethnographic study with a greater focus on observing the interactions of teachers and non-formal staff.

Insight into individual experience (teacher, student or staff) could have been explored in more depth with the inclusion of observation and more interviews with each participant. This trade off was made in order to obtain perspectives from a wider pool of participants and given the similarity of perspectives across this pool it is likely the conclusions are valid. Deeper understanding of the perception changes in students could have been obtained with a case study on one or two individuals as has been previously conducted for research into student science identity development (e.g. Barton et al., 2012; Tan & Barton, 2008). Focusing on a few individual students allows in-depth exploration of their experiences and remains a possible though time intensive avenue of research for exploring student interpretation of non-formal programs.

6.7 Conclusion

This thesis has established that there is considerable potential within an ongoing and collaborative non-formal science education program for taking on several key roles in students' secondary education. Principally, the non-formal programs were interpreted by stakeholders to have the capacity for engagement, learning extension, supporting student participation and increasing awareness and interest in STEM careers and sustainability. However there were also challenges to realising these roles and their opportunities for affecting student trajectories into post-compulsory STEM education.

The findings presented here demonstrate that non-formal science education programs have unique features that can engage students and provide them with meaningful and accessible learning experiences not possible at school. In particular there was evidence that the non-formal learning experience inspired student interest in science, changed student perspective on the utility of science for future careers and empowered students to feel more confident in learning science. These outcomes represent opportunities for students' to develop trajectories into STEM as affected students were better positioned to find post-compulsory STEM study more attractive. A particular opportunity of the program was that students' successful participation in the non-formal setting was able to be transferred to the school setting, with teachers from both schools recognizing unlikely students as capable science learners. Crucially this research reveals that these opportunities were often taken up by students who were disengaged in science or typically unsuccessful in learning science at school. However these opportunities were also shown to be limited by various issues, some well-known to the non-formal education sector and some which appear unique to the ongoing nature of a long term collaborative program.

As frequently described in the education literature, a key challenge to realising the potential within non-formal programs lay in adequately preparing students for their non-formal learning experience and in connecting students' learning experiences across settings. This research goes further to demonstrate attention to these issues may be even more crucial in ongoing non-formal programs where students' experiences will affect their attitude towards subsequent programs. In this case, despite a clear focus on aligning the non-formal programs to the science curriculum there was considerable conflict in scheduling between individual schools and KIOSC. This made it difficult for teachers to incorporate students' non-formal experiences into their school science learning. In order to overcome this challenge it is vital that time is invested into maintaining a connection during the implementation of a non-formal program as well as during the initial design. Providing the educators involved (school teachers and non-formal staff) with time to build relationships and develop familiarity with each other's ways of operating will also help develop a more effective partnership and refine the incorporation of programs into students' school learning.

Students' interpretation of KIOSC as a day off school is another point of concern. As well as hindering students from seeing the programs as a learning experience, it sets up unrealistic expectations for enjoyment and risks cultivating a perception of not being worthwhile in students who don't enjoy it. Again, these interpretations were observed to become more pivotal over time as students grew older. Underutilisation of the unique resources of the non-formal setting for junior student programs may further contribute to students' declining enthusiasm over time. As this is a new model of non-formal education in Australia, and indeed worldwide, it is very important to understand how the ongoing nature of such programs makes it different from more common, short term experiences. In this case it increased the opportunities available to teachers and their students for engaging in a variety of scientific topics, but it also amplified issues in maintaining student engagement in the program over time.

Student background was shown to be a considerable influence on how they interpreted and responded to their non-formal learning experiences. Often students who perceived strong support from their parents and teachers for their science education felt that their non-formal learning experiences had positively affected their perceptions of science. These students also tended to have positive pre-existing attitudes towards learning science along with strong affiliation and aspiration in science. Students without this support and with a poor valuation of science tended to feel that their non-formal learning experience had negatively affected their perceptions of science. It can also be seen that encouraging the participation of students with pre-existing negative attitudes towards science was particularly challenging for teachers. Thus an ongoing challenge for non-formal science education programs is to make the experience attractive to such students in order to realise the opportunities of the setting for them and to avoid reinforcing existing negative stereotypes about STEM.

While the collaborative model of the non-formal programs enabled stakeholders to refine the programs and overcome various issues of miscommunication and scheduling, it also introduced several other challenges to the partnership. Collaboration was not always easy; teachers and staff had different agendas and interpretations of the non-formal programs. Occasionally ineffective collaboration was itself the source of issues in students' experiences at KIOSC. But collaboration was also the main way teachers and staff were able to tackle challenges and adapt the programs to suit each other's needs. The ongoing nature of the KIOSC programs was a key advantage in building these relationships and improving collaboration between the school and KIOSC communities. As the ones 'on the ground', teachers and staff are acutely aware of problems and the best positioned to resolve them. Helping teachers to be more meaningfully involved in the collaboration would also contribute to realising the potential roles of the non-formal programs and maximise their impact on students. Hence further efforts to develop the KIOSC programs should facilitate teacher and staff efforts to work collaboratively.

Investing more time in preparing teachers to use the non-formal programs would further see useful benefits for teachers as well as for students. While previous studies into non-formal science education programs have demonstrated the professional development gained through teacher participation in non-formal science education it has not been clearly demonstrated in the Australian context, nor for non-science teachers in addition to science specialist teachers. This research showed that the non-formal programs could function as useful professional development experiences for science specialist and non-science teachers alike. Further development of this role would be a valuable resource to schools, as well as providing non-formal institutions with an additional marketable service.

In light of these findings and recommendations it is noted however this study was relatively small scale with only two schools and one non-formal science education institution participating. Hence the findings of this thesis are mostly only indicative of current trends in non-formal science education. More comprehensive research on a larger scale into non-formal science education programs would provide firmer evidence the observed trends.

To assist further development and implementation of non-formal science education programs a list of recommendations is provided here. It is noted that KIOSC is already doing some of these suggestions however they are included here to help similar programs and to emphasize their importance in realising the opportunities of non-formal education.

- Activities
    - Explicitly link program activities/content to specific career examples
    - Present students with activities that take advantage of the centre's unique resources, e.g. space, technology or time from their very first visit.
    - Provide activities that have a range of roles students can take on so not only the 'science enthusiast' student is catered to.
- Program Implementation
    - Provide flexibility in program timing to accommodate different school schedules. For instance, a year round availability of discrete modules.
    - Set aside time for teacher and staff collaboration on developing programs together
    - Encourage teachers and staff work together on identifying individual and joint goals for particular programs and to align their agendas for students.

- Supporting school learning
    - Emphasize that the programs as learning experiences and not as novel or optional fun days out.
    - Focus less on standalone programs and more on ‘value-adding’ to students’ learning; providing them with an experience that could not be done at school but adds to what they’ve done in class.
    - Develop a module for attending teachers, particularly non-science teachers, to tie in the non-formal program to their professional development.

This thesis concludes that the overall contribution of ongoing non-formal science education programs to Australian secondary science education is largely determined by the successful incorporation of students’ non-formal learning experiences into their school learning. The findings also highlight that while non-formal science education offers many opportunities for students, these opportunities are easily missed or limited in effect.

In order to realise the potential of these programs to support students into post-compulsory STEM education, efforts must be focused on empowering teachers and staff to facilitate this incorporation. Above all else, investment in teacher and staff collaboration is the key to developing ongoing and collaborative non-formal science education programs into valuable learning experiences for students.

References

About Tech Schools. (2017, 11 October 2017). Retrieved from http://www.education.vic.gov.au/about/programs/learningdev/techschools/Pages/aboutechschools.aspx

Abraham, J., & Barker, K. (2015). An Expectancy-Value Model for Sustained Enrolment Intentions of Senior Secondary Physics Students. *Research in Science Education, 45*(4), 509-526. doi:10.1007/s11165-014-9434-x

Adelman, L. M., John H, & James, S. (2000). Impact of National Aquarium in Baltimore on visitors' conservation attitudes, behavior, and knowledge. *Curator: The Museum Journal, 43*(1), 33-61.

Affeldt, F., Tolppanen, S., Aksela, M., & Eilks, I. (2017). The potential of the non-formal educational sector for supporting chemistry learning and sustainability education for all students - a joint perspective from two cases in Finland and Germany. *Chemistry Education Research and Practice, 18*(1), 13-25. doi:10.1039/C6RP00212A

Ahrenkiel, L., & Worm-Leonhard, M. (2014). Offering a Forensic Science Camp To Introduce and Engage High School Students in Interdisciplinary Science Topics. *Journal of chemical education, 91*(3), 340-344.

Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice*: Teachers College Press.

Allner, M., McKay, C., Coe, L., Rask, J., Paradise, J., & Wynne, J. J. (2010). NASA's explorer school and spaceward bound programs: Insights into two education programs designed to heighten public support for space science initiatives. *Acta Astronautica, 66*(7), 1280-1284.

Alon, N. L., & Tal, T. (2017). Teachers as Secondary Players: Involvement in Field Trips to Natural Environments. *Research in Science Education, 47*(4), 869-887. doi:10.1007/s11165-016-9531-0

Andersen, L., & Chen, J. A. (2016). Do High‐Ability Students Disidentify With Science? A Descriptive Study of US Ninth Graders in 2009. *Science Education, 100*(1), 57-77.

Andersen, L., & Ward, T. J. (2014). Expectancy‐value models for the STEM persistence plans of ninth‐grade, high‐ability Students: A comparison between black, hispanic, and white students. *Science Education, 98*(2), 216-242.

Anderson, D., Kisiel, J., & Storksdieck, M. (2006). Understanding teachers' perspectives on field trips: Discovering common ground in three countries. *Curator: The Museum Journal, 49*(3), 365-386.

Appleton-Knapp, S. L., & Krentler, K. A. (2006). Measuring student expectations and their effects on satisfaction: The importance of managing student expectations. *Journal of marketing education, 28*(3), 254-264.

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*.

Archer, L., Dawson, E., Seakins, A., & Wong, B. (2016). Disorientating, fun or meaningful? Disadvantaged families' experiences of a science museum visit. *Cultural Studies of Science Education*, 1-23.

Archer, L., DeWitt, J., & Dillon, J. (2014). 'It didn't really change my opinion': exploring what works, what doesn't and why in a school science, technology, engineering and mathematics careers intervention. *Research in Science & Technological Education, 32*(1), 35-55.

Archer, L., Dewitt, J., & Osborne, J. (2015). Is science for us? Black students' and parents' views of science and science careers. *Science Education, 99*(2), 199-237.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11 - year - old schoolchildren's constructions of science through the lens of identity. *Science Education, 94*(4), 617-639.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science Aspirations, Capital, and Family Habitus How Families Shape Children's Engagement and Identification With Science. *American Educational Research Journal, 49*(5), 881-908.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). 'Not girly, not sexy, not glamorous': primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society, 21*(1), 171-194.

Archer, L., DeWitt, J., & Willis, B. (2014). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching, 51*(1), 1-30.

Archer, L., DeWitt, J., & Wong, B. (2014). Spheres of influence: what shapes young people's aspirations at age 12/13 and what are the implications for education policy? *Journal of Education Policy, 29*(1), 58-85.

Archer, L., Moote, J., Francis, B., DeWitt, J., & Yeomans, L. (2016a). The "Exceptional" Physics Girl A Sociological Analysis of Multimethod Data From Young Women Aged

10–16 to Explore Gendered Patterns of Post-16 Participation. *American Educational Research Journal*, 0002831216678379.

Archer, L., Moote, J., Francis, B., DeWitt, J., & Yeomans, L. (2016b). Stratifying science: a Bourdieusian analysis of student views and experiences of school selective practices in relation to 'Triple Science'at KS4 in England. *Research Papers in Education*, 1-20.

Archer, L., Osborne, J., DeWitt, J., Dillon, J., Wong, B., & Willis, B. (2013). ASPIRES: young people's science and career aspirations, age 10-14.

Arora, V., Schneider, B., Thal, R., & Meltzer, D. (2011). Design of an Intervention to Promote Entry of Minority Youth into Clinical Research Careers by Aligning Ambition: The TEACH (Training Early Achievers for Careers in Health) Research Program. *Journal of Social Issues, 67*(3), 580-598. doi:10.1111/j.1540-4560.2011.01715.x

Aschbacher, P., Ing, M., & Tsai, S. (2014). Is Science Me? Exploring Middle School Students' STE-M Career Aspirations. *Journal of Science Education and Technology, 23*(6), 735-743. doi:10.1007/s10956-014-9504-x

Aschbacher, P., Li, E., & Roth, E. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564-582. doi:10.1002/tea.20353

Ash, M. C., Carlone, H. B., & Matthews, C. E. (2015). "Almost a Herpetologist": The Iterative Influence of Four Lumbee Male High School Students on an Informal Herpetological Research Field Experience. *Journal of American Indian Education, 54*(3), 54-75.

Austin, C. Y. (2010). Perceived Factors that Influence Career Decision Self-efficacy and Engineering Related Goal Intentions of African American High School Students. *Career & Technical Education Research, 35*(3), 119-135. doi:10.5328/cter35.310

Ball, C., Huang, K.-T., Cotten, S. R., Rikard, R., & Coleman, L. O. (2016). Invaluable values: an expectancy-value theory analysis of youths' academic motivations and intentions. *Information, Communication & Society, 19*(5), 618-638.

Bandura, A. (1997). *Self-efficacy: The exercise of control*: Macmillan.

Banerjee, P. A. (2017a). Does continued participation in STEM enrichment and enhancement activities affect school maths attainment? *Oxford Review of Education, 43*(1), 1-18. doi:10.1080/03054985.2016.1235031

Banerjee, P. A. (2017b). Is informal education the answer to increasing and widening participation in STEM education? *Review of Education*.

Barton, A. C. (1998). Teaching science with homeless children: Pedagogy, representation, and identity. *Journal of Research in Science Teaching, 35*(4), 379-394.

Barton, A. C., Birmingham, D., Sato, T., Tan, E., & Calabrese Barton, S. (2013). Youth as community science experts in green energy technologies. *Afterschool Matters*.

Barton, A. C., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2012). Crafting a future in science tracing middle school girls' identity work over time and space. *American Educational Research Journal*, 0002831212458142.

Barton, A. C., & Osborne, M. D. (2001). Urban Girls' Participation in Informal Science Settings: Playing with Identities and Borders. *Curriculum and Teaching, 16*(2), 17-37.

Barton, A. C., & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching, 46*(1), 50-73.

Barton, A. C., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *The Journal of the Learning Sciences, 19*(2), 187-229.

Barton, A. C., & Tan, E. (2017). *EQUITABLE AND CONSEQUENTIAL BECOMING IN STEM: HOW YOUTH IMAGINE FUTURES BRIDGING COMMUNITY & SCIENCE* Paper presented at the ESERA, Dublin.

Barton, A. C., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *American Educational Research Journal, 45*(1), 68-103.

Bell, P., Lewenstein, B., Shouse, A., & Feder, M. . (2009). Learning science in informal environments: People, places, and pursuits. *Washington, DC: National Research Council.*

Bevan, B., Dillon, J., Hein, G. E., Macdonald, M., Michalchik, V., Miller, D., . . . Yoon, S. (2010). *Making Science Matter: Collaborations Between Informal Science Education Organizations and Schools. A CAISE Inquiry Group Report*. Retrieved from Washington, D.C:

Bevan, B., & Semper, R. J. (2006). Mapping informal science institutions onto the science education landscape. . Retrieved from http://www.exploratorium.org/cils/research.html

Bøe, M. V., Henriksen, E. K., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: young people's

achievement ‐ related choices in late ‐ modern societies. *Studies in Science Education, 47*(1), 37-72.
Bouillion, L. M., & Gomez, L. M. (2001). Connecting school and community with science learning: Real world problems and school–community partnerships as contextual scaffolds. *Journal of Research in Science Teaching, 38*(8), 878-898.
Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology, 3*(2), 77-101.
Braund, M., & Reiss, M. (2006). Towards a More Authentic Science Curriculum: The contribution of out ‐ of ‐ school learning. *International Journal of Science Education, 28*(12), 1373-1388. doi:10.1080/09500690500498419
Brickhouse, N. W., & Potter, J. T. (2001). Young women's scientific identity formation in an urban context. *Journal of Research in Science Teaching, 38*(8), 965-980.
Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher, 18*(1), 32-42.
Bryant, C., Gore, M., & Stocklmayer, S. (2015a). The Australian Science Centre Movement 1980–2000: Part 1—Questacon, the National Science and Technology Centre. *Historical Records of Australian Science, 26*(2), 122-132.
Bryant, C., Gore, M., & Stocklmayer, S. (2015b). The Australian Science Centre Movement 1980–2000: Part 2—Science Centres in the States. *Historical Records of Australian Science, 26*(2), 133-149.
Burgin, S. R., McConnell, W. J., & Flowers, A. M. (2014). 'I Actually Contributed to Their Research': The influence of an abbreviated summer apprenticeship program in science

and engineering for diverse high-school learners. *International Journal of Science Education, 37*(3), 411-445. doi:10.1080/09500693.2014.989292

Carlone, H., Haun‐Frank, J., & Webb, A. (2011). Assessing equity beyond knowledge‐ and skills‐based outcomes: A comparative ethnography of two fourth‐grade reform‐based science classrooms. *Journal of Research in Science Teaching, 48*(5), 459-485.

Carlone, H., Huffling, L., Tomasek, T., Hegedus, T., Matthews, C., Allen, M., & Ash, M. (2015). 'Unthinkable' Selves: Identity boundary work in a summer field ecology enrichment program for diverse youth. *International Journal of Science Education, 37*(10), 1524-1546. doi:10.1080/09500693.2015.1033776

Carlone, H., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187-1218.

Carlone, H., Scott, C., & Lowder, C. (2014). Becoming (less) scientific: A longitudinal study of students' identity work from elementary to middle school science. *Journal of Research in Science Teaching, 51*(7), 836-869.

Charette, R. (2013). The STEM crisis is a myth. *Spectrum, IEEE, 50*(9), 44-59.

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., & Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *Journal of Social Issues, 67*(3), 469-491.

Clegg, T., & Kolodner, J. (2014). Scientizing and Cooking: Helping Middle‐School Learners Develop Scientific Dispositions. *Science Education, 98*(1), 36-63.

Coll, R. K., Gilbert, J. K., Pilot, A., & Streller, S. (2013). How to benefit from the informal and interdisciplinary Dimension of Chemistry in Teaching *Teaching chemistry–A studybook* (pp. 241-268): Springer.

Council, E. (2015). *National STEM school education strategy: A comprehensive plan for science, technology, engineering and mathematics education in Australia.* Retrieved from Canberra:

Crawford, L., & Huscroft-D'Angelo, J. (2015). Mission to Space: Evaluating One Type of Informal Science Education. *Electronic Journal of Science Education, 19*(1).

Creswell, J. (2013a). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches.* (3rd ed.): Sage.

Creswell, J. W. (2013b). *Research design: Qualitative, quantitative, and mixed methods approaches*: Sage publications.

Dabney, K. P., Tai, R. H., Almarode, J. T., Miller-Friedmann, J. L., Sonnert, G., Sadler, P. M., & Hazari, Z. (2012). Out-of-School Time Science Activities and Their Association with Career Interest in STEM. *International Journal of Science Education, Part B, 2*(1), 63-79. doi:10.1080/21548455.2011.629455

Dawson, E. (2014). “Not Designed for Us”: How Science Museums and Science Centers Socially Exclude Low‐Income, Minority Ethnic Groups. *Science Education, 98*(6), 981-1008.

Department of Education and Early Childhood Development. (2009). *Energising Science and Mathematics Education in*

Victoria. Retrieved from Education Policy and Research Division Office for Policy, Research and Innovation Department of Education and Early Childhood Development:

DeWitt, J., & Archer, L. (2015). Who Aspires to a Science Career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*(ahead-of-print), 1-23.

DeWitt, J., Archer, L., & Osborne, J. (2013). Nerdy, brainy and normal: Children’s and parents’ constructions of those who are highly engaged with science. *Research in Science Education, 43*(4), 1455-1476.

DeWitt, J., Archer, L., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2011). High aspirations but low progression: the science aspirations–careers paradox amongst minority ethnic students. *International Journal of Science and Mathematics Education, 9*(2), 243-271.

DeWitt, J., & Hohenstein, J. (2010). School trips and classroom lessons: An investigation into teacher–student talk in two settings. *Journal of Research in Science Teaching, 47*(4), 454-473.

DeWitt, J., & Osborne, J. (2007). Supporting Teachers on Science‐focused School Trips: Towards an integrated framework of theory and practice. *International Journal of Science Education, 29*(6), 685-710. doi:10.1080/09500690600802254

DeWitt, J., & Storksdieck, M. (2008). A Short Review of School Field Trips: Key Findings from the Past and Implications for the Future. *Visitor Studies, 11*(2), 181-197. doi:10.1080/10645570802355562

Digweed, B. E. (2015). Impact of a Youth Development Camp on Participants' Skills, Attitudes, and Views Towards Science and Scientific Inquiry.

Dougherty, K., Oliver, C., & Fergusson, J. (2014). Pathways to space: A mission to foster the next generation of scientists and engineers. *Acta Astronautica, 99*, 184-192. doi:http://dx.doi.org/10.1016/j.actaastro.2014.01.026

Dowie, M. J., Barrow, M., & Nicholson, L. F. B. (2015). "It Was Like I Had Found My Tribe": Influence of a Neuroscience Outreach Program on High Achievers. *The Neuroscientist*. doi:10.1177/1073858415600150

Dunkley, R. A. (2016). Learning at eco-attractions: Exploring the bifurcation of nature and culture through experiential environmental education. *The Journal of Environmental Education*, 1-9.

Eccles, J. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist, 44*(2), 78-89.

Eshach, H. (2007). Bridging In-school and Out-of-school Learning: Formal, Non-Formal, and Informal Education. *Journal of Science Education and Technology, 16*(2), 171-190. doi:10.1007/s10956-006-9027-1

Falk, J., & Storksdieck, M. (2005). Using the contextual model of learning to understand visitor learning from a science center exhibition. *Science Education, 89*(5), 744-778.

Fallik, O., Rosenfeld, S., & Eylon, B.-S. (2013). School and out-of-school science: a model for bridging the gap. *Studies in Science Education, 49*(1), 69-91. doi:10.1080/03057267.2013.822166

Fensham, P. J. (2008). *Science education policy-making: Eleven emerging issues.* Retrieved from

Fields, D., & Enyedy, N. (2013). Picking up the mantle of “expert”: Assigned roles, assertion of identity, and peer recognition within a programming class. *Mind, Culture, and Activity, 20*(2), 113-131.

Finkelstein, N. D., Mayhew, L., Henderson, C., Sabella, M., & Hsu, L. (2008). *Acting in Our Own Self-Interests: Blending University and Community in Informal Science Education.* Paper presented at the Aip Conference Proceedings.

Francis, B., & Archer, L. (2007). Understanding Minority Ethnic Achievement: London: Routledge.

Friedman, A. J. (2010). The evolution of the science museum. *Physics Today, 63*(10), 45-51.

Garner, N., & Eilks, I. (2015). The Expectations of Teachers and Students Who Visit a Non-Formal Student Chemistry Laboratory. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(5), 1197-1210.

Garner, N., Hayes, S. M., & Eilks, I. (2014). Linking formal and non-formal learning in science education–A reflection from two cases in Ireland and Germany. *Sisyphus-Journal of Education, 2*(2), 10-31.

Gokpinar, T., & Reiss, M. (2016). The role of outside-school factors in science education: a two-stage theoretical model linking Bourdieu and Sen, with a case study. *International Journal of Science Education*, 1-26.

Gonsalves, A., Rahm, J., & Carvalho, A. (2013). “We could think of things that could be science”: Girls' re‐figuring of science in an out‐of‐school‐time club. *Journal of Research in Science Teaching, 50*(9), 1068-1097.

Henriksen, E. K., Jensen, F., & Sjaastad, J. (2015). The Role of Out-of-School Experiences and Targeted Recruitment Efforts in

Norwegian Science and Technology Students’ Educational Choice. *International Journal of Science Education, Part B, 5*(3), 203-222.

Hesse-Biber, S. N. (2010). *Mixed methods research: Merging theory with practice*: Guilford Press.

Holmegaard, H. T., Madsen, L. M., & Ulriksen, L. (2012). To Choose or Not to Choose Science: Constructions of desirable identities among young people considering a STEM higher education programme. *International Journal of Science Education, 36*(2), 186-215. doi:10.1080/09500693.2012.749362

Hoyles, C., Reiss, M., & Tough, S. (2011). *Supporting STEM in schools and colleges in England; the role of research*. Retrieved from Institute of Education, University of London: http://www.universitiesuk.ac.uk/policy-and-analysis/reports/Pages/supporting-stem-in-schools-and-colleges.aspx

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology, 102*(4), 880.

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science, 326*(5958), 1410-1412.

Irwin, B., Pegram, E., & Gay, H. (2013). New Directions, New Relationships: The Smithsonian's Twenty‐first Century Learning in Natural History Settings Conference and the Natural History Museum, London. *Curator: The Museum Journal, 56*(2), 273-278.

Itzek-Greulich, H., Flunger, B., Vollmer, C., Nagengast, B., Rehm, M., & Trautwein, U. (2016). Empirical study: Effectiveness of lab-work learning environments in and out of school: A cluster randomized study. *Contemporary Educational Psychology*. doi:10.1016/j.cedpsych.2016.09.005

Jarvis, T., & Pell, A. (2005). Factors influencing elementary school children's attitudes toward science before, during, and after a visit to the UK National Space Centre. *Journal of Research in Science Teaching, 42*(1), 53-83.

Jenkins, E. W., & Nelson, N. (2005). Important but not for me: Students' attitudes towards secondary school science in England. *Research in Science & Technological Education, 23*(1), 41-57.

Jensen, F., & Bøe, M. V. (2013). The influence of a two-day recruitment event on female upper secondary students' motivation for science and technology higher education. *International Journal of Gender, Science and Technology, 5*(3), 317-337.

Jensen, F., & Sjaastad, J. (2013). A Nowegian out-of-school projects influence on secondary students' STEM motivation. *International Journal of Science and Mathematics Education, 11*(6), 1437-1461.

Kahle, J. (2007). Systemic reform: Research, vision, and politics. *Handbook of research on science education*, 911-942.

KIOSC. (2017, 27th November). Retrieved from http://www.kiosc.vic.edu.au/

Kisiel, J. (2005). Understanding elementary teacher motivations for science fieldtrips. *Science Education, 89*(6), 936-955. doi:10.1002/sce.20085

Kisiel, J. (2010). Exploring a school–aquarium collaboration: An intersection of communities of practice. *Science Education, 94*(1), 95-121.
Kisiel, J. (2014). Clarifying the complexities of school–museum interactions: Perspectives from two communities. *Journal of Research in Science Teaching, 51*(3), 342-367.
Krapp, A., & Prenzel, M. (2011). Research on Interest in Science: Theories, methods, and findings. *International Journal of Science Education, 33*(1), 27-50. doi:10.1080/09500693.2010.518645
Lindahl, B. (2007). *A longitudinal study of students' attitudes towards science and choice of career.* Paper presented at the NARST Annual Conference, April 15-18, 2007, New Orleans.
Luehmann, A. L. (2009a). Accessing resources for identity development by urban students and teachers: Foregrounding context. *Cultural Studies of Science Education, 4*(1), 51-66.
Luehmann, A. L. (2009b). Students' Perspectives of a Science Enrichment Programme: Out ‐ of ‐ school inquiry as access. *International Journal of Science Education, 31*(13), 1831-1855. doi:10.1080/09500690802354195
Luehmann, A. L., & Markowitz, D. (2007). Science teachers' perceived benefits of an out ‐ of ‐ school enrichment programme: identity needs and university affordances. *International Journal of Science Education, 29*(9), 1133-1161.

Lundh, P., House, A., Means, B., & Harris, C. J. (2013). Learning from Science: Case Studies of Science Offerings in Afterschool Programs. *Afterschool Matters, 18*, 33-41.

Lyons, T., & Quinn, F. (2010a). Choosing Science: Understanding the declines in senior high school science enrolments.

Lyons, T., & Quinn, F. (2010b). *Looking back: Students' perceptions of the relative enjoyment of primary and secondary school science.* Paper presented at the Science, Technology, Engineering and Mathematics (STEM) in Education Conference Proceedings.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education, 95*(5), 877-907.

Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). STEM: country comparisons: international comparisons of science, technology, engineering and mathematics (STEM) education. Final report.

McCreedy, D., & Dierking, L. (2013). *Cascading Influences: Long-Term Impacts of Informal STEM Experiences for Girls*. Retrieved from

Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*: John Wiley & Sons.

Monteiro, B. A. P., Martins, I., de Souza Janerine, A., & de Carvalho, F. C. (2016). The issue of the arrangement of new environments for science education through collaborative actions between schools, museums and science centres in the Brazilian context of teacher training. *Cultural Studies of Science Education*, 1-19.

Norton, A. (2013). A bubble about to burst: why we don’t need more maths and science graduates Retrieved from

Australian National University

Norton, A., & Cakitaki, B. (2016). *Mapping Australian higher education 2016*. Retrieved from

OECD. (2006). *Evolution of Student Interest in Science*

and Technology Studies Policy Report. . Retrieved from Paris:

OECD. (2010). *Encouraging student interest in science and technology studies*. Retrieved from Paris: Global Science Forum:

OECD. (2012). Higher education and adult learning – Recognition of non-formal and informal learning. Retrieved from http://www.oecd.org/edu/skills-beyond-school/recognitionofnon-formalandinformallearning-home.htm.

OECD. (2016). *PISA 2015 assessment and analytical framework: Science, reading, mathematics and financial literacy.* Retrieved from Paris:

Office of the Chief Scientist. (2012). *Mathematics, engineering and science in the national interest.* Retrieved from

Office of the Chief Scientist. (2014). *Science, Technology, Engineering and Mathematics: Australia's Future*. Retrieved from Canberra:

Ogawa, R. T., Loomis, M., & Crain, R. (2009). Institutional history of an interactive science center: The founding and development of the Exploratorium. *Science Education, 93*(2), 269-292.

Olson, S., & Riordan, D. G. (2012). Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. *Executive Office of the President*.

Orion, N., & Hofstein, A. (1994). Factors that influence learning during a scientific field trip in a natural environment. *Journal of Research in Science Teaching, 31*(10), 1097-1120.

Osborne, J., & Dillon, J. (2007). Research on Learning in Informal Contexts: Advancing the field? *International Journal of Science Education, 29*(12), 1441-1445. doi:10.1080/09500690701491122

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (Vol. 13): London: The Nuffield Foundation.

Panizzon, D., Corrigan, D., Forgasz, H., & Hopkins, S. (2015). Impending STEM Shortages in Australia: Beware the 'Smoke and Mirrors'. *Procedia - Social and Behavioral Sciences, 167*, 70-74. doi:http://dx.doi.org/10.1016/j.sbspro.2014.12.644

Paris, S. G., Yambor, K. M., & Packard, B. W.-L. (1998). Hands-on biology: A museum-school-university partnership for enhancing students' interest and learning in science. *The Elementary School Journal*, 267-288.

Peacock, A., & Pratt, N. (2011). How young people respond to learning spaces outside school: A sociocultural perspective. *Learning Environments Research, 14*(1), 11-24. doi:10.1007/s10984-011-9081-3

Pedretti, E. (2002). T. Kuhn meets T. Rex: Critical conversations and new directions in science centres and science museums.

Polman, J. L., & Hope, J. M. (2014). Science news stories as boundary objects affecting engagement with science. *Journal of Research in Science Teaching, 51*(3), 315-341.

Polman, J. L., & Miller, D. (2010). Changing stories: Trajectories of identification among African American youth in a science outreach apprenticeship. *American Educational Research Journal, 47*(4), 879-918.

Rahm, J. (2007). Youths' and scientists' authoring of and positioning within science and scientists' work. *Cultural Studies of Science Education, 1*(3), 517-544.
Rahm, J. (2008). Urban youths' hybrid positioning in science practices at the margin: A look inside a school–museum–scientist partnership project and an after-school science program. *Cultural Studies of Science Education, 3*(1), 97-121.
Rahm, J., Lachaine, A., & Mathura, A. (2014). Youth voice and positive identity-building practices the case of ScienceGirls. *Canadian Journal of Education*(1), 1.
Rajala, A., Kumpulainen, K., Hilppö, J., Paananen, M., & Lipponen, L. (2016). Connecting learning across school and out-of-school contexts: A review of pedagogical approaches. *O. Erstad, K. Kumpulainen, Å. Mäkitalo, K., P. Pruulmann-Vengerfeldt & T. Jóhannsdóttir (Eds.) Learning across contexts in the knowledge society. Sense publishers: Rotterdam*.
Redman, C., Dawborn-Gundlach, M., & Symons, D. (2017). *POSITIVE POSITIONING OF PARTICIPANTS IN SCIENCE EDUCATION CENTRE LEARNING PARTNERSHIPS*. Paper presented at the ESERA, Dublin.
REMPLAN. (2018). Economy Profile: Knox. Retrieved from www.economyprofile.com.au/knox/
Rennie, L. J. (2007). Learning science outside of school. *Handbook of research on science education, 1*.
Rennie, L. J. (2014). Learning Science Outside of School. In N. G. L. S. K. Abell (Ed.), *Handbook of research on science education* (pp. 120-144). New York: Taylor & Francis.
Riedinger, K. (2015). Identity Development of Youth during Participation at an Informal Science Education Camp.

International Journal of Environmental and Science Education, 10(3), 453-475.
Riedinger, K., & McGinnis, J. R. (2016). An investigation of the role of learning conversations in youth’s authoring of science identities during an informal science camp. *International Journal of Science Education, Part B*, 1-27. doi:10.1080/21548455.2016.1173741
Ritchie, J., Lewis, J., Nicholls, C. M., & Ormston, R. (2013). *Qualitative research practice: A guide for social science students and researchers*: Sage.
Robertson, A. (2007). Development of shared vision: Lessons from a science education community collaborative. *Journal of Research in Science Teaching, 44*(5), 681-705.
Rubin, H. J., & Rubin, I. S. (2011). *Qualitative interviewing: The art of hearing data*: Sage.
Şentürk, E., & Özdemir, Ö. F. (2012). The Effect of Science Centres on Students' Attitudes Towards Science. *International Journal of Science Education, Part B, 4*(1), 1-24. doi:10.1080/21548455.2012.726754
Sha, L., Schunn, C., Bathgate, M., & Ben‐Eliyahu, A. (2015). Families support their children's success in science learning by influencing interest and self‐efficacy. *Journal of Research in Science Teaching*.
Shanahan, M. C., & Nieswandt, M. (2011). Science student role: Evidence of social structural norms specific to school science. *Journal of Research in Science Teaching, 48*(4), 367-395.
Shuda, J. R., Butler, V. G., Vary, R., & Farber, S. A. (2016). Project BioEYES: Accessible Student-Driven Science for K–12

Students and Teachers. *PLoS Biology, 14*(11), 1-11. doi:10.1371/journal.pbio.2000520
Sjøberg, S., & Schreiner, C. (2007). Perceptions and images of science and science education *Communicating European Research 2005* (pp. 151-158): Springer.
Sjøberg, S., & Schreiner, C. (2010). The ROSE project: An overview and key findings. *Oslo: University of Oslo*.
Smith, E. (2011). Staying in the science stream: patterns of participation in A ‐ level science subjects in the UK. *Educational Studies, 37*(1), 59-71.
Smith, E., & Gorard, S. (2011). Is there a shortage of scientists? A re-analysis of supply for the UK. *British Journal of Educational Studies, 59*(2), 159-177.
Stake, J. E. (2006). The critical mediating role of social encouragement for science motivation and confidence among high school girls and boys.
Stake, J. E., & Mares, K. R. (2005). Evaluating the impact of science-enrichment programs on adolescents' science motivation and confidence: The splashdown effect.
Stake, R. E. (1994). Case studies *N.K. Denzin and Y.S. Lincoln Handbook of Qualitative Research*. London: Sage.
Stavrova, O., & Urhahne, D. (2010). Modification of a school programme in the Deutsches Museum to enhance students' attitudes and understanding. *International Journal of Science Education, 32*(17), 2291-2310.
Stern, M. J., Powell, R. B., & Ardoin, N. M. (2008). What Difference Does It Make? Assessing Outcomes From Participation in a Residential Environmental Education Program. *Journal of Environmental Education, 39*(4), 31-43. doi:10.3200/JOEE.39.4.31-43

Stevens, S., Andrade, R., & Page, M. (2016). Motivating Young Native American Students to Pursue STEM Learning Through a Culturally Relevant Science Program. *Journal of Science Education and Technology*, 1-14.
Stewart, O. G., & Jordan, M. E. (2017). “Some explanation here”: a case study of learning opportunities and tensions in an informal science learning environment. *Instructional Science, 45*(2), 137-156. doi:10.1007/s11251-016-9396-7
Stocklmayer, S. M., Rennie, L. J., & Gilbert, J. K. (2010). The roles of the formal and informal sectors in the provision of effective science education. *Studies in Science Education, 46*(1), 1-44. doi:10.1080/03057260903562284
Storksdieck, M. (2001). Differences in teachers’ and students’ museum field-trip experiences. *Visitor Studies Today, 4*(1), 8-12.
Taconis, R., & Kessels, U. (2009). How choosing science depends on students' individual fit to ‘science culture’. *International Journal of Science Education, 31*(8), 1115-1132.
Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning Early for Careers in Science. *Science*.
Tal, T., & Steiner, L. (2006). Patterns of teacher ‐ museum staff relationships: School visits to the educational centre of a science museum. *Canadian Journal of Science, Mathematics and Technology Education, 6*(1), 25-46. doi:10.1080/14926150609556686
Tan, E., & Barton, A. C. (2008). Unpacking science for all through the lens of identities-in-practice: The stories of Amelia and Ginny. *Cultural Studies of Science Education, 3*(1), 43-71.
Tan, E., & Barton, A. C. (2010). Transforming science learning and student participation in sixth grade science: A case study of

a low-income, urban, racial minority classroom. *Equity & Excellence in Education, 43*(1), 38-55.

Tan, E., Barton, A. C., Kang, H., & O'Neill, T. (2013). Desiring a Career in STEM-Related Fields: How Middle School Girls Articulate and Negotiate Identities-In-Practice in Science.

Thiry, H., Archie, T., Arreola-Pena, M., & Laursen, S. (2017). Linkages between youth diversity and organizational and program characteristics of out-of-school-time science programs: a mixed-methods study. *International Journal of Science Education, Part B, 7*(2), 121-145. doi:10.1080/21548455.2015.1105397

Thomson, S., De Bortoli, L., & Underwood, C. (2017). *PISA 2015: Reporting Australia's results*. Retrieved from

Todd, B. (2016). Little Scientists: Identity, Self-Efficacy, and Attitudes Toward Science in a Girls' Science Camp.

Traphagen, K., & Traill, S. (2014). How cross-sector collaborations are advancing STEM learning. *Los Altos, CA: Noyce Foundation*.

Tripney, J., Newman, M., Bangpan, M., Niza, C., Mackintosh, M., & Sinclair, J. (2010). Factors influencing young people (aged 14-19) in education about STEM subject choices: a systematic review of the UK literature.

Tytler, R., & Osborne, J. (2012). Student attitudes and aspirations towards science *Second international handbook of science education* (pp. 597-625): Springer.

Tytler, R., Osborne, J., Williams, G., Tytler, K., & Cripps Clark, J. (2008). *Opening up pathways: Engagement in STEM across the Primary-Secondary school transition*: Department of Education, Employment and Workplace Relations.

Tytler, R., Symington, D., & Clark, J. C. (2016). Community-school collaborations in science: Towards improved outcomes through better understanding of boundary issues. *International Journal of Science and Mathematics Education*, 1-19.

UNESCO. (2010). *Engineering: Issues, Challenges and Opportunities for Development.* Retrieved from Paris: UNESCO:

van Eijck, M., & Roth, W.-M. (2009). Authentic science experiences as a vehicle to change students' orientations toward science and scientific career choices: Learning from the path followed by Brad. *Cultural Studies of Science Education, 4*(3), 611-638.

Victorian Auditor General. (2012). *Science and mathematics participation rates and initiatives*. Melbourne: Victorian Government Printer.

Weinstein, M., Whitesell, E. R., & Schwartz, A. E. (2012). Can Formal-Informal Collaborations Improve Science Literacy in Urban Middle Schools? The Urban Advantage Middle School Science Initiative in New York City.

White, C. (2017). *A critical review of evidence for the claims and perceptions of a shortage of science and engineering graduates in the UK.* University of Sussex.

Wong, B. (2015). Minority ethnic students and science participation: A qualitative mapping of achievement, aspiration, interest and capital. *Research in Science Education*, 1-15.

Yin, R. K. (2014). *Case study research : design and methods*: Los Angeles : SAGE, 2014.

Fifth edition.

Yin, R. K. (2015). *Qualitative research from start to finish* (2nd ed.): Guilford Publications.

Zimmerman, H. T. (2012). Participating in science at home: Recognition work and learning in biology. *Journal of Research in Science Teaching, 49*(5), 597-630.

Appendix A: Materials used in Participant Recruitment

Teacher and general school invitation-This was emailed to the six schools partnered with KIOSC.

Dear teachers at __________School.

My name is Kathleen Hayes, I am a PhD candidate at the Australian National University (ANU). I would like to invite the teachers and students of years 7 and 9 at ______ School to participate in a research project at KIOSC in 2016.
I aim to investigate whether the programs at KIOSC empower students to develop viable science identities that enable them to pursue STEM careers. I am interested in looking at year 7s, as they are at a critical age for aspiration formation and are also unlikely to have attended a KIOSC program before, and also year 9s who will soon be choosing V.C.E. subjects and career paths. I would like to observe students' self-perceptions and their awareness of STEM careers over a normal year of attendance at KIOSC. My questions are generally reflective in nature and would encourage students to contemplate their experiences, enhancing their learning from it.

I anticipate that findings from this research will give teachers and KIOSC staff greater insight into students' identity development and formation of their aspirations for STEM related careers. I hope this will contribute to the design of effective learning experiences at science centres and give educators a greater awareness in how identity construction can facilitate study and career pathways.

The time required of students and teachers for this research is outlined below. Once everything is organized to the teachers' convenience (approximately 30 minutes for administrative matters) I anticipate the impact of the research on teachers' time will be minimal. All participants will be the option of not being identified, using a pseudonym and using their full name.

Students

- Questionnaire 1 (30 minutes) February or before first KIOSC program
- Questionnaire 2 (30 minutes) November
- 10 focus group interviews (30 minutes) of groups of 5 students throughout the year.
- Post each KIOSC visit- 5 minutes to complete reflection diary

Teachers

- Optional teacher interview: July-December, (30 minutes)

KIOSC will be used as the preferred venue for conducting interviews and questionnaires however if it is more convenient for this to take place at school then temporary access to school grounds will be required.

Please forward the information and invitation for this research project to any potential participating teachers. If you have any questions regarding this research please contact me at kathleen.hayes@anu.edu.au or by phone at 0417 058 488.

Sincere regards,

Kathleen

Principal invitation

This was emailed to the principals of the six schools partnered with KIOSC.

Dear Principal (NAME)

My name is Kathleen Hayes, I am a PhD candidate at the Australian National University (ANU). I would like to invite the teachers and students of (name of school) to participate in a research project to be conducted at KIOSC in 2016.

I aim to investigate how situated learning experiences such as provided by KIOSC empowers students to develop viable science identities that enable them to pursue STEM careers. I am interested in looking at year 7s, as they are at a critical age for aspiration formation and are also unlikely to have attended a KIOSC program before, and also year 9s who will soon be choosing V.C.E. subjects and career paths.

I anticipate that outcomes from this research would include insights into how students receive science learning experiences outside school environments and how they interpret it through the boundaries of their already established identities. I hope this will contribute to the design of effective learning experiences at science centres and give educators a greater awareness in how identity construction can facilitate study and career pathways.

I would like to observe students' self-perceptions and their awareness of STEM careers over a normal year of attendance at KIOSC. My questions are generally reflective in nature and would encourage students to contemplate their experiences, enhancing their learning from it.

This research would only require some time throughout the year for students to complete 2 questionnaires (30 minutes each) and group focus interviews (30 minutes) as outlined below. All students participating will write a regular reflection diary after each visit which should only take 5 minutes. Teachers are also requested to participate in an interview (30 minutes) towards the end of the year.

- Questionnaire 1 (30 minutes) February
- Questionnaire 2 (30 minutes) November
- 10 focus group interviews (30 minutes) of groups of 5 students throughout the year.
- Post each KIOSC visit- 5 minutes to complete reflection diary by students
- Teacher interview: July-December, (30 minutes)

All participants will be the option of not being identified, using a pseudonym and using their full name.

For any questions regarding this research please contact me at kathleen.hayes@anu.edu.au. I am also available by phone at 0417 058 488.
Sincere regards,
Kathleen

Parent Invitation

This was given to students to take home to their parents.

My name is Kathleen Hayes, I am a PhD candidate at the Australian National University (ANU) researching how out of school science learning experiences affects students' identity development.

I would like to observe the progress of students' self-perceptions and interest in science over a normal year of attendance at KIOSC in 2016 and request permission from you for children to participate. The research involves students completing a brief questionnaire at the start and end of the year about their perception of science. They will also answer a few questions reflecting on their KIOSC experience and a few students will participate in a further group focus interview.

All questions to students will focus on their interest in science and self-perception of ability. No personal or controversial questions will be asked nor will students be compared against each other.

The questionnaires will be administered at KIOSC or at the school by arrangement and would take no longer than 30 minutes. The reflection questions will only take 5 minutes and will be incorporated as part of the KIOSC experience.

I aim to investigate whether regular usage of programs that involve authentic and engaging tasks empowers students to develop viable science identities that enable them to pursue STEM careers. I am particularly interested in whether out-of-school programs that involve situated learning can overcome the 'invisible' barriers of wealth, ethnicity and gender that are currently dictating the skewed population distributions seen in many science careers.

I anticipate that outcomes from this research would include insights into how students receive science learning experiences outside school environments and how they interpret it through the boundaries of their already established identities. I hope this will contribute to the design of effective learning experiences at science centres and give educators a greater awareness in how identity construction can facilitate study and career pathways.

Information given by students will be confidential and only accessible to the researcher. All participants will be given aliases in any reports or papers. Students may withdraw at any point throughout the year if they wish to.

If you do not wish your child to complete the questionnaires or reflection questions as part of their KIOSC experience please contact me via the methods below to opt out of the research. If you agree to allow your child to be interviewed in a small group of students about their KIOSC experience please complete the attached consent form and return it to your child's teacher.

For any questions regarding this research please contact me at kathleen.hayes@anu.edu.au. I am also available by phone at 0417 058 488.

Student Invitation

This was given to students.

My name is Kathleen Hayes, I am a PhD student doing research at the Australian National University (ANU). I'm interested in how science centres like KIOSC can make learning science meaningful to students such as yourself. I want to know, does learning a topic in a certain way enable students to feel better about doing it?

As part of this research I want to find out what *you* think of doing science and how you feel about your experiences at KIOSC.

To do this I would like you to complete two questionnaires, at the start and end of the school year, as well as a short set of reflection questions (5 minutes tops) after each KIOSC experience. Anything you write down will be kept confidential; I won't tell your parents or teachers or the KIOSC staff and you can use a pseudonym if you wish, or simple be anonymous. My research works best when you are completely honest about how you feel.

I would also like to talk to some students in groups of 5 about their KIOSC experiences on top of the questionnaires. These group interviews will be audio recorded and should take around 30 minutes. Again, only the research team will listen to the transcripts and your parents and teachers will never know what you say. You are able to stop participating in the research at any stage throughout the year.

If you have any questions please send me an email at kathleen.hayes@anu.edu.au or call me at 0417 058 488.

Sincere regards

Kathleen

Background information that was included with the general School Invitation, Principal Invitation, Parent Invitation and Student Invitation.

The most recent research has highlighted the role identity plays in students' aspiration for STEM careers and participation in STEM education; one study on Australian students found that 'not being able to picture themselves as scientists' was the most common reason students gave for not choosing post compulsory science subjects.

Many able and interested students are being turned off STEM careers through not being able to reconcile their preferred and supported identity with the overly smart and 'nerdy' perception of scientists that pervades popular culture. During high school students are at a critical stage in their lives where key development of who they are and who they aspire to be takes place. This identity development takes work and must be balanced amidst a range of competing interests and influences from their social, school and family networks. Students who do not have strong, positive science focused influences in their networks tend to find it harder to envision themselves as people who can be STEM professionals and often choose other, less conflicting pursuits. This reinforces the unequal representations seen in many science disciplines with students, especially girls, from working class backgrounds unable to draw on the reservoirs of support and capital that middle class students have.

Despite its acknowledgment as a critical factor in students' science participation, little research has included attempted to measure changes in students' science identities over time. A student's experiences of science at school are often their only experiences of science, thus it is important to examine whether different types of learning experiences can develop a viable science identity in students while still in the school community.

Situated learning experiences where students are actively positioned as powerful agents of their own learning are known to be more engaging and more effective learning experiences than the common ‘transmissive’ set up with teachers in the role of subject expert and students as passive receivers. Contexts which allow tasks to be performed near authentically, where concepts are used as part of achieving a purpose rather than for a grade on a test are also highly regarded as exemplar learning experiences. However these learning experiences are also very time and resource intensive to run. The provision of such programs by specialized science centres like KIOSC offers a potential solution. Whether these programs are able to effectively complement or supplement school science teaching and enable a variety of students to construct viable science identities needs to be explored in order to improve opportunities in science for a variety of students who are currently put off by a lack of awareness and a lack of confidence.

Australian National University

Appendix B: Participant Information Sheets

Participant Information Sheet (Teachers/Staff)

Researcher:

My name is Kathleen Hayes and I am a PhD student at the Centre for the Public Awareness of Science at the Australian National University.

Project Title: Student Science Identity Development through Science Centre programs.

General Outline of the Project:

Description and Methodology:

The aim of this research is determine if secondary students develop identities as people who do science after a year of attending several learning programs at KIOSC (Knox Innovation, Opportunity and Sustainability Centre). Information will be gathered in a number of ways:

- Two questionnaires for students
- Group focus interviews with students
- One on one interviews with KIOSC staff
- One on one interviews with teachers

Participants: Year 7, 8 and 9 students from schools in the Knox area partnered with KIOSC, teachers of participating students and KIOSC staff.

Use of Data and Feedback: Data will be shared in peer reviewed professional education journals and/or conferences and also published in a doctoral thesis. An executive summary report outlining the purpose and findings of the research will be made available to participants through a shared drop box document.

https://www.dropbox.com/s/bvu3ot9ypo7mql5/Research%20Summary%20Report.docx?dl=0

Participant Involvement:

Voluntary Participation & Withdrawal: Participation in the project is **voluntary** and you may, without any penalty, decline to take part or withdraw from the research at any time until the work is prepared for publication or submitted as a part of a thesis without providing an explanation. You can also refuse to answer a question. If you do withdraw, your data will be withdrawn from the study and destroyed. Only complete sets of data will be used.

What will participants have to do? Participate in a one-on-one interview (30 minutes)

The interviews will be recorded (not filmed) and then transcribed. All data will be de-identified and stored in a password protected environment, accessible only to the researcher.

Location and Duration: The interviews will take place at KIOSC or participating schools and should last around 30 minutes.

Risks: There are minimal risks associated with participating in this research. While your comments can be attributed by request to a pseudonym or not attributed at all, it is the responsibility of the participant to ensure that they avoid disclosing information which is of confidential status or which is defamatory of any person. Some comments may be attributable to a particular school.

Confidentiality:

The confidentiality and privacy of participants will be protected as far as the law allows. Interviews will be conducted in a private space. Your responses will be coded in a manner allowing re-identification only by the research team. In an effort to limit risks and protect the confidentiality of all participants, no data will be reported verbally or in writing in a manner that could identify individuals without prior consent of these individuals. Reported findings will use one of the following identification for participations; first names, pseudonyms or no attribution as requested on the consent form.

Data Storage:

Electronic data (recordings and transcripts) will be stored securely on a password protected USB throughout this study and the duration of the main researcher's PhD (2015-2017). It will then be electronically stored at ANU for at least (5) years following publications arising from the research. No data will be released in raw form. Only the research team will have access to information provided by participants.

Queries and Concerns:

Contact Details for More Information:

Kathleen Hayes (main researcher)
Centre for the Public Awareness of Science
Australian National University
Physics Link Building 38A
Canberra ACT 2601
Email: kathleen.hayes@anu.edu.au
Phone: 0417 058 488

Dr Merryn McKinnon (supervisor)
Centre for the Public Awareness of Science
Australian National University
Physics Link Building 38A
Canberra ACT 2601
Email: merryn.mckinnon@anu.edu.au
Phone: 02 6125 4951

Contact Details if in Distress: Should any aspect of this research cause you any form of distress, you are encouraged to contact Lifeline on 13 11 14.

Ethics Committee Clearance:

The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee. If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.Officer@anu.edu.au

Australian National University

Participant Information Sheet (Students and Parents)

Researcher:

My name is Kathleen Hayes and I am a PhD student at the Centre for the Public Awareness of Science at the Australian National University.

Project Title: Student Science Identity Development through Science Centre programs.

General Outline of the Project:

Description and Methodology:

The aim of this research is determine if secondary students develop identities as people who do science after a year of attending several learning programs at KIOSC (Knox Innovation, Opportunity and Sustainability Centre). Information will be gathered in a number of ways:

- Two questionnaires for students
- Group focus interviews with students
- One on one interviews with KIOSC staff
- One on one interviews with teachers

Participants: Year 7, 8 and 9 students from schools in the Knox area partnered with KIOSC, teachers of participating students and KIOSC staff.

Use of Data and Feedback: Data will be shared in peer reviewed professional education journals and/or conferences and also published in a doctoral thesis. An executive summary report outlining the purpose and findings of the research will be made available to participants through a shared drop box document.

https://www.dropbox.com/s/bvu3ot9ypo7mql5/Research%20Summary%20Report.docx?dl=0

Participant Involvement:

Voluntary Participation & Withdrawal: Participation in the project is **voluntary** and you may, without any penalty, decline to take part or withdraw from the research at any time until the work is prepared for publication or submitted as a part of a thesis without providing an explanation. You can also refuse to answer a question. If you do withdraw, your data will be withdrawn from the study and destroyed. Only complete sets of data will be used.

What will participants have to do? Participation in this study will require you to complete 2 questionnaires (20 minutes each), one at the start of the school year and one at the end. Some participants will also be invited to participate in a group interview of around 30 minutes.

The interviews will be recorded (not filmed) and then transcribed. All data will be de-identified and stored in a password protected environment, accessible only to the researcher.

Location and Duration: The questionnaires and interviews will take place at KIOSC or participating schools.

- Questionnaire: 20 minutes
- Group focus interviews: 30 minutes

Risks: There are minimal risks associated with participating in this research. While your comments can be attributed by request to a pseudonym or not attributed at all, it is the responsibility of the participant to ensure that they avoid disclosing information which is of confidential status or which is defamatory of any person. Some comments may be attributable to a particular school.

Confidentiality:

The confidentiality and privacy of participants will be protected as far as the law allows. Interviews will be conducted in a private space. Your responses will be coded in a manner allowing re-identification only by the research team. In an effort to limit risks and protect the confidentiality of all participants, no data will be reported verbally or in writing in a manner that could identify individuals without prior consent of these individuals. Reported findings will use one of the following identification for participations; first names, pseudonyms or no attribution as requested on the consent form.

Data Storage:

Electronic data (recordings and transcripts) will be stored securely on a password protected USB throughout this study and the duration of the main researcher's PhD (2015-2017). It will then be electronically stored at ANU for at least (5) years following publications arising from the research. No data will be released in raw form. Only the research team will have access to information provided by participants.

Queries and Concerns:

Contact Details for More Information:

Kathleen Hayes (main researcher)
Centre for the Public Awareness of Science
Australian National University
Physics Link Building 38A
Canberra ACT 2601
Email: kathleen.hayes@anu.edu.au
Phone: 0417 058 488

Dr Merryn McKinnon (supervisor)
Centre for the Public Awareness of Science
Australian National University
Physics Link Building 38A
Canberra ACT 2601
Email: merryn.mckinnon@anu.edu.au
Phone: 02 6125 4951

Contact Details if in Distress: Should any aspect of this research cause you any form of distress, you are encouraged to contact Lifeline on 13 11 14.

Ethics Committee Clearance:

The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee. If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University

Australian National University

Telephone: +61 2 6125 3427

Email: Human.Ethics.Officer@anu.edu.

Australian National University

Appendix C: Participant Consent Forms

WRITTEN CONSENT for Staff/Teachers

Student Science Identity Development through Science Centre programs.

I have read and understood the Information Sheet you have given me about the research project, and I have had any questions and concerns about the project addressed to my satisfaction.

I agree to participate in the project and I understand that the interviews will be audio recorded. YES ☐ NO ☐

I agree to be identified in the following way within research outputs:

Full name	YES ☐	NO ☐
Pseudonym	YES ☐	NO ☐
No attribution	YES ☐	NO ☐

I understand my comments will be attributable to KIOSC/a particular school even if I remain anonymous. YES ☐ NO ☐

A summary report of this research will be provided through the following link:

https://www.dropbox.com/s/bvu3ot9ypo7mql5/Research%20Summary%20Report.docx?dl=0

Australian National University

Signature:…………………………………………….

Australian National University

WRITTEN CONSENT for Students

Student Science Identity Development through Science Centre programs.

I have read and understood the Information Sheet you have given me about the research project, and I have had any questions and concerns about the project addressed to my satisfaction.

I agree to complete two questionnaires in 2016. YES ☐ NO ☐

I agree to participate in a focus group interview which will be audio recorded. I understand my comments will be attributable to a particular school or centre. YES ☐ NO ☐

I agree to being identified in any research publication by:

first name ☐ pseudonym ☐ no attribution ☐

A summary report of this research will be provided through the following link:

https://www.dropbox.com/s/bvu3ot9ypo7mql5/Research%20Summary%20Report.docx?dl=0

Signature:…………………………………………….

Appendix D: Interviews – Indicative Areas of Questioning

Staff Interview Questions

Introduction: Explain research, assure confidentiality e.g. "I'm a PhD student researching how structured experiences at a science centre, such as KIOSC, affect students' attitudes and perceptions to learning science….."

To start off generally….**How would you define a good science student?**

Why, why not? – What qualities do you think are required?

Does KIOSC provide a different kind of science learning experience to school?

Can you describe some similarities/differences? Are these good or bad?

What outcomes do you want to achieve in students after their KIOSC experience?

How do you try to get those outcomes?

I.e. strategies to get them interest, topics to help them see relevance, examples of future jobs

Did you observe all students participating in the activities at KIOSC? How?

Are they engaged? Which ones tend to not want to be there, why?

How do you deal with/engage students not interested in science?

Did you notice any key moments in students during their visit to KIOSC, such as a change in their thinking or behaviour?

Change in perceptions of science? Interest, usefulness, relevance

Change in self-perceptions as capable of science?

Are there any particular students? Do you try and facilitate those moments?

What sort of *science* experiences do you want students to have at KIOSC?

Teacher Interview Questions

Introduction: Explain research, assure confidentiality e.g. "I'm a PhD student researching how structured experiences at a science centre, such as KIOSC, affect students' attitudes and perceptions to learning science….."

To start off generally….

How would you describe a good science student?

Is KIOSC a different learning experience to school?

What sort of experiences would you like your students to have at KIOSC?

- What outcomes do you want from KIOSC visits?

How do your students feel about visiting KIOSC?

- Do you notice any changes in students' behaviour when they visit KIOSC?
    - Why do you think there is change/no change?

Were any activities at KIOSC particularly engaging for students?

- Why do you think this is?
- Were they interested?
- Did they have the chance to feel competent?
- Do you think they had a chance to be recognized as capable?

Were any activities particularly <u>not</u> engaging for students?

- Why do you think this is?
- What do you think could make the KIOSC experience more engaging for those students?

Were any students in particular engaged?

- Why do you think the activities appealed to them?
- Were any students very disengaged? Why do you think they were?

During and following the visit to KIOSC have you observed any change:

- **In students' perception of science?**
- **In their self-perceptions of their capability in science?**
- **In their participation in science?**
  - Do you think there were any specific activities that were influent in this change?
  - Has this change persisted?

Has visiting KIOSC changed your perceptions of science?

- Has it changed your perceptions of your students'?

Australian National University

1st Round of Student Focus Group Questions

Introduction: Explain research, assure confidentiality e.g. "I'm a PhD student researching how structured experiences at a science centre, such as KIOSC, affect students' attitudes and perceptions to learning science….."

To start off generally….

How would you describe yourselves?

What are your hobbies, favourite subjects? What are you good at?

What do you think about doing science?

Is there anything about science that you enjoy or find interesting?

What sort of person do you think does science?

Do you think you could do a job that involved science?

Why, why not? Do you want to do science in the future? As a career?

What do you think about going to KIOSC each year?

Would you rather be at school? Is it valuable use of your time? Recommend it to others? Is what you do at KIOSC different to what you do at school? How?

Can you describe the KIOSC experience to me?

What do you do? What was most/least interesting? What are some things that you liked/didn't like? What was difficult? Boring? Was it relevant, authentic, your actions matter? What were you good at? (try to prompt others to describe each other)

Did you learn anything new at KIOSC?

Did your experiences at KIOSC change the way you think about or participate in science?

Interesting/useful, good career, fun activities? Interesting topics?

What sort of *science* experience would you like to have at KIOSC?

If you had to describe what you do at KIOSC to a new student who had never been there before what would you say?

What would make you more confident in doing science?

What would make doing science more interesting for you?

2nd Round of Student Focus Group Questions

Introduction: Explain research, assure confidentiality e.g. "I'm a PhD student researching how structured experiences at a science centre, such as KIOSC, affect students' attitudes and perceptions to learning science….."

Can you describe your latest KIOSC experience to me?

What do you do? What was most/least interesting? What are some things that you liked/didn't like? What was difficult? Boring? Was it relevant, authentic, your actions matter? What were you good at? (try to prompt others to describe each other)

Did you learn anything new at KIOSC?

What do you know now about doing science that you didn't know last time I talked to you?

Have you changed your mind on what you think about doing science?

Is there anything about science that you enjoy or find interesting?

Do you know anything more about the sort of person who does science? Have your opinions changed?

Have you changed your mind on whether you think you could do a job that involved science?

Did your (latest) experiences at KIOSC trigger you to find out more information? Try out an activity? Change behaviour?

What do you guys think about going to KIOSC regularly/ again next year?

What sort of science experience would you like to have at KIOSC?

Would you rather be at school? Is it valuable use of your time? Recommend it to others?

Is what you do at KIOSC different to what you do at school? How?

If you had to describe what you do at KIOSC to a new student who had never been there before what would you say?

Is there anything that would make you more confident in doing (well) science?

Is there anything that would make doing science more interesting for you?

Appendix E: Interview Transcript Example

Student Interview Transcript

Interview between researcher and two year 8 boys from School 2.

Researcher talking in bold.

Boy 1 talking.

Boy 2 talking.

Brackets were used to distinguish between the interviewer talking or to note pauses, external noises like laughter or wind etc.

All right, so thank you both for helping me out with this....I'm recording so I can remember what you say, everything is confidential...if you do feel upset you can leave at any time, all voluntary.

Ok

Sweet

All right

So first [Boy 2]

Yes

and [Boy 1]

yep

And I'm Kathleen. So first a bit about yourselves, what's your favourite subject?

My favourite subject would have to say would be materials, so just wood works, metal works.

Yeah?

Stuff like that.

And what about you?

Uh mine's digital media cause I love playing with computers and video games

Cool

All that technology stuff.

Awesome, I love computer games too. All right and what do you guys think about doing science?

I enjoy it we do pracs which can be fun at times yeah.

I enjoy the mice project that's fun

Cool. So what about science do you find particularly interesting?

(pause)

Most things, even just thinking of what others haven't thought of, conspiracies also are good

OK, and what about you [Boy 1]?

Not quite sure like uh, like playing with chemicals and all that is fun yeah.

Anything about science that you find rather boring?

The whole like study part of it

(laughs)

Yeah?

I don't really find much of it boring, nothing that I can think of.

OK, and what uses do you think science can have?

Uh multiple things say, for example the way that medical research has been going

Yeah? cool, and what about you [Boy 1]?

teach you like what different things do together, like chemicals, something I don't know put something together and it blows up or something

Cool, and that's useful? All right. So do you guys do any science related activities outside of school?

Outside of school, no.

Neither do I

No? all right. And is anyone in your family interested in science?

Not that I really know of, I think I have a couple of family which are little all right with science like, they do a little bit

And what about you?

I don't think my family really would, cause my brother is an electrician, my mum's a teacher and my sister does dancing so I don't…

OK, so does anyone in your family or perhaps a family friend who does a science related job?

Yes one of my friends their parent used to work with science

Cool

Not that I know of

OK, do you know specifically what they did, what field?

No all I know is that they worked with science

OK cool. **I'd like to know more about yourselves in science, would you guys describe yourselves as science people?** (heads shaking) **No?**

Nup

No, I'd describe myself as reasonably intelligent I can get through all the pracs, I can do all the work.

OK, so why wouldn't you describe yourself as a science person? *Just don't enjoy sitting down for long times writing and stuff, the pracs are fun I enjoy that, I can do that really easy* **And [Boy 2] you wouldn't describe yourself as a science person?** No I'd just, yeah I don't really think of myself as that person who is all about science, is all yeah. You can do this with this.

So how do you guys think you go in science? or do?

I think I'm going pretty well yeah, good enough to pass

Yeah? Cool

Get good grades

Awesome, all right, so can you guys tell me what you think a science related job would involve?

Depends multiple science related jobs

yeah

there are, for example chemists, they work with, yeah, bacteria chemicals to help make things, medical lives better.

Cool, and you [Boy 1], any ideas on what a science related job would involve?

When I think of like a science job I think of sitting in a like a guy in white coat, like looking through a microscope at some like little bacteria I don't know something on a, something in there

Yeah? that's cool. Do either of you guys think you could do a science related job?

I could if it didn't mean sitting down for like long hours periods of time, because I just start getting distracted.

And you think that's possible?

Yeah I certainly think it's possible, cause science isn't all about sitting down writing

OK

Still of course have to do things

Excellent, and you [Boy 1]?

I honestly don't think I could do it because like [Boy 2] I get distracted very easily, and I don't like sitting down for long times

OK, do you guys think you'll study science later on at school?

Uh yeah I think it might be helpful to have during a job like even architecture that uses a form of science, that uses physics

Exactly yeah

I have to study science to do that

And [Boy 1]?

I honestly don't think so

OK. All right so has any particular experience or person that's lead you to that idea? Studying science later on?

Studying science later on, no not really. My dad's an electrician so he doesn't really do much with science, of course using electricity that's one thing that kinda urges me to

(pause)

And what kind of person do you guys think would be good at doing science?

I think definitely one of those people who can yeah, who can sit down for long times and concentrate +who can sit down. Who have like a one track mind, who's a, yes I'm going to do this and I'm going to it for a period of time. I actually finish the task.

OK, any other qualities you think a good science student would need to have?

(pause)

I'm not sure

OK that's all right. So let's talk about KIOSC, have you guys been there before this year?

Uh yeah, not this year I went

yeah we went last year

And you didn't go this year?

Oh yes we did go this year sorry.

Cool, so what do you think about going to KIOSC?

Yeah I really enjoyed it I loved it, the different activities you do, and they obviously go to a lot of effort just to set it all up so

And you?

I enjoyed this year's one, (sounds hesitant) *on the murder case*.

Yeah?

I really enjoyed that one but the last two ones I didn't find interesting

What did you do then?

I think, I don't know if I actually, I went to one

One was studying rocks wasn't it?

Yeah, I went to two, there was one where we studied rocks, and one where it was like a cooking one.

Oh, OK

We found like where food came from and all that

All right, so is KIOSC different to school?

(pause)

Yeah I think it's quite different, the different things they do like setting up for example the murder mystery this year, at this school we don't really do that stuff we just work with like Bunsen burners, stuff like that.

OK, what about you [Boy 1], Is KIOSC different to school and if so how?

I think it's different to school because here we usually just sit down and do a task but there there's a lot of, you can go around and do a lot of activities and it's just really, like fun cause you actually do things

OK, so what's the best bit about going to KIOSC?

(pause)

get out of school

(both chuckle)

OK fair enough

I think really just, doing the activities like, with the murder mystery, yeah again going back to that it was quite interesting to put our brains to work, trying to figure out who did it and knowing that if this was a real, if this was real life, if you got it wrong this person would be charged and things like that

Cool. **So what's the worst bit about going to KIOSC?**

(wind picked up, very noisy)

Careful your...The part that [Boy 2]

(.... laughter, wind blowing papers).

What about you [Boy 1], what's the worst bit about going to KIOSC?

If it's not like interesting you're like stuck there and you have do all these, if like you're not interested you have to do all these boring activities

Yeah? and what about you [Boy 2]?

Yeah, I sorta agree with [Boy 1] like with the rock one in year 7 last year they kind of, it wasn't all that interesting, like you were just studying rocks, which I don't really think is something I could do

Yeah?

Yeah

OK

So do you think , going to KIOSC is a valuable use of your time?

(pause)

Yep

Yeah

Totally, like it teaches you thing, you can use in the real world depending on different jobs

Cool

Once again for the cooking and the rock, cooking obviously for chef, rock for, (pause) forgot the wording

palanetology?

No that's dinosaurs

Yeah?

Yeah, geologists that's it and with this one obviously forensic scientist so yeah, I'd totally think it's (indistinguishable)

And [Boy 1]?

I forgot the question what was it?

Do you think going to KIOSC is a valuable use of your time?

Yes, because in at school we don't really learn a lot about these different subjects like ah, like for the forensic science we don't I don't think

Nah we don't really do that

we would never do that so it teaches you about something you wouldn't usually

OK. Cool, so which setting do you prefer to do science in, KIOSC or school?

I quite enjoy, KIOSC it kinda just depends what we're doing there and school it's still nice to sit down and right things but, it's also nice you know to get your hands a little dirty and do stuff

Mm yeah I honestly, I prefer KIOSC because I like to move around, I don't like to stuck in one spot and uh it's just a lot funner like at KIOSC.

Is there anything in particular that makes KIOSC fun?

Oh, just, just the activities, the different things to go to, the different stages and, like a plan or something

Cool. So over the past two years you've been going to KIOSC, what's really stood out in your mind, what's the most memorable thing?

I reckon this year one

Yeah this year's KIOSC with the forensic science cause that was really fun like with the UV-

yeah that was fun-lights-*we got to like search tops and that* (talking over each other)

Yeah?

And working with the different dirt samples that was really fun

Cool. All right, and is there anything, what's something new that you've learnt at KIOSC?

Something new

That you could see a lot of the (wind blowing)

Yeah, how you can measure foot sizes with just shoe prints

I think though like the size of sole match

Yeah the size of someone

Yeah, yeah, cool. **Is there anything new that you've done at KIOSC that you might not have done before?**

A murder case, trying to solve a murder case

(chuckles)

Fair enough

I don't think we would have done that at school

I've obviously, I've thought about it during like watching NCIS or stuff like that but I've never actually gone around and done the different stages to work it out

OK cool. All right did your experiences at KIOSC change your interest in science at all?

Yeah this one definitely did

Yeah? How did it change?

Uh, it's got me a lot more in like that topic, of forensic science, because the other ones were quite boring I would say

Yeah, all right

Yeah I kinda agree with [Boy 1] with the forensic science thing, cause, yeah that definitely opened up my mind to forensic science and the different possibilities you can do with just simple chemicals

Cool. All right and did, your experiences at KIOSC change the way you participate in science? Your behaviour?

No

I don't think so no

Not really for me, I tend to just, I tend to do the work get it done do what needs to be done to get it done

Fair enough. **And, so I guess, did it change the way, the sorta science related activities that you do, didn't, no you've kinda answered that question already. All right did it change your perception of science? or, who can do science?**

Actually yeah it kinda did

Yeah *it was like yeah with the rake cause they just put all the tools out there and we just did it, was pretty, yeah, it was pretty easy.*

Yeah and for me, going back a bit to one of [Boy 1]'s answers, I used to think science was mainly just men in lab coats working with biology and stuff like that but now, I've learnt that there are different types of science like forensics science, where police and obviously forensic scientists go out

And how has KIOSC affected you in this changing?

Oh, just, just the thought that, even someone with,

no experience even,

Yeah even someone with no experience can go and do something so difficult and work it out.

So do you think it's changed the way you perceive yourselves in science? going to KIOSC and doing these things?

Yeah totally I used to think, I would never be able to do anything like that.

Yeah I used to never like but now I used to never look forward to KIOSC

Yeah but now we've actually-*doing something*-been able to do the things (talking over one another)

Yeah?

Yeah

Sorry you're speaking over a bit so can I grab what you said again? Just to make sure I get it all

Forgot what I was saying

(chuckles)

Happens to me all the time. **Change the way you think about yourself in science?**

(pause)

Uh, yeah it like

(pause)

Lost it sorry

That's all right, thank you anyway. **Cool, so what sort of experience would you guys like to have at KIOSC in the future**?

Mm, at KIOSC, I would like to work with like, is it, is engineering technically a form of science?

Yeah

Well if you're looking at you know STEM subjects, science, technology, engineering, maths

Yeah I was thinking I'd like to learn the science of technology things like that

Like build something, like a moving thing like you could build like a car and you could have like a race or something

OK

Yeah like even just basic solar panels things like that

All right. **So, is there anything, so those are some of the science related activities you'd like to do**?

Yeah

Is there anything you think that you'd like to do that would help you feel better, think, improve your confidence in doing science?

Not really, I'm pretty, I'm already pretty confident with my science

Yep?

Yeah so am I

OK

It's like pretty easy

Fair enough, enough, cool, well that's all my questions unless, there's anything else you'd like to say about the impact of KIOSC or the lack thereof on your life?

(chuckles)

Pretty fine

Cool. I'm just trying to think of any other questions I can ask you while I've got you here captive

(laughs)

(pause)

Do you think going to KIOSC has helped, support, helped you feel more confident in doing science?

Yeah totally, yeah.

Any particular activity, oh no it was what you guys were talking about, the forensics

Yeah forensics

All right well thank you both for participating. Are you guys looking forward to going to KIOSC again?

Really depends, it kinda depends on what we do there.

Yeah hopefully they do something fun next time, like they did something fun last time but hopefully they do it like, something that's interesting

Yeah cause that was really good.

Staff Interview Transcript

Interview between researcher and Helen, staff member at KIOSC.

Researcher talking in bold.

Some general questions to start off with, how would you define a good science student?

Well, someone who's inquisitive, who's curious about the world, who wants to learn, a thirst for knowledge. That's how I'd describe my perfect science student.

Cool, those are the qualities that they would have?

Yeah, yeah being able to tinker and problem solve and think critically about the world in which they live and you know, ask for help, look at research, read, try and understand why. Because that's all that we want to know, we want to know why, so that's my perfect student.

Do you think KIOSC provides a different learning experience of science to school?

Yeah, yes I do. I mean I'm new this year I've been here since the beginning of the year so all I've done is teach in the last 17 years in secondary schools in science. Kids are able to have different investigations, they're able to play with different types of technology. I think that's a real bonus about this place, sometimes we get more time with them, like when we run the whole day activities. There's a whole day for them to sit and digest information and work with it and you know problem solve and inquire and come to the end point.

It's a really unique opportunity and it's one that's going to get better and better the more that you know we understanding what our role is within the schools. And that's you know, starting to play in, in the last couple of years and this year we're trying to look at getting the VCE components in there as well. So it'll be a really interesting process I think.

One that will never stop, we gotta stay ahead of the game. Which is very exhausting and very hard to do. And I don't want KIOSC to be like school. I want it to be that amazing experience when they get to come and not see a show, but be wowed and excited and a little bit entertained and you know be able to actually grasp it and get involved and go hey, I really like this. My philosophy is always been in science that I just wanna teach the kids. If they don't love it, that’s fine, I just want to give them the appreciation for it and let them function in our society with the scientific literacy.

That sounds great. So what outcomes do you aim to get as a result of the KIOSC experience? You might have touched on this in your previous answer but if you could describe what sort of outcomes KIOSC experiences should have in your opinion.

Well, I think sometimes kids are, they're in school, school can be boring, it can be disengaging to a lot of kids. We get kids here that the teacher will come and say to us, oh look watch him, or watch her you know, they're a bit of a problem. And you get to see them tinker, and you get to see their eyes light up, and you get to see them solve a problem. and I think that's probably one of the best experiences that they can have to know that I did it doesn't have to be on my own, but I got to the end point.

An example would be solar cars. The kids have to build a gear box, and they don't understand anything about gears and yet you give them a little bit of scaffolding for it. They build a gear box, it might be wrong but it doesn't matter. Because they can go back in and they can change it. The robotics is another perfect example where it’s a trial and error process, it's that resilience and the persistence that those kids have to go, I'll get to an end point. So, I think we have an obligation as teachers, to make sure that kids can see an outcome, that they can see yes I can do it. I can see it might be hard work but I'll get there eventually so it's that's queuing and that scaffolding that we do as teachers to get to the end, and if they really like the journey and they really like the path that they're on then that's the encouragement that they keep going in science.

And some of them do and some of them don't. But the best thing is to always have a kid that enjoys the lesson, enjoys what they've done. and you know they go home and tell mum. What they'd do at school today because that doesn't happen very often. So yeah just a real love of learning and of course science because I'm biased, that's my passion.

Yep all right, so, going specifically to talk about today with the year 7 School 1. Did you observe all the students participating?

No they weren't all participating. The first session they did quite well, so that was 75 minute session. It was engaged in a very different activity and it was interesting to watch how because there's so much technology in that room they sat there and they're like hmm, what's going to happen here. Like there nothing they've experienced before, and, you could just see when is the task going to become school like. And it never really got to that cause they got the iPad, they got to work in their teams, some of them got to get up and one boy in particular who was a bit disruptive in the second session (mm) he was great in the first session. Cause he could get up, he could talk to the kids about things that he knew and he was quite knowledgeable, and I encouraged that with him. And so the first session worked really well. The second session it was more of a classroom based activity which this is boring, I could do this at school. And the second session, the sustainable packaging is under review at the moment. We're looking to change components of it and we did change a little bit of it today, we put things in different orders. But there's still lots of tweaks that need to happen, the kids, the concept is fantastic, but the kids don't get to the end point like ok how are you going to package coke. I'll put it in a can. And that's actually not what we want them to get to we want them to use the materials that they're been experimenting with to figure out what they can use. So it's about really connecting those dots and how to get them to that end point.

Like I said to Mary before perhaps we should be giving them made up products. And so then they actually have to think well, if it, you know, is very delicate what do I need to package it in, what have I already tested? that would help me with that? So the thing that I really love about the girls is that they always continually want to improve You know how did the lesson go, do things need to change, you know, could I have done that better and it's very different depending on what year level we get, what's school we get, you know a group of kids, you know it could even be the same school, one lesson to the next you know 75 minute later you get a different group. So I think continual improvement is something that we look for. Um, and we do want to change that activity, but I don't think it's going to change for next week. Not with all the chemicals I have do [prepare] too.

Alright, so you talked a lot about, lets restart that. Do you notice any moments of, where students perhaps changed their perceptions of science? What it involved or who could do it?

Yeah there was one boy in the second session, um, you know he had to go and test the materials, and he didn't understand how to use the data sheet, didn't know, didn't want to write stuff down. And so I said to him, just tick or cross. You know does it break, yes give it a tick. , no it doesn't give it a cross. and soon as I did that for him, because now he didn't have to write down copious amounts of words he went 'oh' and off he went. and he went around and he did all the stations and I looked over his shoulder at the end. I mean he didn't have time to finish because he stuffed around at the start but he actually knew where he was going and I really built that relationship with him and the boy that he was sitting with in the next activity, he was actually spur him on and say come on, couldn't you do this, this and this so it’s sometimes those little insights that you have with the kids that you make that relationship, that you build that connection with them. And that little spark goes on.

So do you think that were moments today where, as you described there the kids could change in their confidence or interest in what they were doing?

Yeah, absolutely. And I didn't see Bridgette’s session today, yeah I would say that the second session, I would say most of the boys in particular were a little bit turned off by it. Because it was a creative you know type of activity. Whereas the girls, off they went, they grabbed all the coloured pens and whatever they were and they actually started putting stuff down on paper. You see that’s very hard for boys to do as well. So you know the next activity which was basically a game, I assume the boys would have been really into it. You know calling out the answers, you know really wanting to push forward. Whereas some of the girls who were actually quite shy probably wouldn't have worked as well in that activity.

Ok, so but do you think in the two sessions that you observed did they, do you think they came away with a different awareness or understanding of what they could do in science.

Yeah I think it gives them to scope to understand, it takes a lot of different types of, um people to build a town. Likes there's lots of decisions that need to be made, and the four of pillars of sustainability which look at you know, what's the economic cost, what's the social cost, cultural, environmental cost, and you've got to weigh up those balances. And when you put up the graph and the kids get to change the graph and see what happens, you just watch the realisation of making one small decision and how it affects everything else

And do you think that happened today?

Yeah quite a few kids in the first session got there, one of the boys in particular, didn't like a lot of the decisions that were made. But you could see him tracking the data cause, the kids actually want to get it right they do, they want to get to the end point where they think, yeah we got the right answer, cause, but there is no right answer when you're talking about town planning. Because different groups of people have different ideas about what they want to do.

Second session I'd say it's a little bit more difficult. Because we didn't really get to, the end focus, like I've only seen it run once, that's the first time I've seen it. And so I mean, Mary and I have already had a conversation over lunch about certain things that we can change but I don't think, probably the second session, there was such a connection at the end.

Ok, cool, alright well my final question, I think you've already answered in a way. What sort of experiences do you want students to have at KIOSC but if there's any final concluding remarks you would like to make.

I want them to have fun. I want them to enjoy the day and I want really get home that take home message, know what's the theme of the day, what are they taking away from KIOSC with them. And of course I want them to come back cause even though, it’s funny like there's kids that I've seen only twice, but I still remember them you know, still able to pick them out. And I do miss kids, being a teacher, don't have my own class anymore but that's I think the real take away for me, is you know, to enjoy, you know some parts of the day they might not, but to have an overall yep I really, I really enjoyed the things that we did, you know I have learnt something. And what is it that I've taken away.

Awesome well that's it thank you very much for giving me your time in a very busy schedule.

Teacher Interview Transcript

Interview between researcher and Brian, a specialist science teacher from School 1.

Pseudonym for mentioned student: Jim

Researcher talking in bold.

So thank for talking with me. To start off generally, how would you describe a good science student?

Good science students are just keen on learning. It's all interesting, doesn't matter what it is, they're just happy to learn.

Cool, I thought I'd start you off hard on a Monday morning, get you thinking.

I've been here since 8 so,

Cool, and do you think, is KIOSC a different learning experience to school?

Different venue different teachers, but probably not what we want.

OK, so what sort of experience do you want your students to have at KIOSC?

We want them to be able to do things that we can't do at school, tech wise, or knowledge based, just innovations things like that. And I'll give you an example one of the students that we had a bit of an issue with behaviour wise, they thought it would be like science works so that was his impression as to what it would be like, lots of hands on stuff lots of actual, doing stuff not being spoken to, and talked to throwing things in to bins and that sort of stuff. And that's probably what we would like from them.

So what sort of outcomes would you like for your students going to KISOC?

I suppose just an extension, an extension of what they're learning in their classrooms, and I suppose what they see in everyday life. Probably just what the future of, we're doing, what the future is going to look like, or potentially could look like.

OK, cool. So how do your students generally feel about visiting KIOSC?

Year sevens' no problem, year eights' gets a bit more difficult. Pretty much by year ten they don't want to go even though it's free, even though everything is paid for, even though it's a day out of school, they don't want to go.

OK and do you notice any change in students' behaviour when they do visit KIOSC?

I suppose because it's a new environment for them the only real behavioural they don't engage

Oh OK

So they don't engage like answering questions,

Are they a bit shy?

yeah probably I'd say that, like the experience that you had was probably atypical, you can imagine kids have brought back their permission forms to you, actually into were the ones that were a bit more get up and go.

OK

It's because I think they don't know the staff there, here's someone new there, they don't have the link, it's really hard for the staff there to establish a relationship in 90 minutes

So going twice a year is not enough to build that relationship?

Nah definitely no.

OK

probably what it does do is damages. Now I'm not criticizing the teachers, I think it's not their [fault], they're been kinda told what to teach and doing their best, yeah.

Were any activities at KIOSC particularly engaging? Specifically referring to the last year 8 experience.

Yeah probably the one where they were treating materials was probably the best one, so they had a whole heap of different base materials, and they had a whole heap of scientific tests to actually battery of tests to run through. and I think it was decomposition, and degrading and all that sort of stuff, but one of the kids that you interviewed told me 'we were just getting into it and then hurry up, we need to get moving' and they'd run out of time so I think that one, if they could extend that one that would probably be the better one.

All right, why do you think that activity was particularly engaging for them?

Well it was more hands on, it was more, get into a small group or pair or whatever, go round to the testing station here's your materials here's a heap thing. Still not what probably not peak body stuff that you'd be looking for but at least it was something where the kids were up and running around.

OK, do you think the activities at KIOSC gave students a chance to feel capable or confident in science?

(pause)

I suppose it does but it doesn't extend and that's what I think that's what I'm looking for.

OK were there any activities that were particularly not engaging for students?

Yeah, pretty much the one where they were trying to dump rubbish into the bin, I think it was the last one, so probably the first one and the last one were the least important. Some of our, like I sat with a group that has difficult forming in working in teams, so I sat with them particularly to try in the first activity to try and get them to discuss and encourage, once again it's a really difficult thing for the girls to start to realise not all kids work well in teams and there's some things you have to do before they get into that activity even though we had grouped them based on what KIOSC wanted, similar ideas about the important of some of the, the six R’s and that sort of stuff, so we drew a groups that they should have been able to work together and I suppose where one of the difficulties lie, if you don't know the kids and I think some of those activities would, they last well at 30 minutes but not for you know an hour or whatever it is

On that note, do you think there's any way, what do you think could make those activities more engaging for students?

Higher tech, just looking more at I suppose I just extending their knowledge their understanding, their skill levels so.

More of a challenge?

Yeah, I suppose challenging would be better, but I think more challenging in terms I said you know you've got the whole use, if you've got the whole use of Swinburne Uni there behind it, come up with some good programs that really are going to make a difference, really going to pack a punch

OK. so what, any of the students on that year 8 waste experience, did you notice any of them that were really engaged in particular?

I probably noticed one guy fluctuate big time.

Was that (Jim)?

Yep.

I remember.

He was just really keen on the first one, where they were discussing the future and the little township they developed and the rest of it, so he was going pretty well with that. And then the second activity he just bombed straight out and then the third activity he was heading back getting back into it again. But generally I think we had a bit of chat about it afterwards and the kids generally thought as the day went on their efforts were, got less and less.

So I guess, my second question were any students very disengaged, again there's (Jim).

Yeah he will act out as a condition, but there are other kids there that just withdraw just talk amongst themselves quietly, don't create distraction don't create any fuss, but they're not on task.

OK, all right, I was going to ask why do you think the activities appeal to the students who are particularly engaged, so why do you think (Jim) really engaged in one and not so much engaged in the other?

I suppose it depends on the students' likes, so what they like doing. What they're capable of doing, so different learning styles

So for all the students generally?

Yeah, we would try to fit our school, I suppose because you know the kids a bit better, to have the activity but have a variety of things within that activity so they'll be those for kids who like making, they'll be those for kids who like you know the computer work, there are those who like to do, so if you can maybe cater for a more variety

Of approaches?

of approaches to the one topic then that's probably a good thing

OK

Like if you look at that last one, I reckon on our worst day we'd probably come up with something like that we had you know, I said to Amanda say this morning, we've got a year 8 group what are we doing? We'll have a, we'll quickly go and organize that, that's our, that'd be a pretty bad day for us. And if that's where they, where KIOSC is aiming, I think I think they're missing the boat pretty big time

OK. So during and following the visit to KIOSC have you observed any change in student's perception of science?

Um. not really

OK. In their self-perceptions of their capability in science?

Nah.

OK, and last question, I apologize if this does seem a bit repetitive, so in their participation in science, so they're engagement in class or out of class?

Nah, not really

Nah?

You've gotta put it in context I suppose. You know, it's a long term, kids have battled on through a fair bit of stuff

But for the year eights in particular, the last few weeks since the experience, there hasn't been any observable temporary or more long lasting change?

Nah, nah, and we went back through and did the review with them there was a bookend activity we actually went through.

So after the KIOSC experience you do a review with each class?

Ah yeah for all the ones that went and even it helps the kids that didn't go they actually catch up on kinda what they missed out on

OK, what form does this review take?

Class discussion, they'll write down some reflections, like the learning, that sort of thing we'll do a whole like a think pair share sort of activity and they'll think about it, pair up have a bit of a talk about it and then we'll share stuff on the board.

OK, so you get good insight into their perceptions of KIOSC that way?

Yeah. You generally get some pretty straight shooting, some honest answers.

OK fair enough. Has visiting KIOSC changed your perceptions of science?

(pause)

look I think it disappoints me, not the, I'm into learning and I'm into (science) I'm into everything, doesn't matter if it's science or whatever it is, I think that it's a really important thing for the rest of your life, and that's what we try and get the message across to our students the only thing that I probably harped on this enough, it just disappoints me that we have a world class facility just sitting there and it just seems to me that the staff had been asked to teach stuff is below what even they would like to be teaching.

I'll give you a classic example in the book, so this was the waste section, we asked for this, just give this to us digitally (yeah) which they couldn't do, but there's all these hyperlinked things, so there's documents we have no access to those things, these are core.. core activities core groupings, that we have no access to

Because you don't have the URL, because it's behind a wall?

Those ones are really easy to get to because it's just a website whereas these ones were just hyperlinked to whatever document they were working within.

Yeah which you don't have

Which we don't have so even though we stressed that to them. Like group 4, who gets the trash it's a map, it's a hyperlinked map to their document it's not to anything that they've provided to us we just would try and come up with similar sorts of, we think that's what the... similar notions. And some of the links don't work whether they're old or,

Do you do much preparation before a visit?

We probably spend, we probably spent 3-4 sessions working through what KIOSC asked us to work through. So there's like a book, we'll keep doing the same thing, like I'll ring Lindsey up and see if we can actually get

The digital?

The digital stuff so we can actually link to whatever they're talking about because the whole way through there's hyperlinks there that obviously can't open and then there's one of the things that we actually did do, it tells us about what the KIOSC stuff is going to be like but there's also the follow up as well.

OK, so you do think if this was in a digital format it would be a good resource?

Well juries out because we don't know what the hyperlinks are.

Yeah fair enough. alright, I'll have to get a copy of that, a copy from KIOSC at some point. Alright last question, has visiting KIOSC changed your perceptions of your students?

(pause)

I suppose not really, those, those that learn anywhere, doesn't matter what environment you put them in they are still really keen to do their best and to learn I suppose that’s kids that I suppose, there is something we've been talking to the staff at KIOSC about where do you want us to step in, where do you want total control of the group? They just need to let us know like with (Jim) in that last, sorry second activity where it was a bit out of control, we need to have these conversations before we go in there as to what they expect from us. You know is there a code word that they want us to take a student for, where do we step in, we don't like to usurp their authority but at some stage, we don't like the students to impact on the programs.

So you mention that the students who learn anywhere are fine learning at KIOSC, the students' who aren't so eager to learn, are they able to learn at KIOSC?

Well, they probably are, they probably are but once again it just depends on the time of day, how windy it is, the weather, what they had for lunch there's a whole heap of factors that just throws some kids off straight away.

Well I think that's all for now, thank you very much, that was really informative.

Australian National University

Appendix F: Student Questionnaire

Reflection Survey

About you

This is private survey and only the researcher will read the results. Your teachers and your parents will not be able to see what you answer. There are no right or wrong answers, please pick what you truly feel. Thank you for doing this survey.

1. What is your name?

2. I am a (select one)

- boy
- girl
- other

3. When were you born?

Date: DD / MM / YYYY

4. If you identify with a particular ethnicity as well as Australian please write it here. (e.g. Chinese, French, Torres Strait Islander)

5. What language or languages do you speak at home with family?

6. How many books does your family have at home?

- None
- Very few
- One shelf filled with books
- One bookcase filled with books
- More than one bookcase filled with books

Australian National University

Reflection Survey

Your Family

7. Think about your family and their education. Mark all the answers that apply.

	Mother or stepmother or both	Father or stepfather or both	One or more brother(s) or sister(s) who are old enough to work	One or more other adults in my family (legal guardian, grandparent, aunt, uncle, etc.)	No one in my close family that I know of.
Did either of your parents/carers NOT complete high school (VCE or equivalent)?	☐	☐	☐	☐	☐
Has anyone in your family gone to TAFE or a similar institution?	☐	☐	☐	☐	☐
Has anyone in your family gone to university?	☐	☐	☐	☐	☐

8. Think about your parents/carers and their jobs. Mark **all** the phrases which apply to them (include other adults in family)

☐ Has a job that does not need any qualifications (e.g. cleaner, factory worker, waiter, Mc Donald's)

☐ Works with customers (e.g. answers phones, shop sales assistant, taxi driver)

☐ Looks after people (e.g. child care worker, hairdresser, carer, beautician, secretary)

☐ Does skilled work with their hands (e.g.builder, cook, plumber, mechanic, electrician, bus driver)

☐ Supervises or manages people

☐ Has a professional job (e.g. doctor, lawyer, teacher, accountant, banker)

☐ Is a scientist or does another job using science (e.g. lab technician, vet, nurse, doctor)

☐ I don't know

☐ No job

☐ Other

Other (please specify)

Australian National University

Reflection Survey

Your Family extra

9. Which of the following people in your family have a science related job? Select all that apply.

- ☐ Mother or stepmother or both
- ☐ Father or stepfather or both
- ☐ One or more brother(s) or sister(s) who are old enough to work
- ☐ One or more other adults in my family (legal guardian, grandparent, aunt, uncle, etc.)

Australian National University

Reflection Survey

Your Family continued

10. How much do you agree or disagree with the following statements about your family (or legal guardians)? Mark whether you agree or disagree with each statement.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
They expect me to do further education or training after high school, such as university or TAFE	○	○	○	○	○
They know how well I am doing in my classes	○	○	○	○	○
They think it is important for me to learn science	○	○	○	○	○
They think science is interesting	○	○	○	○	○
They would be happy if I decided to pursue a career in science	○	○	○	○	○
They always attend parents' evenings at school	○	○	○	○	○
They want me to make a lot of money when I grow up	○	○	○	○	○
My family talks to me about how science and mathematics will help me in my life	○	○	○	○	○

Australian National University

Reflection Survey

Your Teachers and Friends

11. Mark whether you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
My teacher makes learning science interesting and fun	○	○	○	○	○
My teacher thinks I could be a good scientist one day	○	○	○	○	○

12. How many of your friends both inside and outside of school... (Mark one in each row)

	None	A few	Some	Most
Like science?	○	○	○	○
Think science is cool?	○	○	○	○
Get good grades in science?	○	○	○	○
Would think less of you if you did science activities?	○	○	○	○
Care about their grades in school?	○	○	○	○
Encourage you to do well in school?	○	○	○	○
Would be described as smart or 'brainy'?	○	○	○	○

Australian National University

Reflection Survey

Science Activities

13. NOT including KIOSC, Have you ever...? (Mark all that applies)

- [ ] Attended a science camp or special science program?
- [ ] Participated in a science club or team?
- [ ] Received an award or special recognition for doing well in your science classes or other science related activities?
- [ ] Worked on a science project in a university or professional lab?
- [ ] Had a teacher who made it exciting to learn science?
- [ ] Had a teacher who made you dislike learning science?
- [ ] None of the above

14. How often do you the following things when you are NOT in school? (Please tick only one box in each row)

	At least once a week	At least once a month	At least once a term	At least once a year	Never
Go to a museum	○	○	○	○	○
Do science activities (e.g. science kits, nature walks, experiments)	○	○	○	○	○
Read a book or a magazine about science	○	○	○	○	○
Visit websites about science	○	○	○	○	○
Visit a science centre, science museum or zoo	○	○	○	○	○
Watch a TV program about science or nature	○	○	○	○	○
Talk with someone at home about what I've been learning in science class at school	○	○	○	○	○
Play games about science	○	○	○	○	○

Australian National University

Reflection Survey

My current thoughts about science (1)

15. Mark whether you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I would like to study science more in the future	○	○	○	○	○
I would like to have a job that uses science	○	○	○	○	○

16. When I compare myself to my classmates I think I am....

WORSE at science | About the same at science | BETTER at science

17. When I compare science to my other subjects I think....

I perform WORSE in science | I perform about the same in science | I perform BETTER in science

Australian National University

Reflection Survey

My current thoughts about science (2)

18. When I compare science to my other subjects I think....

Science is LESS difficult	Science is as difficult	Science is MORE difficult

19. When I compare science to my other subjects I think....

Science is LESS interesting	Science is as interesting	Science is MORE interesting

20. When I compare science to my other subjects I think....

Science is LESS useful	Science is as useful	Science is MORE useful

21. When I compare science to my other subjects I think....

Science is LESS hard work	Science is just as much hard work	Science is MORE hard work

Australian National University

Reflection Survey

How has visiting KIOSC affected your confidence in learning science?

The following questions ask you to think about how you felt after visiting KIOSC. Please mark whether after visiting KIOSC you are MORE or LESS likely to agree with the following statements or if there's been NO CHANGE in how you feel.

22. Since visiting KIOSC I feel that...

	I am now LESS likely to agree	No change	I am now MORE likely to agree
I can do well in science tests and assignments	○	○	○
Science is difficult for me	○	○	○
I am just not good at science	○	○	○
I will be able to master the skills and concepts in next year's science class	○	○	○
I could do a job that involves science	○	○	○
I get good marks in science	○	○	○

Reflection Survey

How has visiting KIOSC affected your interest in learning science?

23. Since visiting KIOSC I feel that...

	I am now LESS likely to agree	No change	I am now MORE likely to agree
Learning science is relevant to my life	◯	◯	◯
Learning science is boring	◯	◯	◯
I often take part in science class discussions and ask questions	◯	◯	◯
I prefer learning about science outside of school	◯	◯	◯
I learn interesting things in science lessons	◯	◯	◯
I look forward to my science lessons	◯	◯	◯

Australian National University

Reflection Survey

How has visiting KIOSC affected how valuable you think learning science is?

24. Since visiting KIOSC I feel that...

	I am now LESS likely to agree	No change	I am now MORE likely to agree
If I study science in the future I will have enough time for friends and hobbies	○	○	○
People will make fun of me if I work hard in science class	○	○	○
Studying science is useful for getting a good job in the future	○	○	○
Science is not that necessary to get into desirable courses at university or TAFE	○	○	○
It's important to me that I get a good grade in science class	○	○	○
Knowing science is useful in many different jobs	○	○	○

Australian National University

Reflection Survey

How has visiting KIOSC affected how you see yourself in science?

25. Since visiting KIOSC I feel that...

	I am now LESS likely to agree	No change	I am now MORE likely to agree
I think I could be a good scientist one day	○	○	○
People who do science are like me	○	○	○
I see myself as a science person	○	○	○
Others see me as a science person	○	○	○
I would like to study more science in the future	○	○	○
I would like to have a job that uses science	○	○	○

26. At the moment on a scale of 0 to 10, would you describe yourself as a science person?

0: No, not at all | 5: Neutral or it depends | 10: Yes, definitely

27. Please explain your answer to the previous question

Appendix G: Survey Variable Categorization Process

The process used to categorized student responses from several related items to a combined variable is illustrated here, using the Parental Science Support variable as an example. This variable was made up of students' scores to four individual items:

1. My family talks to me about how science and mathematics will help me in my life
2. They think it is important for me to learn science
3. They think science is interesting
4. They would be happy if I decided to pursue a career in science

The Parental Science Support scores ranged from 4 to 16, on a possible scale of 0 to 20. The frequency of students' scores were counted and mapped according to their proportion to check the distribution (Figure 9).

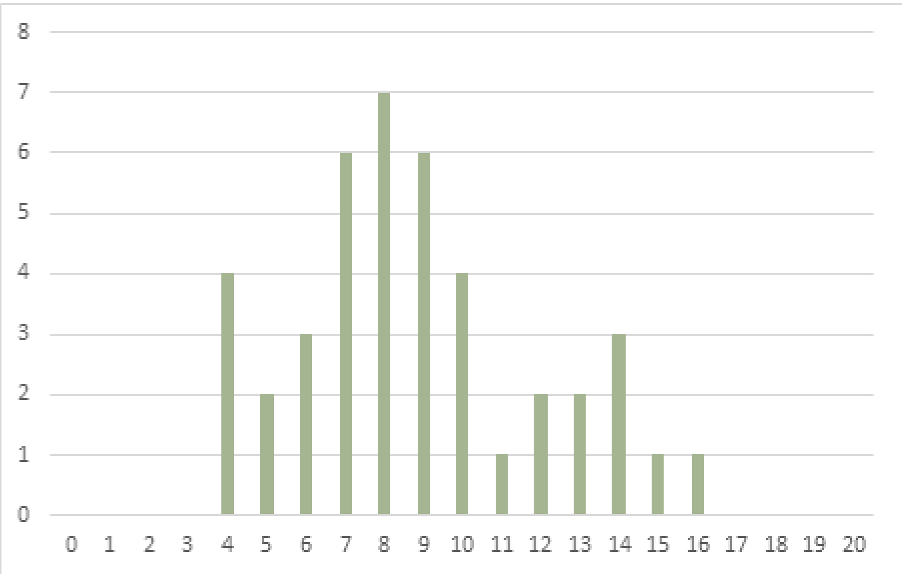

Figure 10. The distribution of student scores for the Parent Science Support variable.

The scores were then used to create a Histogram Chart (Figure 10).

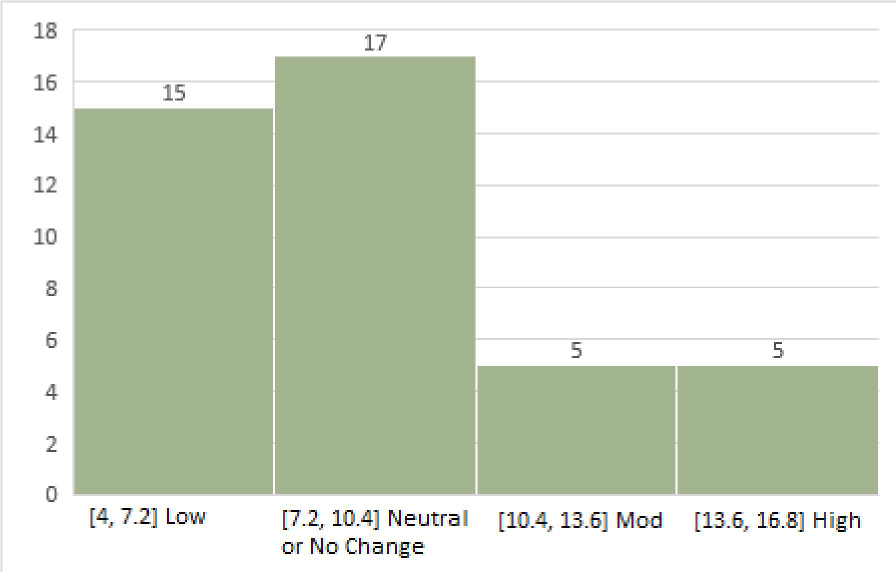

Figure 11. Histogram chart of student scores for the Parent Science Support variable showing the number of students in High, Mod (Moderate), Neutral (No Change) and Low levels.

The ranges for each bin was used to divide student scores into levels (Table 12). Due to variability in student scores across the survey items the combined variables of Friend Study support and Teacher support included a Very Low category which the other variables did not.

Table 122. Categorisation of student scores for Parent Science Support Variable based on Histogram ranges.

Level	Student Scores for Parent Science Support
Very Low	Not applicable
Low	0 - 7
Neutral	7 - 10
Moderate	11 - 13
High	14 - 20

Australian National University

Appendix H: Code List and Definitions

This is the full list of codes that was used to code the interview transcripts. There are 3 levels with the first level (0-5) mainly serving to categorize the codes rather than actually code the data. Quotes are included as examples for a code in each of these overarching categories. Many of these example quotes would be coded with multiple codes.

0. Key overlapping themes
    a. What students and teachers want from KIOSC visits
    b. Attendance negative or neutral
        i. KIOSC is for certain people
        ii. Teacher efforts to motivate

            Example of a teacher comment: *There's all these things that like if you could come up with the right tasks that they could access, but they tend to save it for the year nine's, tens or twelves. By that point as a teacher I'm struggling so far to get the kids to want to come back because they've been so bored by the first two years.*

            Example of a student comment*: We weren't very excited coming this year because last year was a bit boring.*
    c. Attendance, positive
        i. KIOSC is for everyone
    d. dissatisfaction with activities
        i. disappointed expectations
        ii. lack of interactivity
    e. not valued
    f. Satisfaction with activities
    g. Students' valuation of experience
1. Emotive
    a. Boring

        Example of a student comment: *I found it quite boring because there wasn't much fun to it, it was more like sit down class work kinda stuff.*
    b. Enjoyment
    c. Memorable

    d. unmemorable, ambivalent

2. Features

    a. active, interactive, competitive

       Example of a teacher comment: *He wasn't engaged in the second activity because he thought it was going to be something different. He also was referring back to, he thought it was going to be more like Scienceworks, and that was disappointing for him.*

    b. Possible at school or not
    c. agency, independence
    d. challenging
    e. explosions, danger
    f. External educators
    g. general technology
    h. hands on
    i. important for world
    j. natural world, environment understanding and awareness
    k. learning new things
    l. Lego, robots
    m. outside, physical setting
    n. relatable to everyday
    o. Swinburne resource, role
    p. variety of activities
    q. whole day activity

3. KIOSC seen as...

    a. different to learning at school

       Example of a student comment: *Before like the first time I went thought it was like a bit hard but then it got easier because I was more used to it[.] [Be]cause usually at school we usually don't do hands on things.*

    b. not different to learning science at school
    c. KIOSC as a place to do science
    d. not necessarily seen as science
    e. possible at school or not

    f. learning at KIOSC appealing
    g. learning at K not appealing

4. KIOSC roles
    a. as a social skills developer

       Example of a teacher comment: *It's really important for these kids [be]cause [for] a lot of them socializing, they [don't have] the greatest social skills, especially with people outside their friendship groups. So it's good to expose them to that and learning at the same time.*
    b. day off school
    c. inspire motivation
    d. KIOSC as a learning extender
    e. sustainability mindset
    f. Using KIOSC as a career guidance tool
        i. building awareness, desire and incidents
        ii. linkage to careers
5. Impact
    a. affects student competency

       Example of a student comment:

       Student 1: Just the thought that even someone with,

       Student 2: No experience even,

       Student 1: Yeah even someone with no experience can go and do something so difficult and work it out….. I used to think, I would never be able to do anything like that.

    b. effects on student career aspirations
    c. affects students' perceptions, inspire interest
    d. as it affects teachers
        i. Difference in teacher's opinions
        ii. Teacher perception changes of students
        iii. Teachers perception change of science
    e. learning outcomes, what students have got out of it
    f. Limitations of impact
        i. contradictory response, peer pressure

ii. experiences component of long term education

iii. limitations of observing any impact

iv. student participation, none or limited changes

v. student perception of science, none or limited changes

6. Collaboration

   a. connecting experience between school and KIOSC

      i. discussion amongst friends or family, informal connections

      ii. Lack of curriculum connection

   Example of a teacher comment: *I think when it's embedded more into the curriculum then it will be easier to sort of get those ideas from the students and whether it has worked or hasn't worked will be able to be seen straight away rather than later on.*

   b. flexibility of usage, scheduling

   c. negotiating stakeholder roles

      i. multiple schools

      ii. staff role, efforts aims

      iii. Teacher participation, role, at KIOSC

   d. organizational issues

7. Over Time

   a. Adaptation

   Example of a teacher comment: *Looks like it's becoming better, it looks like they're really focused on improving it specially[in] the last six months. There's now more constant emails between us, so that seems to have improved. And the thing with the government putting that money [in], there's free bus costs now... and they are trying new things.*

   b. Attitude over time

   c. comparison of visits

   d. refined organization over time

8. Participation- opportunities

   a. Being a science person at KIOSC

   Example of a student comment: *To me, seeing people at school, there's a lot of different people that you wouldn't expect to do* *science and seeing mostly everyone go to KIOSC and really enjoying it.*

i. Connecting identity performances across settings
ii. Flexible participation
iii. Perseverance of school cultural model
iv. Recognition, relationship with staff

b. participation challenges
   i. behaviour when compared to school, better or same
   ii. challenges, management
   iii. difficulty in participating, behaviour issues
   iv. moderated by teachers, collab effect
c. student participation
   i. engagement
   ii. prior knowledge
   iii. social opportunities
   iv. taking on another role in participating

9. Student Background nodes
   a. background issues
      i. area of poor career pursuit, low SE school
      ii. poor behaviour anywhere

      Example of a teacher comment: *Some of them are just disengaged about school anyways. So, anything you try and do with some of these kids [it] just isn't going to help.*
   b. Science jobs and people
      i. spring set
      ii. The ideal science student
   c. student affiliation with science
      i. Family
      ii. participation in science elsewhere
      iii. Student self-perceived capability in science
      iv. Students future intentions for science
   d. what learning science involves at school

Appendix I: Example of Code Modelling to Theme

Figure 12 on page 221 shows an example of code modelling. This model specifically explores teachers' responses in regards to Research Question 2; *How do stakeholder interpretations of a non-formal science education program vary over time?* Each blue circle represents a code. Note some of the wording may be slightly different to the coding list as the codes evolved over time.

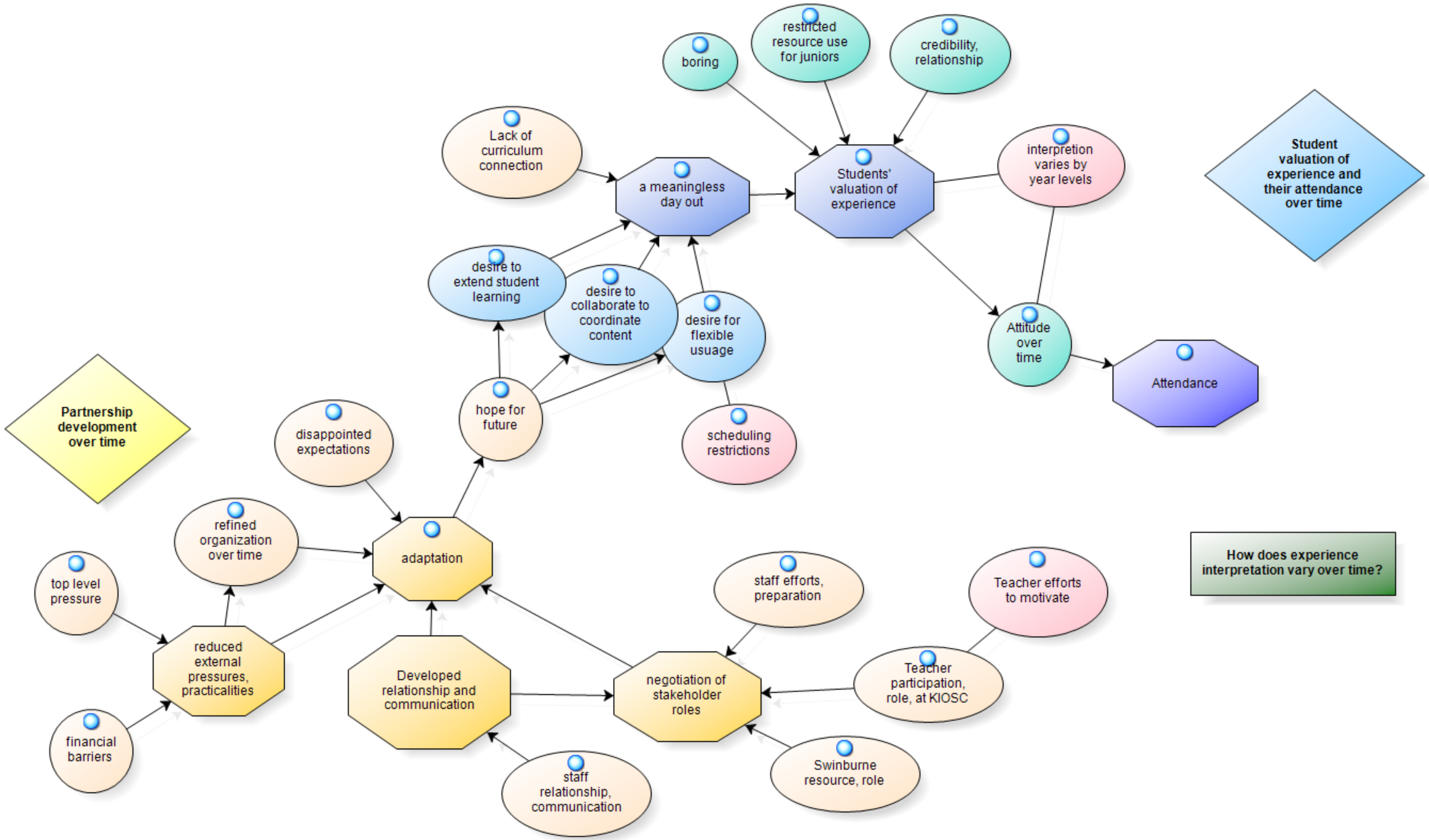

Figure 12. Example of Code Modelling; Teacher interpretations of a non-formal science education program over time (Research Question 2)

Australian National University

Appendix J: Coding Prevalence by Participant Type

The following tables list the 50 most common codes for each participant type in order of the extent to which it was used to code interview data (Tables 13 and 14). For example, in row 1 of Table 13 “Enjoyment” was used 118 times for student interviews. How often a code was used varied amongst participant type primarily due to the disparity in participant number. Hence students who outnumber all participant types have much higher coding numbers. These counts are used here to rank the prevalence of codes within each participant type and should not be taken as an indicator of coding important across participant types.

Another aspect to note is that the extent of codes for students in particular relate partially to the questions asked. For instance all students were asked about using science in jobs and if they knew people who did science in their job. Their answers were subsequently coded (Table 13: 51 in row 9) as “science jobs and people” but were generally negative or vague. Hence despite the high count this code was not very important for examining student interpretations.

Table 133. 50 most common codes in the interviews of Students (n=49) and KIOSC Staff (n=4)

Codes	Students (49)	Codes	KIOSC Staff (4)
Enjoyment	118	What students and teachers want from KIOSC visits	11
Satisfaction with activities	112	Different to learning at school	10
What students and teachers want from KIOSC visits	76	Affects students' perceptions, inspire interest	10
Dissatisfaction with activities	68	Sustainability mindset	9
Different to learning at school	66	General technology	8
Lego, robots	64	Building awareness, desire and incidents	8
Hands on	52	Engagement	8
Science jobs and people	51	Possible at school or not	7
Memorable	50	Not necessarily seen as science	6
Student self-perceived capability in science	47	Staff role, efforts aims	6
Learning at KIOSC appealing	45	Challenges, management	6
Boring	41	Student participation	6

Australian National University

Active, interactive, competitive	40	Dissatisfaction with activities	5
Attendance, positive	38	Using KIOSC as a career guidance tool	5
Students future intentions for science	38	Adaptation	5
Learning new things	35	Flexible participation	5
General technology	33	Variety of activities	4
Outside, physical setting	33	Affects student competency	4
Student affiliation with science	33	Student perception of science, none or limited changes	4
Family	31	Connecting experience between school and KIOSC	4
Affects students' perceptions, inspire interest	30	Satisfaction with activities	3
Comparison of visits	29	Enjoyment	3
Variety of activities	28	Multiple schools	3
What learning science involves at school	22	The ideal science student	3
Students' valuation of experience	20	Outside, physical setting	2
Attitude over time	18	Swinburne resource, role	2
The ideal science student	18	KIOSC as a place to do science	2
Learning outcomes, what students have got out of it	17	Inspire motivation	2
Mixed response	15	Effects on student career aspirations	2
Taking on another role in participating	15	Experiences component of long term education	2
Attendance negative or neutral	14	Negotiating stakeholder roles	2
Important for world	14	Organizational issues	2
Organizational issues	14	Attitude over time	2
Social opportunities	14	94 : behaviour when compared to school, better or same	2
Participation in science elsewhere	14	105 : area of poor career pursuit, low ses school	2
Explosions, danger	13	Memorable	1
Connecting experience between school and KIOSC	13	Active, interactive, competitive	1
Challenging	12	Agency, independence	1

Building awareness, desire and incidents	12	Challenging	1
Discussion amongst friends or family, informal connections	12	External educators	1
Unmemorable, ambivalent	11	Hands on	1
Not different to learning science at school	11	Natural world, environment understanding and awareness	1
Student participation, none or limited changes	11	Whole day activity	1
KIOSC is for certain people	10	Not different to learning science at school	1
lack of interactivity	10	At KIOSC what learning science involves	1
KIOSC as a place to do science	10	KIOSC as a learning extender	1
Natural world, environment understanding and awareness	9	Linkage to careers	1
Being a science person at KIOSC	9	Limitations of impact	1
Student participation	9	Recognition, relationship with staff	1
KIOSC is for everyone	8	Difficulty in participating, behaviour issues	1

Table 14. 50 most common codes in the interviews of Science Teachers (n=6) and Non-Science Teachers (n=3)

Codes	Science Specialist Teacher (6)	Codes	Non-Science Teacher (3)
Dissatisfaction with activities	53	Engagement	16
Lack of curriculum connection	40	Enjoyment	10
Engagement	36	Limitations of observing any impact	10
What students and teachers want from KIOSC visits	30	Satisfaction with activities	8
General technology	30	Hands on	8
Possible at school or not	29	Different to learning at school	6
Attitude over time	24	Affects student competency	6
Flexibility of usage, scheduling	23	Dissatisfaction with activities	5
Satisfaction with activities	22	Learning new things	5
Different to learning at school	20	Possible at school or not	5

Connecting experience between school and KIOSC	20	Active, interactive, competitive	5
Learning new things	19	General technology	5
Attendance negative or neutral	16	Teachers perception change of science	5
Enjoyment	16	Attitude over time	5
Hands on	16	Behaviour when compared to school, better or same	5
Staff role, efforts aims	14	Teacher perception changes of students	4
Organizational issues	14	Poor behaviour anywhere	4
Variety of activities	13	The ideal science student	4
Behaviour when compared to school, better or same	13	Variety of activities	3
Whole day activity	12	Connecting experience between school and KIOSC	3
Adaptation	11	Discussion amongst friends or family, informal connections	3
Teacher efforts to motivate	10	Challenges, management	3
Not valued	10	Science jobs and people	3
Outside, physical setting	10	What students and teachers want from KIOSC visits	2
Student perception of science, none or limited changes	10	Disappointed expectations	2
Difficulty in participating, behaviour issues	10	Students' valuation of experience	2
Day off school	9	Boring	2
Affects student competency	9	Whole day activity	2
Limitations of observing any impact	9	Using KIOSC as a career guidance tool	2
Disappointed expectations	8	Building awareness, desire and incidents	2
Boring	8	Affects students' perceptions, inspire interest	2
Inspire motivation	8	Student participation, none or limited changes	2
Building awareness, desire and incidents	8	Student perception of science, none or limited changes	2
Learning outcomes, what students have got out of it	8	Moderated by teachers, collab effect	2

Refined organization over time	8	Social opportunities	2
Poor behaviour anywhere	8	Attendance, positive	1
Relatable to everyday	7	External educators	1
Teacher perception changes of students	7	Outside, physical setting	1
Teachers perception change of science	7	Inspire motivation	1
Limitations of impact	7	KIOSC as a learning extender	1
Area of poor career pursuit, low ses school	7	Difference in teacher's opinions	1
The ideal science student	7	Lack of curriculum connection	1
Active, interactive, competitive	6	Multiple schools	1
Experiences component of long term education	6	Organizational issues	1
KIOSC is for certain people	5	Adaptation	1
External educators	5	Taking on another role in participating	1
Lego, robots	5		
Using KIOSC as a career guidance tool	5		
Affects students' perceptions, inspire interest	5		
Difference in teacher's opinions	5		