Institute for Positive Psychology & Education

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Great Teaching and Inspired Learning in Science:

A Randomised Controlled Trial of the Impact of the *MyScience* Program

Final Research Report 2016

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- The professional contribution of Mr Marcus Horwood in his role as Research Project Officer including contributing to the development of this report.

Contents

Executive Summary

"Getting the students involved through this inquiry approach has seemed to really improve engagement. I haven't come across any students who disliked the program and all passed or exceeded in regards to assessment."

Year 6 Primary School Teacher

Background

In science education, Australia is faced with two major issues: (1) the low scores of Australian students compared to other developed countries, and (2) the decline in students choosing science leading to national shortages of science-related professionals. The first issue concerns cognitive academic processes in science education whereas the second issue is related to students' motivation in science and self-processes leading to students' positive interest, engagement, and attitudes towards science.

Purpose

MyScience is an educational program that involves volunteer mentors with science expertise who work closely with primary students on authentic scientific investigations. Teachers participate in professional learning, followed by working with science students from neighbouring secondary schools as mentors to facilitate learning activities with primary students. Teachers then work with their students in student-selected scientific investigations in the primary classroom.

The purpose of this research study was to test the impact of the 10 week *MyScience* program on: primary students' knowledge, skills, and attitudes in relation to science; primary teachers' confidence and capacity to teach science; and mentors' attitudes towards science.

Research Design and Methods

Employing a rigorous experimental design and advanced statistical analyses, this project involved an experimental group (*n*=336) and control group (*n*=285) of primary children in Years 5 and 6 and their teachers. Students were drawn from 12 schools (6 Catholic and 6 public: 4 from urban settings and 8 from rural settings) in NSW, Australia. Secondary students (*N*=121) sourced from local secondary schools, and supported by their science teachers, worked as mentors of the primary students in primary school classrooms. The experimental group implemented the *MyScience* program for a period of 10 weeks. The control group did not participate in the *MyScience* intervention until the experimental study was completed.

Participating schools were randomly allocated to the experimental or control group. Participants completed online surveys at three time points (pre, post, and 6 months after the conclusion of the *MyScience* program). A subsample of teachers and mentors participated in semi-structured interviews.

Findings

Primary Students

Results indicated that the *MyScience* intervention had a statistically significant, moderate effect on students' learning in relation to choosing their own investigations ('topic choice', Cohen's *d*=.31) and analysing the data they have collected ('analysing', *d*=.33). Additionally, statistically significant, small effects were found with: student management of investigations ('planning', *d*=.29), communication of findings, ('communicating', *d*=.28), accepting different outcomes ('different solutions', *d*=.26), the desire for student-focused learning ('ownership', *d*=.25), choosing appropriate materials for an investigation ('material choice', *d*=.23), progressing in steps to conduct an experiment ('conducting', *d*=.23), using appropriate equipment and measurement for an investigation ('measuring and devices', *d*=.22), and working effectively as a team on an investigation ('collaboration', *d*=.18).

Primary Teachers

The patterns of change for the teachers (*N*=26) indicated that the experimental group of primary teachers showed increased: sense of ownership in relation to planning science activities; understanding of planning, measurement, and analysis of science learning; science teaching self-concept, and value of the importance of science.

Secondary Students

Three positive aspects of involvement as a mentor were echoed by more than 50% of the interviewed Year 9/10 students:

(1) They experienced significant enjoyment through helping others,
(2) They gained awareness of the processes of science and the different ways that scientific problems can be solved, and
(3) Through the process of teaching others about science their own science learning was improved.

Negative aspects of mentors' involvement related to difficulties with managing groups of primary students and when there was a lack of organisation and resources. Two factors for promoting students' interest and motivation to learn high school science were identified by interviewed students: 65% (17/26) cited hands-on practical activities, and 23% (6/26) specified enjoyment due to interactions with their teacher/s.

Secondary Teachers

Science teachers emphasised that student-based inquiry and real world applications of science promoted secondary students' interest and motivation. One teacher, for example, realised there was a need to focus more on the scientific method in Years 8 and 9. Other teachers realised the benefits of allowing students to have independence and choice in their learning. The secondary science teachers perceived that both primary and secondary students benefitted from participation.

On the other hand, one secondary science teacher expressed frustration around there only being one teacher at the primary school, the lack of this primary teacher's guidance and support during school visits, the lack of student progress between visits, the lack of resources, and the general lack of organisation at the primary school. These are all important and valid comments that will inform future implementation of the intervention.

Implications

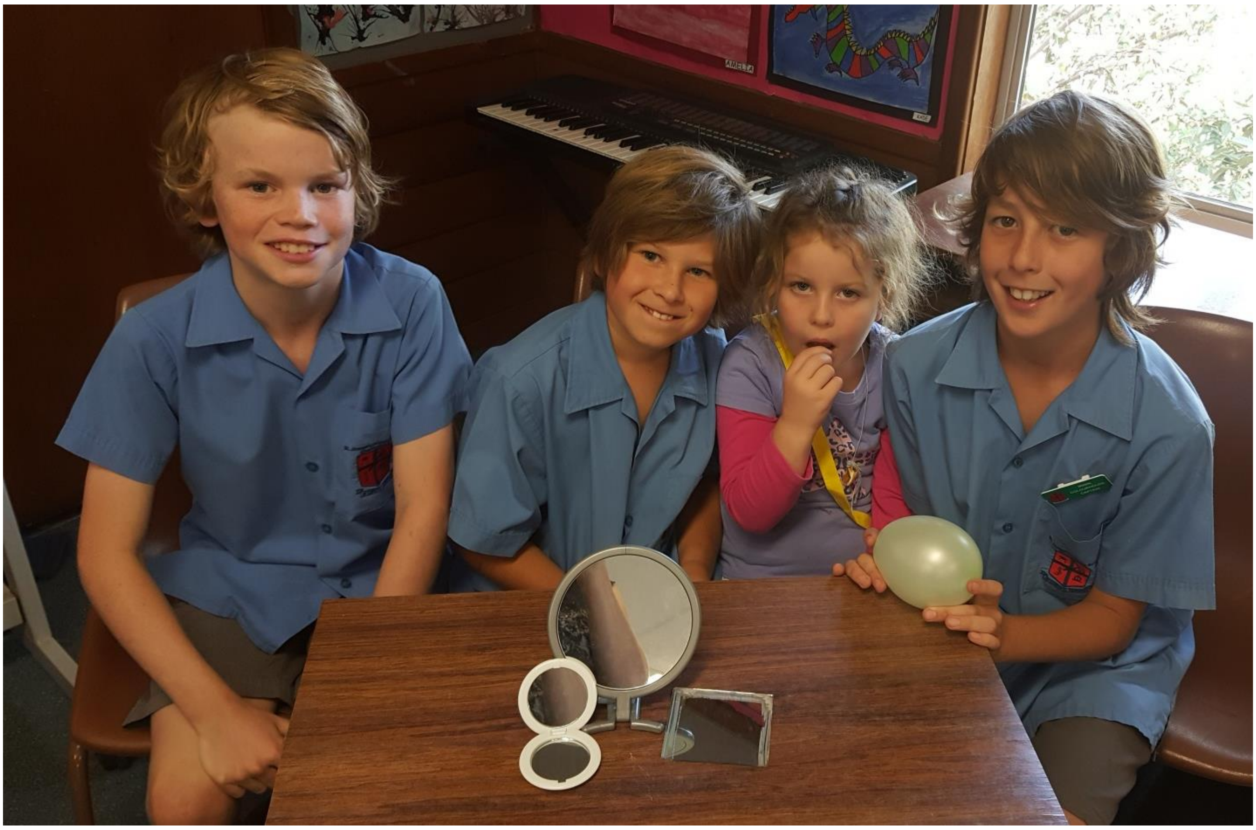
The patterns of change for the small sample of participating primary teachers appear to favour the experimental group in their sense of ownership (a 'Nature of Science' factor), planning, measurement, and analysis ('Science Inquiry Skills' factors), and self-concept and value perceptions (personal factors). A larger sample size is required to investigate these promising patterns so that more robust statistical analyses may be applied.

For primary students, the results suggest that the *MyScience* intervention in its current form is more beneficial for Science Inquiry Skills outcomes than self-concept, behavioural and motivational outcomes. Since self-concept has been demonstrated by international research to be a primary driver of student achievement and other desirable outcomes (Marsh & Craven, 2006), the results imply that the *MyScience* intervention could benefit from an increased focus on targeting teachers' science teaching self-concept, behavioural and motivational outcomes with the expectation of these cascading into enhanced student self-concept outcomes..

Findings based on interviews with secondary science teachers indicate that *MyScience* participation initiated reflection on their own teaching practices particularly around the need to provide students with more scientific method and topic choice experiences. Interviewed teachers also reported that secondary student mentors learned more about science, demonstrated enhanced self-esteem and that there was a positive impact on primary children's learning and enjoyment of science. Independently, secondary science students reported that serving as a mentor was enjoyable and that the experience had a positive impact on their own learning and motivation to engage in science activities. This finding warrants further research.

In summary, *MyScience* was demonstrated to have a positive impact on: students' learning and teachers' professional development. This suggests that it would be useful to conduct a larger-scale investigation to further elucidate the impact of *MyScience* and identify its essential elements of success to capitalise on its strength for further development.

Chapter 1:
Background



Primary Science Education

Historically, it is only in the past 40 years that primary science education has become part of the mandatory primary curriculum in many countries, including Australia (Aubusson, 2011; Connor, 2007). This move has been underpinned, in part, by research findings indicating that young children develop scientific ideas (with or without explicit science teaching) and attitudes towards science well before they reach their secondary years of schooling (Harlen, 2008, 2011; Logan & Skamp, 2008).

In Australia, despite mandatory government requirements to deliver primary science education, the subject area has been found to be frequently marginalised or not taught at all (Australian Science Teachers Association (ASTA), 2014; Goodrum, Hackling, & Rennie, 2001; Tytler, 2007). Compounding factors influencing effective implementation of primary science education have been researched and described by many researchers (Fitzgerald & Schneider, 2013; Harlen, 2011; Morgan, 2012; Skamp & Preston, 2015). They include: primary teachers' lack of science skills, knowledge and understanding; the lauded position of literacy and numeracy in the overcrowded primary curriculum underpinned by high-stakes testing regimens in Australia such as the 'National Assessment Program – Literacy and Numeracy' (NAPLAN, 2016); the lack of science resources for hands-on experiences; and a lack of understanding and support for the implementation of the science curriculum. Furthermore, even when primary science education is being delivered in Australian schools, there is a mismatch between the "ideal or intended curriculum and the actual or implemented curriculum" (Goodrum et al., 2001, p. xiv).

In many countries, school science education is becoming more focused on learning about the nature of science (NOS) - what science is about, how it is done, how evidence is gathered and how claims are made based on the data collected. Falling under this 'umbrella' are a collection of programs, approaches and terms such as: 'authentic science' (Cripps Clark, Tytler, & Symington, 2014), 'ambitious instruction' (Stroupe, 2014), 'inquiry learning' (Carlone, Haun-Frank, & Kimmel, 2010; Harlen, 2008; Harris & Rooks, 2010; Skamp & Preston, 2015), and developing 'big ideas of and about science' (Harlen, 2015), all of which aim to provide students with access to immersive experiences in the NOS. How the NOS may be best nurtured in school science education is yet to be explored.

An emerging practice in school science education is to tap into the science expertise of external stakeholders to support the development of students' and teachers' understanding of the NOS. Such support based on school-community linked initiatives involving mentors with science expertise has been researched in several countries including the United States (Wilson, Krakowsky, & Herget, 2010), New Zealand (Bolstad & Bull, 2013), and Australia (Forbes & McCloughan, 2010; Howitt, Rennie, Heard, & Yuncken, 2009; Rennie, 2012). These programs are effective when participants know that they need to work together, on mutually agreed activities, with a clearly defined outcome or purpose, where everyone's needs are being met – the hallmarks of a community of practice (Wenger-Trayner, 2013).

An effective science teaching approach therefore needs to provide learning opportunities about the nature of science in ways that are engaging, motivating, and interesting. Using a dual approach that facilitates both cognitive and affective aspects of teaching and learning science is arguably best practice for achieving participants' optimal best in this specific domain (Phan, Ngu, & Yeung, in press).

The *MyScience* Program

Serving as a future model for primary school science education, *MyScience* (see www.myscience.com.au) aims to address these issues through:

(1) The provision of sustained teacher professional learning situated in the classroom to facilitate "great teaching and inspired learning" (New South Wales Government, 2013), and

(2) Where possible using scientists and engineers, and local high school science teachers and students as mentors to make optimal use of community resources.

MyScience is a capacity-building initiative across the educational continuum based on validated research findings about the most effective ways to change teachers' pedagogical practices. These findings showed that teachers' willingness to adopt new practices are influenced by a number of factors such as: the location and duration of professional development associated with the reform (Glazer & Hannafin, 2006; Lederman & Lederman, 2012), teachers' personal experiences of changes in their students' engagement and learning in science before they examine and change their own beliefs and practices (Guskey, 1986; Levitt, 2001), and teacher beliefs about science, science learning, and science teaching (Levitt, 2001; Marbach-Ad & McGinnis, 2008; Smith & Southerland, 2007).

The *MyScience* educational model consists of five interrelated elements, which are described in detail by Forbes and McCloughan (2010). The program typically runs over a 10-week period, beginning with a day of face-to-face teacher professional learning. This is quickly followed by a class brainstorm where students identify areas of interest related to a class theme (e.g., natural disasters). An example of a student-selected investigation related to natural disasters is: 'What is the best shape for a levee to disperse water from a tsunami?' During this time, the class teacher works with their students doing 'fair test' investigations related to the class theme to build students' knowledge and understanding of NOS and science inquiry skills (SIS). Mark Hackling's (2005) 'CMS' acronym ('Cows Moo Softly') (p. 18) is used to scaffold learning of the need to control variables in scientific fair tests where each letter represents different scientific processes (i.e., Change one thing, Measure something, and keep everything else the Same).

During the following six weeks, teachers facilitate students who work in groups of twos and threes, with a mentor (approximately six students per mentor) on three separate occasions of 90 minutes where they: (1) identify a testable question and plan how to answer it, (2) conduct the investigation with mentor support, and (3) analyse collected data to look for patterns. They also work together to prepare for a presentation of their work at a final 'Science Fair' where all participants share their learning. It is through interactions with science experts while doing such activities that: (1) classroom communities of science practice develop, (2) teachers experience ongoing professional development, and (3) both students and teachers are immersed in the practices of how to do science and learn more about the NOS. NOS tenets that 'fit' with primary school settings such as those derived by Forbes and Skamp (2013) include that science is: inquiry based, tentative, developmental, subjective, creative, and collaborative. The *MyScience* program enables great teaching and inspired learning by providing a framework for participants to work together and develop sustainable communities of science practice, while building the capacity of participants.

Barriers to effective implementation do exist. They include geographical isolation, lack of resources, disadvantaged populations (especially Indigenous Australians in rural areas) who perform poorly in academic areas including science, students' low academic self-concepts, and low academic expectations by teachers and parents. Currently, there is a lack of appropriately validated instruments to measure participants' understanding of the NOS, and a lack of understanding of the critical factors that may facilitate success in learning science. There is also a lack of understanding of the nature of observed positive intervention effects, whether such effects are sustainable, and the influence of such an intervention on high school pedagogy and student learning. Improving our understanding of the factors that influence the development of science knowledge and understanding and how these factors contribute to participants' views of and attitudes towards science will enable the optimisation of interventions to enhance great teaching and inspired learning in science.

Critical Factors for Success in Science Education

The major purpose of the present investigation was to test the effects of *MyScience* on some of the most salient factors that are crucial for success in school science education for primary students. These critical factors include: student learning and attitudes about science, and teachers' knowledge and understandings of the nature of science and how to teach it.

Nature of Science (NOS)

Two related characteristics of a community of practice (CoP) with a focus on science learning have been identified by Kelly (2008) and Lederman (1992). First, *the discursive practices of science* are the ways that members engage and participate in the knowledge, conventions, and practices of the science community (Kelly, 2008). Second, a justified *outcome of a learning trajectory* for school participants would be "the development of an 'adequate understanding of the nature of science' or an understanding of 'science as a way of knowing'" – the objective for science learning which had consensus and "strong agreement" in Lederman's review (1992, p. 331). These are important findings, as they link the notion of the development of the NOS with participation in the discursive practices of science. It also signals the importance of teachers and other people working with students having an understanding of the NOS so that students are exposed to authentic discursive practices of science.

Science Inquiry Skills (SIS)

Lederman and Lederman (2012) distinguish Scientific Inquiry from NOS emphasising that it "includes the traditional science processes, but also refers to the combining of these processes with scientific knowledge, scientific reasoning and critical thinking to develop scientific knowledge" (p. 338). Accordingly in our study, SIS are separately measured (from NOS) because they are an essential element in the intervention (where mentors facilitate primary students' hands-on inquiries to find solutions to scientific problems). During the process of *MyScience*, students learn to plan their inquiry, choose ways to measure the essential elements of interest in the inquiry, and analyse the observations and measurements obtained from the inquiry. Hence, planning, measuring, and analysing are three essential components of SIS in this study.

Teachers' Perceptions About Science and Science Teaching

Teachers' perceptions about science, science learning, and science teaching directly influence their classroom decisions and actions when teaching science (Levitt, 2001; Marbach-Ad & McGinnis, 2008; Smith & Southerland, 2007). Teachers' classroom practices have been found to induce a 'cascade effect' (Guskey, 1986). This means that when teachers modify what they do in their classrooms, it results in different student learning outcomes, which then also influence teachers' beliefs and attitudes. Motivating teachers to use effective classroom practices is, therefore, key to this sequence of events. Guskey (2002) further developed his thinking around teacher professional development and teacher change stating that:

> significant change in teachers' attitudes and beliefs occurs primarily *after* they gain evidence of improvements in student learning … the experience of successful implementation … changes teachers' attitudes and beliefs. They believe it works *because they have seen it work*, and that experience shapes their attitudes and beliefs (p. 383, emphasis added).

Guskey's (2002) proposed model of teacher change was

> predicated on the idea that change is primarily an experientially based learning process for teachers. Practices that are found to work - that is, those that teachers find useful in helping students attain desired learning outcomes are retained and repeated. Those that do not work or yield no tangible evidence of success are generally abandoned. Demonstrable results in terms of student learning outcomes are the key to the endurance of any change in instructional practice. Attitudes and beliefs about teaching in general are also largely derived from classroom experience (p. 384).

In Guskey's (2002) study, teachers changed their attitudes and beliefs following their direct experience and evidence of students' changed learning outcomes.

Students' Perceptions About Science and Science Learning

For **students**, the learner's self is the most important agent of learning because nothing will happen unless the learner is ready and willing to learn. Among other drivers of learning (e.g., mastery motivation), academic self-concept is one of the most powerful in predicting learning success and achievement (Craven & Yeung, 2015; Yeung, Craven, & Kaur, 2014). Self-concept "makes good things happen" (Marsh & Craven, 2006, p. 134). In science education, learners' self-belief in science is a strong predictor of science learning (Yeung, Kadir, Kuppan, & Foong, 2010). Apart from self-concept, based on expectancy-value theory (Wigfield & Eccles, 1992), students' perceived value of learning in a specific domain is also predictive of learning success. Based on this conceptualisation, in the present investigation we examined students' science self-concept and perceived value of science learning.

Scientific inquiry involves variations in findings, and scientists are often faced with difficulties, uncertainties, and even failure. Therefore learners' resilience when undertaking scientific investigations is a consideration in the development of science knowledge and skills, and is therefore a factor in our present investigation. In essence, science self-concept, enjoyment, and resilience constitute cognitive, affective, and behavioural aspects of the science learner, providing a comprehensive set of indicators for determining science learners' attributes.

Chapter 2:
Research Design and Methodology

Purpose and Objectives

The purpose of this research study was to test the impact of the 10 week *MyScience* program on: primary students' knowledge, skills, and attitudes in relation to science; primary teachers' confidence and capacity to teach science; and mentors' attitudes towards science.

Intervention

The intervention program is a 10 week program designed for primary school settings. It involves science experts in the community such as professionals with science or engineering backgrounds, pre-service secondary science teachers, in-service science teachers, or science students from local secondary schools, who serve as mentors working together with primary class teachers to implement the intervention. Faced with the issue of how to attract and inspire students' learning in the Science KLA, we need to address the critical factors that influence student outcomes. One critical factor is teacher quality where school-based, ongoing professional learning (PL) is key to helping teachers become inspiring and facilitating agents of learning in science and technology. Teacher PL needs to focus on building cognitive (i.e., competence) and affective capacities (i.e., confidence) in effective science pedagogical practices in the foundational years leading to inspired learning not only in the primary years, but also in secondary and tertiary levels of education.

Utilising high school science students as mentors, the research reported here examined the effects of the *MyScience* program on primary teachers' and students' development in their understandings of the nature of science (NOS) and of their science inquiry skills (SIS). These two dimensions were observed at three time points, together with learner attributes (e.g., science self-concept, the value of science).

Methodology

Employing a rigorous experimental design and advanced statistical analyses, this project involved an experimental group (n=336) and control group (n=285) of primary children in Years 5 and 6 and their teachers. Students were drawn from 12 schools (6 Catholic and 6 public: 4 from urban settings and 8 from rural settings) in NSW, Australia (see Table 2.1). Secondary students (N=121) sourced from local secondary schools worked as mentors of the primary students in primary school classrooms. The experimental group implemented the MyScience program for a period of 10 weeks. The control group participated in the *MyScience* intervention after the conclusion of data collection.

Participating schools were randomly allocated to the experimental or control group. Participants completed online surveys at three time points (pre, post, and 6 months after the conclusion of the *MyScience* program). A subsample of teachers and mentors participated in semi-structured interviews.

Table 2.1: Participant breakdown between CEC and DoE Schools

Treatment	CEC primary schools		DoE primary schools	
Location	Urban	Rural	Urba n	Rural
Control	1 school 2 teachers 35 students	2 schools 5 teachers 119 students	1 school 2 teachers 45 students	2 schools 4 teachers 86 students
Experimental	1 school 2 teachers 49 students 22 mentors	2 schools 5 teachers 117 students 46 mentors	1 school 2 teachers 54 students 16 mentors	2 schools 4 teachers 116 students 37 mentors
Total	6 schools 14 teachers 320 students 68 mentors		6 schools 12 teachers 301 students 53 mentors	

Quantitative Data

Data were collected through an online survey, which was designed to capture participants' self-perceptions of science learning/teaching, their motivation in learning/teaching science, and their understanding of science and science investigations. The survey focused on three dimensions: an understanding of the nature of science, the science inquiry process, and self-concept around science learning/teaching associated with motivation and engagement in science (also see Appendix 2).

Dimension 1: Nature of science (NOS). Included are variables reflecting that science is tentative, that solutions can be different under various circumstances, and that science knowledge and inquiry are owned and generated by the inquirer. The variables are named as: (a) Different solutions (i.e., accepting different outcomes of inquiry), (b) Ownership (i.e., the desire for student-led learning).

Dimension 2: Science inquiry skills (SIS). Included are variables reflecting that science inquiry involves planning, conducting the investigation, making choices, taking measurements, analysing collected data, and communicating scientific findings. The variables are named as: (a) Planning, (b) Conducting, (c) Material Choice, (d) Measuring and Devices, (e) Analysing, (f) Communicating.

Dimension 3: The learner. Measures included the learners' self-concept including the cognitive aspects of self-perceptions of science teaching and learning. The variables are named as: (a) Science Cognitive (i.e., a sense of competence in science), (b) Science Affect (i.e., positive attitudes to science). Also included are motivational variables: (a) Science Value (i.e., the perceived value of science), (b) Science Engagement (i.e., an active engagement in scientific activities).

Latent Curve Modelling (LCM) was one of the statistical approaches used for the analysis of change due to the intervention. This technique—commonly referred to as latent growth modelling, latent growth curve analysis, latent trajectory modelling, or growth curve modelling—allows for the direct estimation of average patterns of intra-individual growth observable in the total sample, as well as inter-individual variation around these average trends. Latent Curve Models were used to assess the effect of the *MyScience* intervention on the participating primary students.

Qualitative Data

Interviews (see Appendix 1) were utilised to explore and gather experiential narrative material for the researchers to develop a deeper and richer understanding of what it means to be ‘doing MyScience’ (Van Manen, 1997, p. 66). Consistent with Van Manen’s recommendations, participants were encouraged to “think of specific instance(s), situations(s), (people) or event(s) to explore the(ir) whole experience to the fullest” (Van Manen, 1997, p. 67). Individual face-to-face semi-structured interviews were conducted with the participating secondary school teachers, and 3-5 secondary student mentors from each participating school. Participants’ responses were taped and then transcribed for subsequent analysis. Each transcript was checked against its audio recording for accuracy. The transcribed data were manually coded using content categories utilising an emic approach (e.g., a contextualised approach to reveal the theories and perspectives of the participants; Harris,1997; also see Tatli, & Özbilgin, 2012), and the key dimensions identified in this component of the study’s conceptual framework. This analysis formed the basis for the collaborative discussion and refinement of initial coding categories. The string and patterns identified across the transcripts identified additional possible patterns across the transcribed in-depth interview narratives.

Chapter 3:

Research Findings

Impact of MyScience: Primary Students

Results indicated that the *MyScience* intervention has significant moderate effects on topic choice (Cohen's d=.31) and analysing (d=.33) and smaller effects on the following outcomes: planning (d=.29), communicating (d=.28), different solutions (d=.26), ownership (d=.25), material choice (d=.23), conducting (d=.23), measuring and devices (d=.22), and collaboration (d=.18) (see Figures 3.1 and 3.2). No positive intervention effect was found for the other variables (see Figure 3.3).

Figure 3.1: *MyScience* Intervention – Statistically Significant and Moderate Positive Effects on Student Outcomes

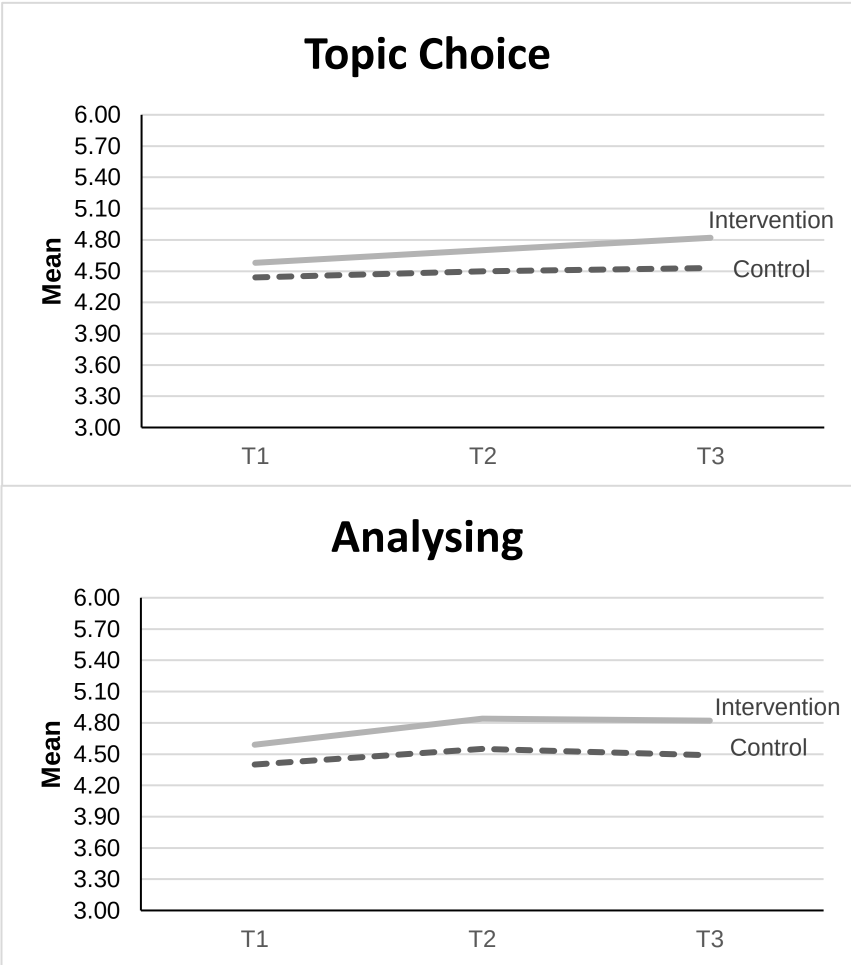
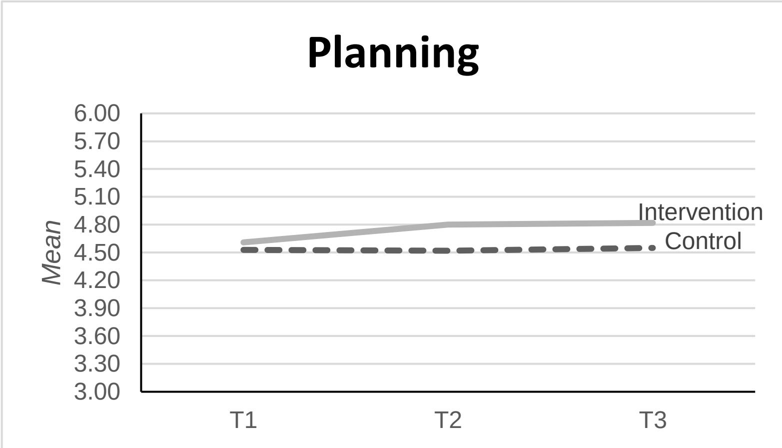


Figure 3.2: *MyScience* Intervention – Statistically Significant and Small Positive Effects on Student Outcomes


Planning
Mean
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5.70
5.40
5.10
4.80
4.50
4.20
3.90
3.60
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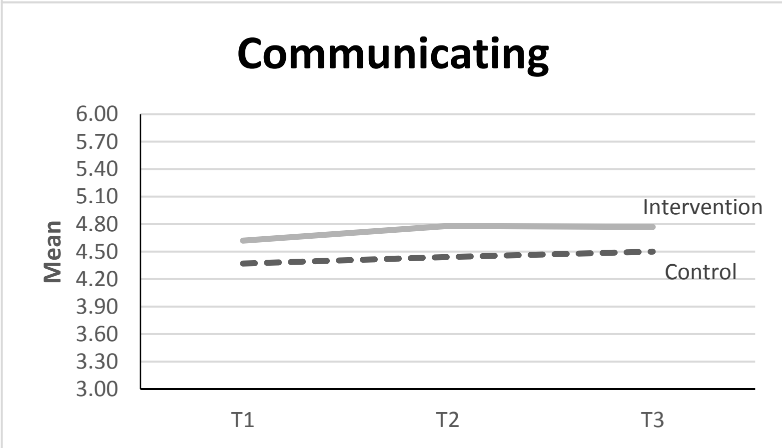
3.00
Intervention
Control
T1
T2
T3


Communicating
Mean
6.00
5.70
5.40
5.10
4.80
4.50
4.20
3.90
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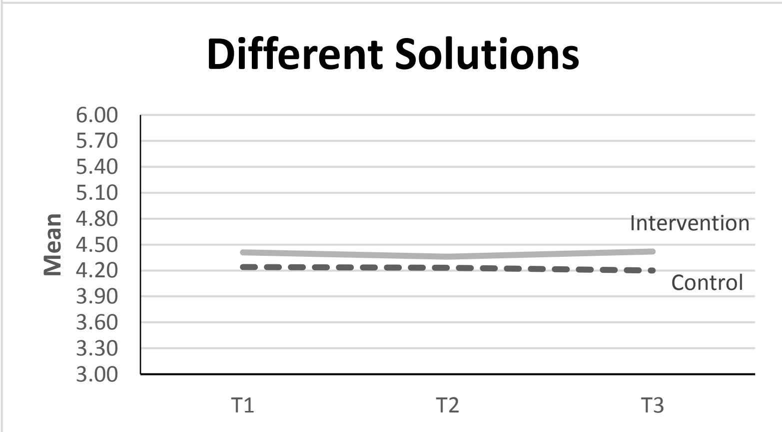
3.30
3.00
Intervention
Control
T1
T2
T3


Different Solutions
Mean
6.00
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5.40
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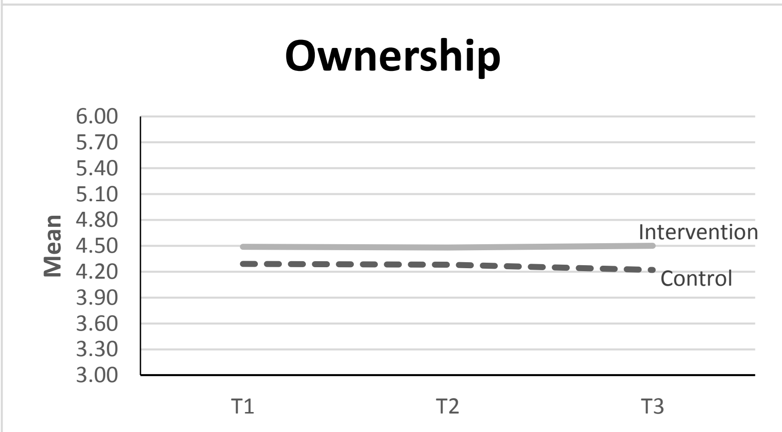
Intervention
Control
T1
T2
T3


Ownership
Mean
6.00
5.70
5.40
5.10
4.80
4.50
4.20
3.90
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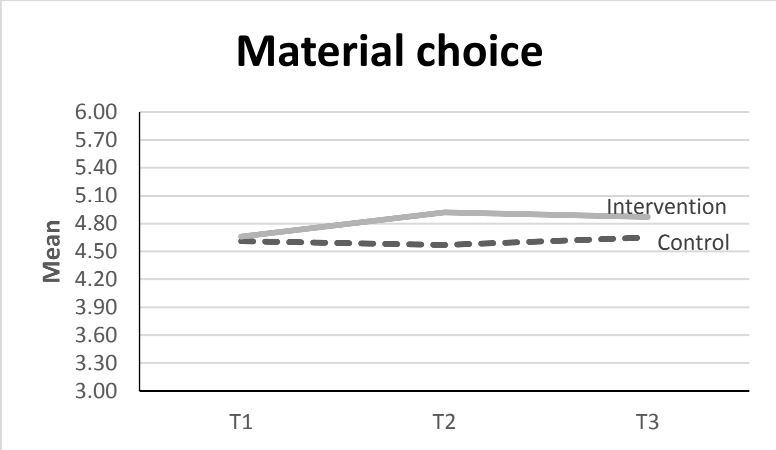
3.30
3.00
Intervention
Control
T1
T2
T3


Material choice
Mean
6.00
5.70
5.40
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4.20
3.90
3.60
3.30
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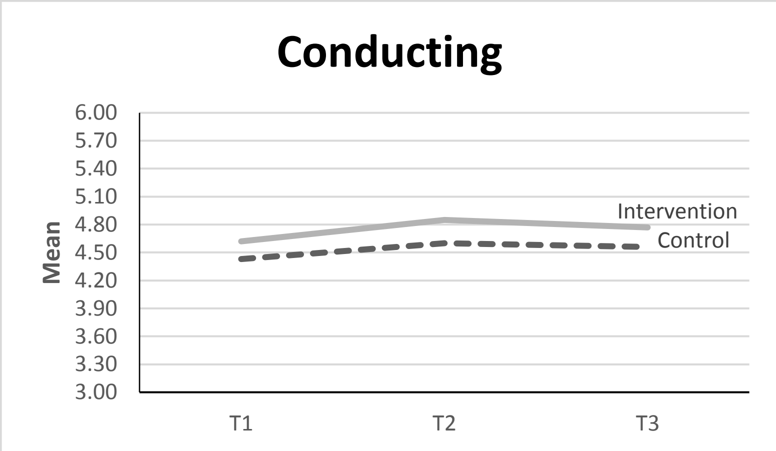
T1
T2
T3
Intervention
Control


Conducting
Mean
6.00
5.70
5.40
5.10
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4.50
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3.90
3.60
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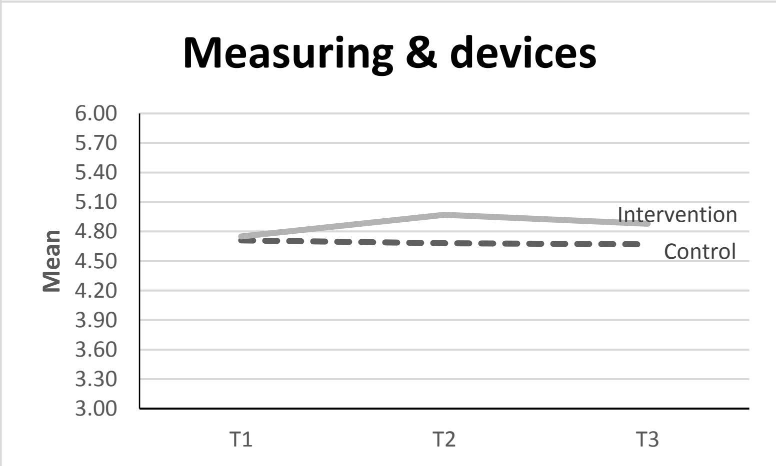
T1
T2
T3
Intervention
Control


Measuring & devices
Mean
6.00
5.70
5.40
5.10
4.80
4.50
4.20
3.90
3.60
3.30
3.00
T1
T2
T3
Intervention
Control

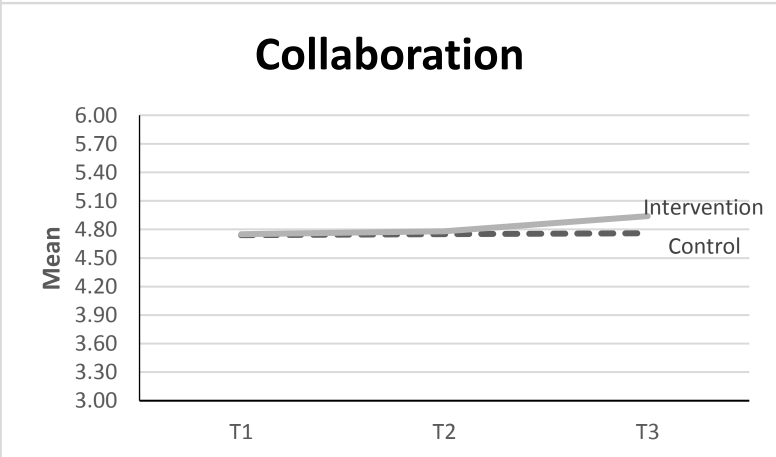
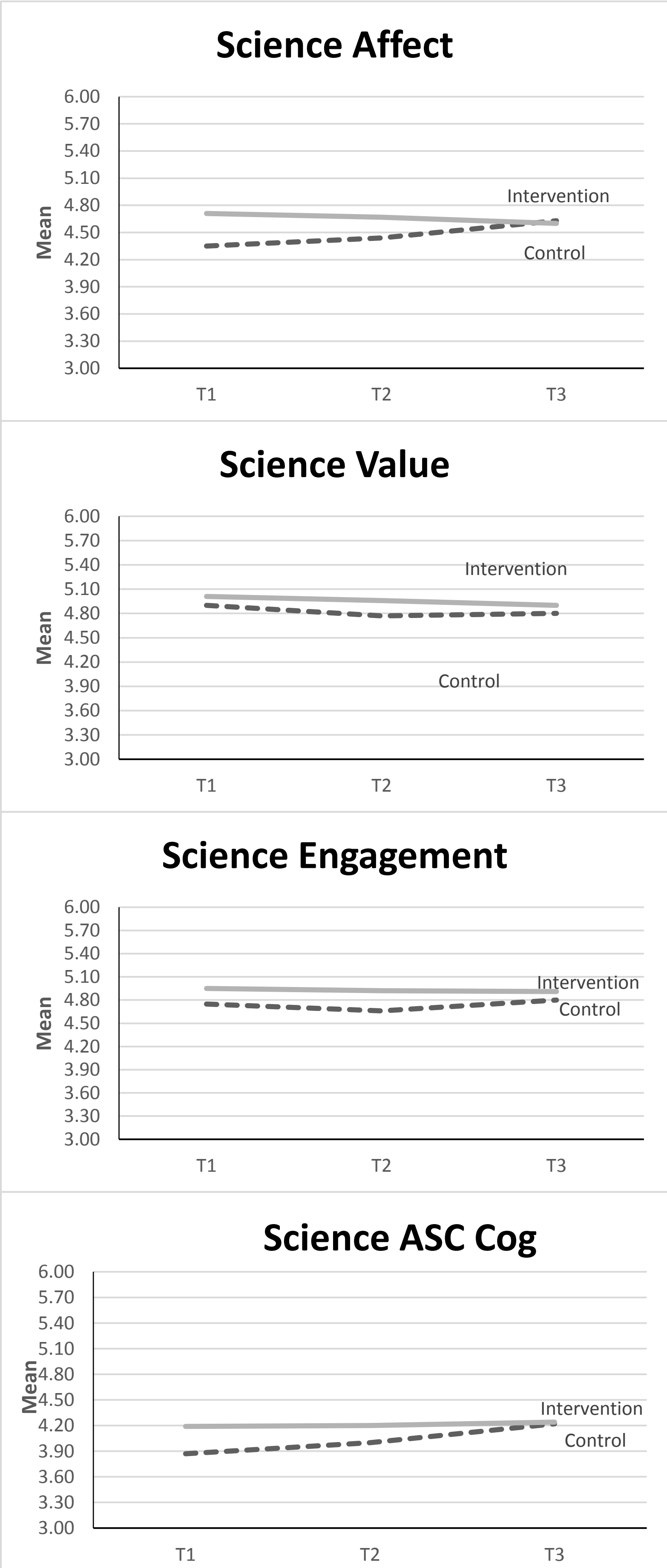

Collaboration
Mean
6.00
5.70
5.40
5.10
4.80
4.50
4.20
3.90
3.60
3.30
3.00
T1
T2
T3
Intervention
Control

Figure 3.3 - *MyScience* Intervention – No Positive Effects on Student Outcomes



The results of this study suggest that the *MyScience* intervention in its current form is more beneficial for nature of science outcomes than self-concept, behavioural, motivational, and teacher affect outcomes. Since self-concept has been demonstrated by international research to be a primary driver of student achievement and other desirable outcomes (Marsh & Craven, 2006), these results imply that the *MyScience* intervention could benefit from revision in relation to targeting teachers' science teaching self-concept and behavioural, motivational, and teacher affect outcomes.

Impact of *MyScience*: Primary Teachers

The patterns of 12 variables examined for teachers of the experimental and control groups at two time points are presented in Figures 3.4 through 3.6. Teachers showed similar results at the pretest for the variables of Different Solutions, Ownership, Measurement, Analysing, Self-concept, and Engagement. However, the gains for the experimental group were more pronounced at the posttest for the variables of Ownership, Measurement, Analysing, and Engagement. For the other variables, which were not so similar at the pretest across groups (Planning, Conducting, Choice, Communicating, Teaching passion, Value), the gains at the posttest all seemed to favour the experimental group. These patterns point to the benefits of the intervention in terms of gains in a range of dimensions. In particular, for NOS and related science inquiry processes, the gains in the concepts of ownership of science knowledge, planning and conducting science inquiries, choice of investigation, measurement, and analysis strategies, together with the communication of scientific findings, are particularly salient in relation to the target goals of the intervention.

Figure 3.4: *MyScience* Intervention – Nature of Science for Teachers

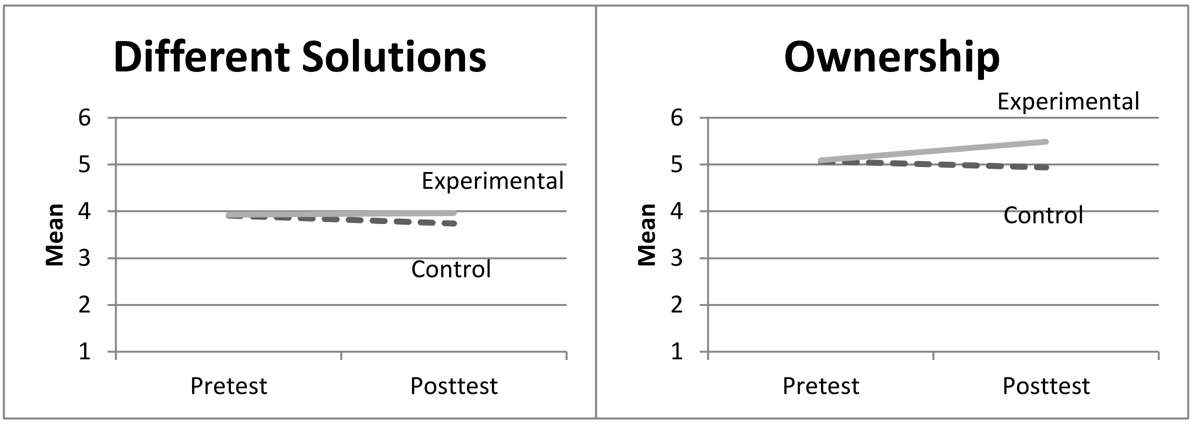


Figure 3.5 – *MyScience* Intervention – Science Inquiry Skills for Teachers

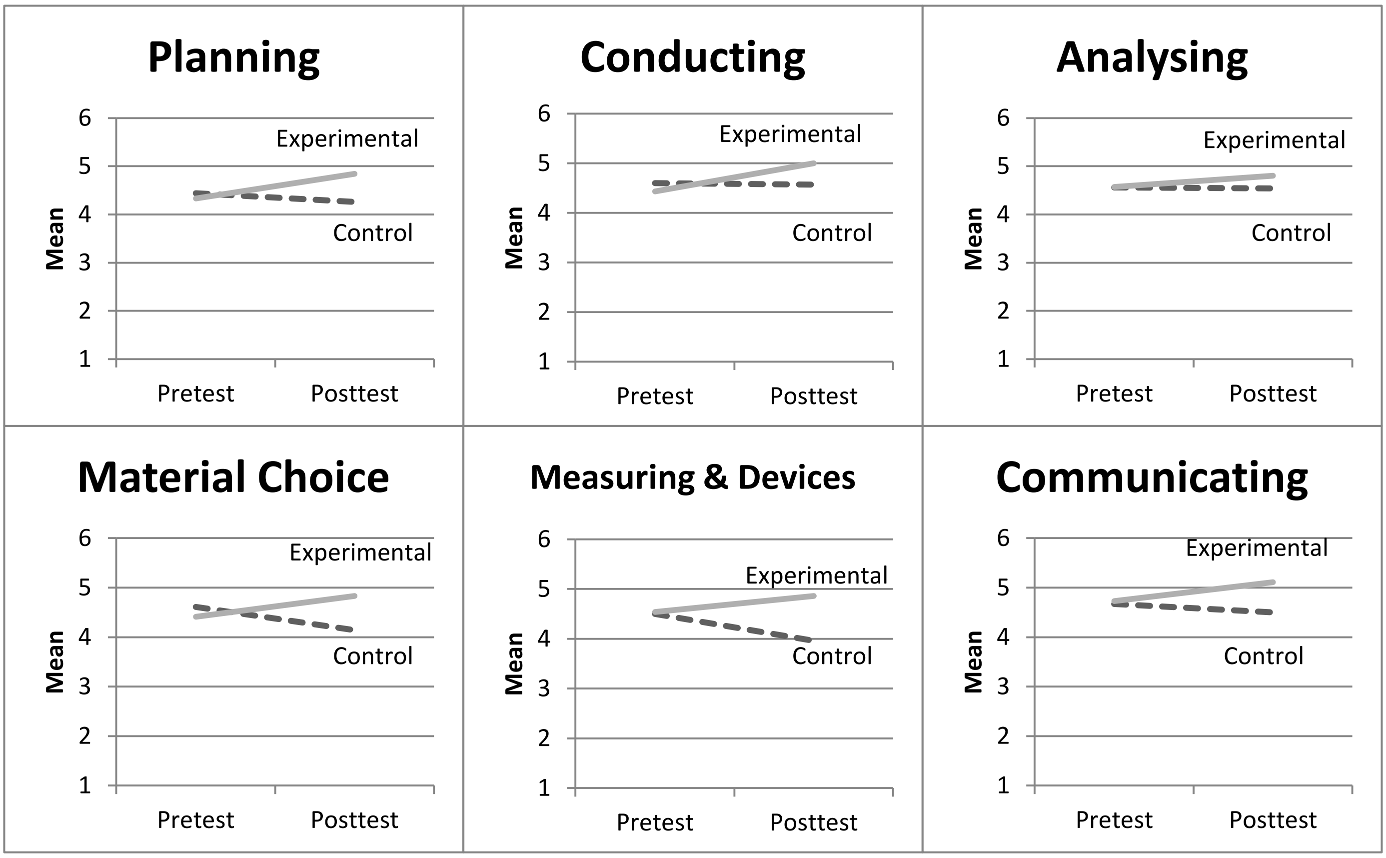
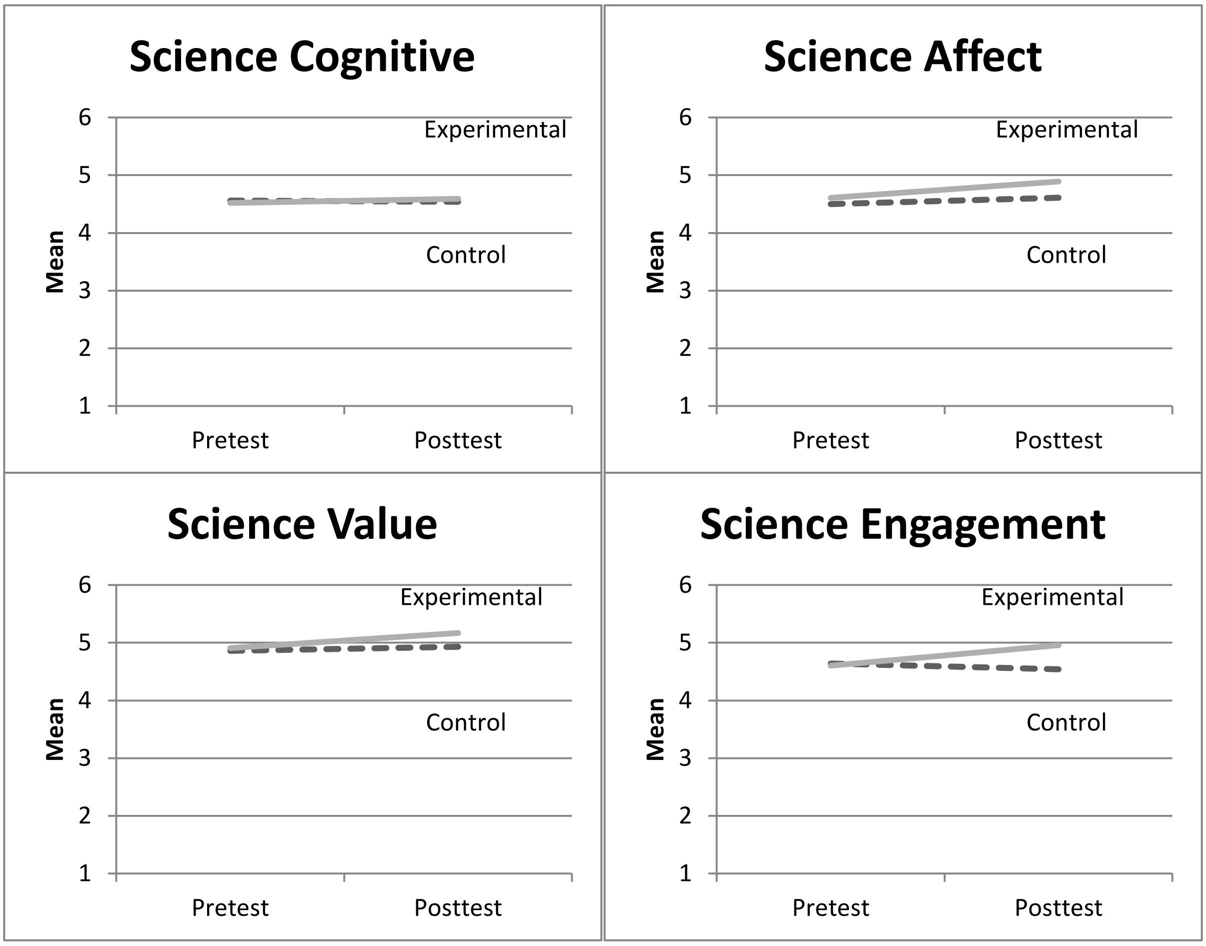


Figure 3.6: *MyScience* Intervention – Teacher Perceptions of Student Learning



The patterns of change for this small sample of teachers favour the experimental group of primary teachers who participated in the program. This suggests that *MyScience* may benefit teachers in their sense of ownership (an NOS factor), planning, measurement, and analysis (SIS factors), and self-concept and value perceptions (personal factors). However, a larger sample size is required to investigate these promising patterns using more robust statistics.

Impact of *MyScience*: Secondary Science Teachers' Views

When asked how *MyScience* had changed their own views of promoting science/science learning in high school there were a range of responses from interviewed teachers including insights into what primary students were capable of and how successfully the Year 9/10 students were able to mentor primary students. Science teachers also emphasised that student-based inquiry and real world applications of science promoted secondary students' interest and motivation (see Table 3.7).

Table 3.7: Science teachers' views of what promotes interest and motivation to learn high school science

Science teachers' views of what promotes interest and motivation to learn high school science (n=7)	1	2	3	4	5	6	7	8	9	10
Student inquiry based investigations: hands-on, but also online research and interactive activities										
Real world application										
Relevance										
Interest										
Variety										

Science teachers also expressed positive and negative views about their experience with working on *MyScience* as shown in Table 3.8 and described in the following:

Table 3.8: Science teachers' positive and negative views of *MyScience*

Science teachers' positive and negative views of MyScience (n=7)	1	2	3	4	5	6	7	8	9	10
Awareness of what Stage 3 is doing in science, level and interest										
Personal enjoyment of links with primary										
Need to develop common language with primary teachers (transition)										
Activated visits between Stage 2 & Stage 5										
Need to focus more on scientific method in Years 8-9										
Gained awareness of enthusiasm of Year 9/10 students										
Observed that primary students enjoyed MySTic visits										
Awareness of importance of choice by students for engagement in secondary science										
Frustration with lack of: teacher guidance during sessions, progress between visits, resources, scientist mentors, organisation										

Science teachers emphasised that it was interesting engaging primary students' with scientific methods.

> *It was very interesting to see the primary students doing it. Because I'm not sure how much exposure they were getting to it beforehand, but basically they were getting the equivalent of what we'd do in Year 7 and Year 8 and it prepares them really well. The mentors really enjoyed the ability to take their knowledge and experience and give it to the kids, the younger kids.* (Secondary Science Teacher 6)

Another teacher realised there was a need to focus more on the scientific method in Years and 9:

> *It sort of made me realise that we don't focus enough on the scientific method. … But after doing MyScience, I went back and had a look at our specific programme. We spend a lot of that time in year seven going through the scientific method, and then we do touch upon it, but again it comes back in year ten, heavily. So year eight and nine we're delivering a lot of content and not looking at the scientific method. And it might mean a whole rearrangement and restructure of... I've been thinking that once a week do we just go, okay, we're going to work on the scientific principle, and have a whole lesson dedicated to that? I don't know. It's brought back lots of things that I need to think about on how we deliver our lessons and how we teach the concept.* (Secondary Science Teacher 3)

Other teachers noted the benefits of allowing students to have independence and choice in their learning (i.e., for the teachers to be a facilitator not a director of learning).

> *Have the ability to be able to stand back and let the kids come up with their own ideas and use their own imagination".*(Secondary Science Teacher 6)

> *It's the realisation that they need to have a little bit more independence, I think. That we tend to be too controlling in our classrooms.* (Secondary Science Teacher 5)

Secondary science teachers perceived that both primary and secondary students benefitted from participation. One teacher commented on a school holiday workshop that they were conducting where a couple of primary students came up and were *"still talking about the excitement"* of doing their MyScience investigations. Secondary students were observed to step out of their "comfort zone" and "doing things that they wouldn't normally do" (Secondary Science Teacher 4) as well as gaining responsibility and awareness that they knew some science:

> *seeing those kids working in groups together, and the way that they talk about it on the bus on the way back. Because the kids would be, 'My kids are doing this and my kids are doing that, this little boy said this and this little boy said that'. So the kids really responded well to that level of responsibility. And it gave them a chance to figure out they actually do have some knowledge, I think it was very rewarding for their self-esteem. Those kids are generally mature kids; they're a very diverse group of kids. But they all would get on the bus, thinking that was the best thing they've done that day. The ones that participated, it did help them to learn themselves as they had to explain it to somebody else. So in a sense, putting themselves out there, they made sure that they were prepared and able to help the primary students.* (Secondary Science Teacher 6)

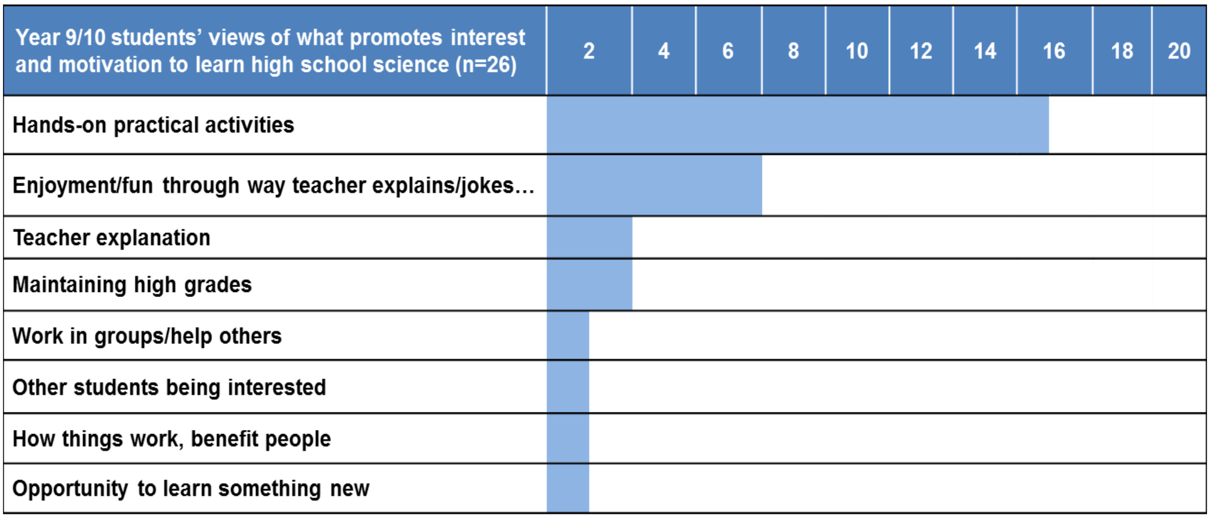
One secondary science teacher (6) expressed frustration around there only being one teacher at the primary school, the lack of primary teachers guidance and support during school visits, the lack of student progress between visits, the lack of resources, and lack of organisation at the primary school. These are all important and valid comments that will inform future implementation of the intervention.

Findings based on interviews with secondary teachers indicated that *MyScience* participation had stimulated them to reflect on their own teaching related to the scientific method and providing students with more topic choices. Teachers also reported that mentoring enabled their students to learn more about science and enhanced their self-esteem.

Impact of *MyScience*: Mentors

Year 9/10 students were asked about what promotes their interest and motivation to learn high school science. They emphasised that hands on practical activities were motivating and that teachers with a sense of humour made science interesting (see Table 3.9).

Table 3.9: Year 9/10 students' views of what promotes interest and motivation to learn high school science



Students commented on the importance of hands-on practical activities when asked "What promotes your learning in science in high school?":

> *I do a lot of experiments in class. I really enjoy those. It gives us a chance to do something practical. It's always better and I find that it helps me learn more than just doing theory work.* (Student 6)
>
> *More so the prac lessons. They're more engaging. You can get more out of it than just writing in a book. You remember more. I find I remember more in a prac lesson than I do with the theory lessons.* (Student 12)
>
> *The fact that we do a lot of pracs, it helps me understand how to do things better.* (Student 13)
>
> *It's easier to learn hands on.* (Student 15)
>
> *The experiments and stuff are like, my favourite. … I don't really like sitting down and doing one thing. Like, I prefer getting up and doing stuff.* (Student 16)
>
> *I think that when we do them (pracs) I actually get a better understanding of things about science.* (Student 21)
>
> *The different experiments are a sort of really big thing of, like… We do that sort of stuff and it's, like, interesting, so it makes us want to do more of it. Yes.* (Student 22)
>
> *I think learning stuff by doing it is really important. It makes learning more fun, and it brings, like, an excitement to it all.* (Student 26)

Another key factor cited by several students related to enjoying their actual time in science classes.

> *It always seems like a lot of fun. Everyone seems… All the students that I know who have done science, and teachers all seem to always be having fun with it, which is good. (Student 6)*
>
> *When my teacher makes it seem fun. So this... I do senior science, and my teacher, who's actually a teacher there, she… The subject we're learning is about plants and it's not necessarily the most fun subject but she makes it fun. Like she just says all these like, you know, she's really enthusiastic and that makes me want to learn about it. When the teacher's enthusiastic about it. Makes you enthusiastic about it.* (Student 21)
>
> *They have jokes and stuff and it makes it like really fun so we can… Yes, like it sparks your interest and you get more into it then, yes.* (Student 8)

Three positive aspects of involvement as a mentor were echoed by more than 50% of the 26 interviewed Year 9/10 students:

(1) They experienced significant enjoyment through helping others,
(2) They gained awareness of the processes of science and the different ways that scientific problems can be solved, and
(3) Through the process of teaching others about science their own science learning was improved.

Negative aspects of their involvement related to difficulties with managing groups of primary students and when there was a lack of organisation and resources for implementing lessons (see Table 3.10).

Table 3.10: Science students' positive and negative views of *MyScience*

Year 9/10 students' positive and negative views of MyScience (n=26)	1	2	3	4	5	6	7	8	9	10
Enjoyment through helping others										
Gained awareness of the processes of science, ways to solve problems										
Gained awareness that teaching helps own learning										
Gained awareness of how to teach/explain science to others										
Gained awareness of primary students' enthusiasm										
Increased own interest in science/science teaching as a career										
Gained awareness of the benefits of working with others										
Gained awareness of primary students' high level of understanding										
Promote science interest in others										
Increased own interest in science										
Gained awareness of primary students' creativity										
Gained personal motivation										
Gained personal patience										
Gained personal group skills										
Gained insights into the life of a science teacher										
Difficulties with primary students groups										
Lack of resources/organisation										

Table 3.11 lists the frequency of secondary science students' views of the benefits of having them as mentors. Year 9/10 students perceived that benefits for primary students of having them as an older peer mentor were that: Primary students seemed more interested in science, experienced science as being more enjoyable, and gained knowledge of the processes of science.

Table 3.11: Secondary students' views of the benefits for primary students of having them as mentors

Year 9/10 Students' views of benefits for Primary Students of having them as Mentors (n=26)	1	2	3	4	5
Promoted interest in science					
Experience the enjoyment of science					
Gained awareness of science in high school/career					
Gained awareness of the process of science					
Gained awareness of achievement when apply themselves					
Gained awareness of science in the world					
Learned more about science					
Opportunity to do science					
Behaved more maturely					
Improved their communication skills					

Secondary students commented repeatedly on how much they had enjoyed mentoring because they experienced the primary students' high levels of excitement, creativity and collaboration. They felt that through explaining concepts to the primary students they developed deeper personal knowledge of the processes of science, including that there are a variety of ways to solve scientific problems (compared with high school science where everyone follows the same procedure/approach):

> *I just found it really interesting and it definitely taught me more about science. It doesn't have to be so straight line, you can broaden out to other areas.* (Student 1)

> *A lot of the work done with the younger students has shown me that there's more than one way to do things. I knew that a lot before, but watching children figure it out for the first time shows that there's more to what you just think,* (Student 11)

> *Well, it sort of changed my perception, especially with the ideas that people come up with for science. So the kids in my group wanted to test how a lemon battery would work, but we had to change it because the measurement wouldn't be appropriate to what we were trying to achieve. So we ended up testing a lemon, a potato, and an apple to see how much electricity it would produce. And everyone… We all thought it would be the lemon, but it was actually the potato that produced more. But I like how it's very inspiring to see younger kids especially seem very inquisitive and very curious, and how my perception has changed, because of the kids.* (Student 23)

Some students commented on their heightened awareness of teaching through participation in the community of practice – how *they* learned from interactions with the primary students:

> *the teaching side. Teaching kids and helping them to understand different things. That's probably impacted me the most out of the My Science.* (Student 13)

> *it's helped me develop a lot of skills that I might have not had if I hadn't had done the MyScience program. So explaining things in a scientific sense versus how ordinary, like, you'd explain it. So through how averages work in mathematics, versus how they would have to relate in science.*

> *I think the primary students kind of brought a sort of knowledge to me that I didn't have before. Like, how to effectively explain to someone who doesn't quite get a concept yet. How it works, and why it works. And it just cemented all the things that I knew, that I could explain that to others, so that I had that knowledge and I could share it. And I think that was… I feel like that was*

> *something that really built the girls' and my relationship, because we understood each other, and we were beginning to learn together as a group.* (Student 23)

Several students commented on how helping others advanced their own learning:

> *that you can help other people with it and learn yourself.* (Student 4)

> *You learn as much as you teach, doing stuff like that.* (Student 6)

> *So, getting active with other, like, kids younger than us as well, it's really good because they've got so many questions and it just tests your own knowledge and you kind of think of stuff with those kids with their, like, inspiration. You think of stuff you wouldn't normally think of.* (Student 7)

> *The aspect of teaching someone as opposed to being taught has helped me a lot, because it forces me to understand things before I can pass them on. And that's made me focus a lot more in class as far as paying attention to textbooks and teachers and work on the board and stuff.* (Student 11)

> *Maybe it's easier to learn when you're learning with them.* (Student 15)

> *I always like the little kids. I mean, they made it all the more fun. Like, it helped me, because I had to explain to them all the concepts I knew on what they were doing, which made it clearer in my mind what I was thinking and what I'd learned. So explaining to them really helped, and I had to explain to them all these fancy science terms and make it cool. Like, they didn't know all the words that we use, like hypothesis, or things like that. So I had to explain to them what a hypothesis was, and how to write, like, scientific… What are they called? Do you know what those things are called? I had to explain to them controls and all that sort of stuff. And I think it just made it clearer to me and the girls what we were all doing. It was really good for both of us, I think.* (Student 26)

For some students their mentoring experience actually made them look forward to school science: "Well, like it's changed a lot since, like, I've been there and, like, it's a lot different now so I'm like more keen on like looking forward to science and stuff" (Student 8), and for others they have new insights into career pathways as scientists and science teachers:

> *It's definitely changed the way I look at science as a career. Like, it's now putting the… Putting not only becoming a scientist but science teacher into what I see in the foreseeable future*

> *it was really surprising to see what they learnt and what they hadn't learnt and stuff like that. And to help them along and maybe push them towards science was… Really changed what I think about science as a career.* (Student 6)

> *It's kind of made… Gave me an interest in science teaching, a bit.* (Student 9)

> *I think it changed it because I'm more… I kind of had a thought after that maybe I should, like, teach science or something like that. Because I'm quite interested in science, and I kind of like kids as well.* (Student 25)

Two interviewed students (16 & 18) expressed frustration around trying to explain concepts to the primary students "*Because everyone's on different levels and stuff. … like some of them would be really into it and then others weren't. Like they wouldn't listen to me and stuff and it was hard to get them to, like, do it*" (Student 18). Student 16 commented on the lack of resources and organisation (a similar concern voiced by their science teacher.

These results imply that secondary school student mentors perceive that they positively impact primary children's learning and enjoyment of science. They also reported that mentoring was enjoyable and had a positive impact on their own learning and motivation to engage in science activities. This finding warrants further research.

Chapter 4:

Strengths, Limitations, and Implications for Research and Practice

This analysis adopted a randomised control study in order to investigate the effects of the *MyScience* intervention. Rigorous statistical analyses were employed to identify the impact of the *MyScience* intervention on specific constructs targeted. The qualitative component of the study also further enriched the findings.

The small-scale of the study is a key limitation and further research would benefit from a larger-scale investigation with higher numbers of primary school students, teachers, and secondary students. For example, the small sample of primary teachers completing the online surveys limited assessments of the validity of the constructs used in the evaluation. In addition, researchers did not measure the fidelity of the implementation of the intervention, which could confound intervention effects. Future research could benefit from assessing the fidelity of the implementation of the intervention and testing the construct validity of scales utilised with a larger sample of teachers. Actual science achievement was also not measured as a component of this investigation. It would be useful to include science achievement measures in future investigations to test the impact of *MyScience* on science learning more fully.

The results imply that participating in *MyScience* has positive impacts on primary students' knowledge – specifically around Science Inquiry Skills and the Nature of Science - and enjoyment of science. However, the intervention had no significant effect on science self-concept. Given self-concept shares a dynamic reciprocal relation with achievement it is recommended that *MyScience* training sessions for teachers and mentors include specific instruction on enhancing students' science self-concepts.

Results suggest that *MyScience* has important multiplier effects for secondary teachers and secondary students as mentors. Secondary students reported that mentoring enhanced their own knowledge and enjoyment of science, which was also independently reported by secondary science teachers. Secondary science teachers acknowledged a shift in their own pedagogy towards more student-led, inquiry-based experiences.

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Appendices

Appendix 1-Interview questions

Secondary science teacher questions

1) What aspects of high school science best promote science learning for high school students?
2) What aspects of high school science best promote motivation to learn for high school students?
3) What aspects of high school science best promote interest in science activities for high school students?
4) In what ways has participation in *MyScience* changed your views of (1), (2), (3)?
5) What aspects of your participation in *MyScience* contributed to changing your views in (1), (2), (3)?
6) How has *MyScience* impacted on you?
7) How has *MyScience* impacted on the primary students?
8) In a nutshell which aspects of *MyScience* were most significant in changing (or not changing) your views about high school students' learning, motivation and interest in school science?

Secondary science student questions

1) What aspects of high school science best promote your science learning?
2) What aspects of high school science best promote your motivation to learn?
3) What aspects of high school science best promote your interest in science activities at school?
4) In what ways has participation in *MyScience* changed your views of (1), (2), (3)?
5) What aspects of your participation in *MyScience* contributed to changing your views in (1), (2), (3)?
6) How has *MyScience* impacted on you?
7) How has *MyScience* impacted on the primary students?
8) In a nutshell which aspects of *MyScience* were most significant in changing (or not changing) your views about your learning, motivation and interest in school science?

Appendix 2 - Survey Scales

Nature of Science

Focus Area	Number of Items	Example Survey Item
Different Solutions	5	When doing an investigation, everyone has different ideas about how to do it
Ownership	5	I would rather work out a SCIENCE and TECHNOLOGY problem myself than be given the answers

Science Inquiry Skills

Focus Area	Number of Items	Example Survey Item
Collaboration	4	I work together with my classmates in science and TECHNOLOGY
Topic Choice	4	In my SCIENCE & TECHNOLOGY class, we choose our own investigation
Planning	4	We change one thing at a time in our investigation
Conducting	5	We take the same measurements several times
Analysing	4	I use tables to make sense of our results
Communicating	4	I report what we find to others
Material choice	4	I choose materials to suit our investigation and designs
Measuring & Devices	4	I am confident in choosing appropriate equipment to make measurements

The Science Learner: Self-Concept

Focus Area	Number of Items	Example Survey Item
Science Cognitive and Competence	4	I am good at SCIENCE and TECHNOLOGY
Science Affect	4	I love SCIENCE and TECHNOLOGY classes

The Science Learner: Motivation and Engagement

Focus Area	Number of Items	Example Survey Item
Science and Technology Engagement	6	I try my best to complete my work in SCIENCE and TECHNOLOGY
Science Value	6	What I learn in SCIENCE and TECHNOLOGY will be useful one day