Stage 3
Interim research and evaluation report 15

Impact of *Primary Connections* on students' science processes, literacies of science and attitudes towards science

A research report for the Australian Academy of Science

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The views expressed in this report do not necessarily represent the views of the Australian Academy of Science nor the views of the Australian Government Department of Education, Employment and Workplace Relations. The author accepts responsibility for the views expressed and all errors and omissions in this report.

Contents Page

Executive Summary **4**

Introduction **6**

Purpose and Research Questions **8**
Purpose 8
Research Questions 8

Method **8**
Approach 8
Development of Instruments and Coding Schemes 8
Procedure 10
Sampling and Demographic Data 10
Demographic data 11
Jurisdictions, science program, year level and gender 11
Socioeconomic index band, ATSI and LBOTE backgrounds 12
Coding of Student Responses 14
Data Analysis 14

Results **15**

Task 1: Draw Your Thumb Task **16**

Task 2: Shoe Size Task **21**
Part 1: Measuring Shoe Size and Recording Results in a Table 21
Part 2: Shoes Size and Length – Graphing Data 24
Part 3: Interpretation of Shoe Size Task Results 25
Year 4 students 25
Year 5, 6 and 7 students 26

Task 3: Rolling Ball Task **28**

Comparison of Groups on the Tasks **32**

Attitudes Towards School Science **37**
Students' Perceptions about Frequency of Science Lessons 38
Attitudes about School Science 38

Summary of Key Findings **41**

Discussion **43**

Conclusions and Implications **47**

References **48**

Appendices **49**
Appendix 1: Specification grids

Appendix 2: Assessment tasks

Appendix 3: Marking guides for the assessment tasks

Executive Summary

Previous research conducted on the impact of *Primary Connections* has demonstrated that: *Primary Connections* improves teachers' confidence with a range of science and literacy teaching strategies and their self-efficacy beliefs for teaching science; teachers report that their pedagogy has improved and that they spend more time teaching science; students report that they enjoy learning science with *Primary Connections*; and, that *Primary Connections* promotes students' development of conceptual understandings (Hackling & Prain, 2005; Hackling, Peers & Prain, 2007).

There is an international consensus that the main purpose of primary science education is the development of scientific literacy. Scientific literacy is a multidimensional construct and requires that students develop conceptual understandings, literacies of science, science processes and a positive disposition to science so that they can engage with scientific matters in real world contexts (Bybee, 1997; OECD PISA, 2006; Roberts, 2007). Given that previous studies have demonstrated *Primary Connections*' impact on students' development of conceptual understandings, the purpose of this study was to evaluate the impact of *Primary Connections* on students' development of literacies of science, science processes and attitudes towards school science.

Literacies of science are required to interpret and construct science texts, to make and evaluate claims (Mortimer & Scott, 2003; Norris & Phillips, 2003) and to communicate findings from science investigations (MCEETYA, 2006). The literacies of science evaluated in this study were students' use of tools and conventional forms to reason about and represent scientific data, such as labelled diagrams, data tables and graphs. Processes of science are integral to investigation and scientific literacy (Goodrum, Hackling & Rennie, 2001) and the national statements of learning for science (MCEETYA, 2006). Processes of collecting data by observation and measurement, reasoning with data and variables such as formulating investigable questions, identifying relationships between variables, and planning investigations that are fair tests were included in the evaluation. An interest in science is a component of scientific literacy (Goodrum et al., 2001; OECD PISA, 2006) and a positive disposition to school science is critical if we are to enhance the scientific literacy of Australian citizens and increase enrolments in post compulsory secondary science and university enrolments in the enabling sciences. Students' responses to school science such as enjoyment, interest and curiosity were therefore included in the evaluation.

To evaluate scientific literacy learning in *Primary Connections*, novel assessment tasks were developed which allowed students to demonstrate how effectively they could apply literacies of science and science processes to authentic science tasks in real world contexts. Students also responded to a seven item attitude scale. Students completed age-appropriate versions of the test. The test of literacies and processes (Cronbach's alpha 0.841) and the attitude scale (Cronbach's alpha 0.852) were highly reliable.

A total of 1467 students in Years 3-7 were recruited from 26 government schools in Western Australia and Queensland to participate in the testing program which was conducted in Term 4 of 2007. Students were recruited from classes which had studied science using *Primary Connections* and from comparison classes which had studied science using other programs. *Primary Connections* classes and comparison classes were matched on the socioeconomic index levels of the schools. Most of the *Primary Connections* classes had completed two units during the year and there was no assumption of fidelity of implementation of the *Primary Connections* teaching and learning model. Comparison classes were recruited from teachers who volunteered to participate in the evaluation and taught science using other programs. These classes formed a legitimate group against which the performance of *Primary Connections* classes could be compared.

Students' responses to the assessment tasks and to the attitude scale were coded and analysed. Data were aggregated by task for science literacies and for science processes for Year 3 students, for Year 4 students and for Years 5-7 students. Performance on science processes was mapped against the National Scientific Literacy progress Map (MCEETYA, 2005). For all age groups and for all assessment tasks, students from *Primary Connections* classes achieved significantly higher mean scores on literacies of science and for processes of science than students from comparison classes. Effect size (Cohen, 1988) values for literacies and processes of science indicate that *Primary Connections* had a substantial impact on students' achievement of literacies and processes of science.

The aggregated data for Year 5-7 students were further analysed by the types of students who completed the tests. These analyses revealed that for all groups; males, females, students of Aboriginal and Torres Islander descent (ATSI), students with a language background other than English (LBOTE) and for non-ATSI and non-LBOTE students; students from *Primary Connections* classes achieved significantly higher mean literacies of science and science processes scores than students from comparison classes. Of particular interest are the much higher mean scores for Indigenous students studying in *Primary Connections* classes compared with Indigenous students from comparison classes.

The attitude scale revealed that a majority of all sampled primary students enjoyed school science, however, for two items there was a statistically significant difference in favour of students from *Primary Connections* classes. Students in *Primary Connections* classes experienced curiosity and learned interesting things more frequently than students from comparison classes.

Previous research demonstrated that students achieve strong conceptual growth in *Primary Connections* classes (Hackling, Peers & Prain, 2007). This study has shown that students in *Primary Connections* classes achieve higher mean scores on literacies of science, processes of science and on some aspects of attitudes to school science. These are all important components of scientific literacy which is the main purpose of primary science education in Australian schools (Goodrum et al., 2001). Significantly, this study has shown that students from *Primary Connections* classes have outperformed students from comparison classes on those aspects of achievement that the latest science education literature indicates count as learning in science.

Introduction

Primary Connections is a teacher professional learning program supported with exemplary curriculum resources. *Primary Connections* was developed to support teachers improve the teaching and learning of science in primary schools. Previous research conducted on the impact of the program has demonstrated that: *Primary Connections* improves teachers' confidence with a range of science and literacy teaching strategies and their self-efficacy beliefs for teaching science; teachers report that their pedagogy has improved and that they spend more time teaching science; students report that they enjoy learning science with *Primary Connections*; and, that *Primary Connections* promotes students' development of conceptual understandings (Hackling & Prain, 2005; Hackling, Peers & Prain, 2007).

The purpose of science in primary schools is to provide opportunities for students to know science as a body of knowledge, as a way to know and as a human endeavour, and to develop students' scientific literacy (MCEETYA, 2006). Science education is considered, by those taking a sociocultural view, to be a process of enculturing students into the particular ways of knowing and representing the world and making claims from a scientific perspective. An important aspect of this culture relates to language. Mortimer and Scott (2003) argue that each school subject area has its own distinctive social language "that can be thought as a tool, offering a distinctive way of talking and thinking about the world" (p.13). Norris and Phillips (2003), Gee (2004), Lemke (1998) and Unsworth (2001) argue that students need to acquire the particular languages, vocabulary and representational practices of a discipline. From a fundamental perspective, science literacy entails being able to interpret and construct science texts (Norris & Phillips, 2003). The crucial role played by language and other forms of representation in learning science and in being scientifically literate provides part of the rationale for the approach taken by *Primary Connections* in integrating the teaching and learning of science and literacy and for the explicit teaching of literacies of science required to reason with and develop science understandings, represent science data and communicate science information in conventional ways. The definition of scientific literacy adopted by the statements of learning for science (MCEETYA, 2006) is derived from Goodrum, Hackling and Rennie's (2001) Australian review of science education and states that:

> Scientific literacy is a high priority for all citizens, helping them
> - to be interested in, and understand the world around them,
> - to engage in the discourses of and about science,
> - to be sceptical and questioning of claims made by others about scientific matters,
> - to be able to identify questions, investigate and draw evidence-based conclusions, and
> - to make informed decisions about the environment and their own health and well-being. (Hackling, Goodrum, & Rennie, 2001, p. 7)

This definition of scientific literacy demonstrates the importance of students' interest in science, their mastery of the literacies necessary for communicating and making claims in the discourses of science and the capacity to use the processes of science to investigate scientific questions.

Scientific literacy can be considered from fundamental (being able to construct and interpret science texts) or derived (being knowledgeable in science) perspectives (Norris & Phillips, 2003) and from a functional literacy perspective as "science knowledge needed by individuals to enable them to function effectively in specific settings" (Ryder, 2001, p. 3). Scientific literacy is a multidimensional construct (Bybee, 1997, OECD PISA, 2006; Roberts, 2007) and requires citizens to be interested and engaged with scientific matters and have the knowledge and skills that can be applied in real-world contexts to investigate, represent and communicate findings and solve everyday problems (Figure 1). The literacies of science and processes of science components are closely inter-related, for example, science investigation requires the application of processes such as observation and measurement to gather data, literacies of science to represent data as diagrams, tables and graphs in ways that enable relationships and patterns in data to be identified and interpreted using processes of science and then claims are made on data and communicated using literacies of science.

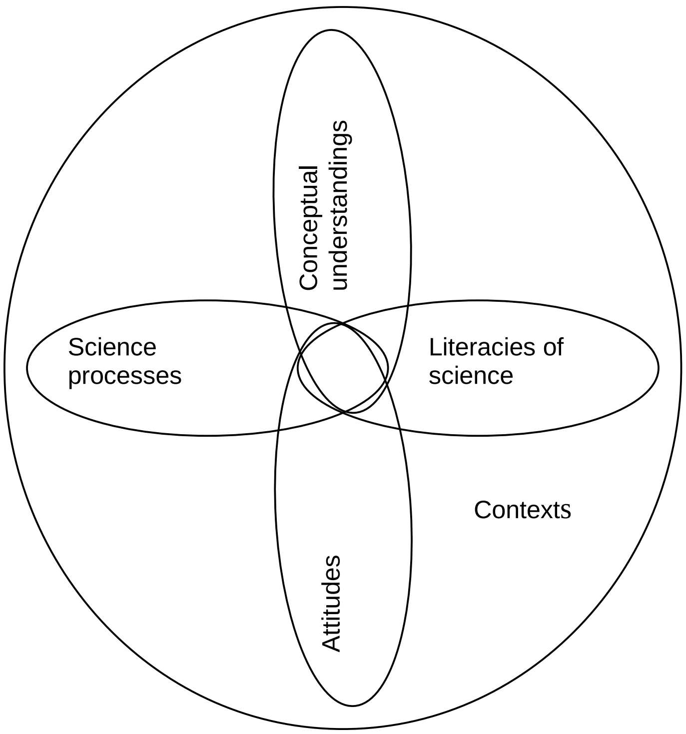

Figure 1: Scientific literacy – a multidimensional construct

Key principles underpinning the *Primary Connections* teaching and learning model include; linking science and literacy teaching and the explicit development of literacies of science; and, an inquiry approach to science to develop the process skills required for investigation; and, that the program should include authentic, purposeful and engaging activities that may improve students' attitudes towards science. Given that these intended outcomes are also key elements of scientific literacy it was appropriate to conduct further research that assessed the impact of *Primary Connections* on students' literacies of science, science processes and attitudes towards school science. This research will complement the previous evaluations that had demonstrated the positive impact of *Primary Connections* of students' conceptual development (Hackling & Prain, 2005; Hackling, Peers & Prain, 2007).
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Purpose and Research Questions

Purpose
The purpose of this study was to conduct an evaluation of the impact of *Primary Connections* on students' literacies of science, science processes and attitudes towards school science by comparing the performance of students who have studied science in classrooms using *Primary Connections* with a comparison group who have studied science using other programs.

Research Questions:
1. What literacies of science and science processes are Year 3-7 students who have learned science with *Primary Connections* developing, and to what level?
2. Is the achievement on literacies of science and science processes by *Primary Connections* students greater than that of students from non-*Primary Connections* classes in equivalent schools?
3. Can progression in learning be identified within the literacies of science and science processes?
4. Do *Primary Connections* students have more positive attitudes towards school science than non-*Primary Connections* students?

Method

Approach
The research approach adopted for the evaluation was to compare the performance of students in classes that had based their instruction on *Primary Connections* with the performance of students from equivalent classes that had used other science programs. Students' ability to complete authentic assessment tasks involving the application of science processes to investigate a number of phenomena and to record their observations and measurements, represent and communicate findings using literacies of science was assessed in Term 4 of 2007. Students also responded to a scale which gathered data about students' perceptions of school science.

Development of Instruments and Coding Schemes
It was necessary to break new ground with highly innovative approaches to evaluation given that the latest science education literature indicates that what counts as science learning involves the ability to apply processes and literacies of science to meaningful tasks in authentic contexts. High priority was given to the development of assessment tasks that were authentic in the sense that process skills performance would be demonstrated in familiar, real-world contexts and would involve students planning investigations, making observations and measurements, recording these, constructing tables and graphs to represent their data which would provide opportunities for students to demonstrate their mastery of science reasoning processes and appropriate representational tools and the conventional forms of representing science data and information. The tasks required students to construct a labelled scientific diagram, data tables and a graph which provided opportunities for them to demonstrate their mastery of the representational forms used most commonly in science to communicate data. Students also responded to an attitude scale comprising items that tapped into their responses (e.g., enjoyment, interest, curiosity) to school science. Given the constraint of only being able to evaluate a sample of the domain of knowledge, the three main constructs assessed in this study were therefore:

- processes of science associated with experimental design, collecting data and reasoning with variables and data;
- literacies of science associated with representing data in the conventional forms used to communicate scientific information; and
- attitudes to school science in terms of students' responses to school science.

In order to develop precise measurement of student performance, tasks were designed so that they could be completed by students individually. Tasks were set in familiar and real-world contexts so that they were meaningful to students and care was taken to ensure that performance would not be constrained by any lack of particular science content knowledge as the students would have completed a range of different science topics during the year. All assessment tasks were unrelated to any *Primary Connections* curriculum units so that students from *Primary Connections* or comparison classes would find the tasks novel and would not be advantaged. Given that students required developed representational skills to record their responses to the tasks, the evaluation was limited to students in Years 3-7

The domain of knowledge and skills to be assessed was defined based on an analysis of the investigation process skills from Levels 1-4 of the National Scientific Literacy Progress Map (MCEETYA, 2005) and the draft literacies of science map developed by the *Primary Connections* research consultants and the Academy of Science team. From this specification of the domain, a test specification grid was developed (Appendix 1) that specified the processes and literacies that would be assessed by the tasks and the *Primary Connections* stages and year groups for which the tasks would be appropriate.

Draft instruments were developed, piloted in one school that had adopted *Primary Connections* and then were reviewed by the *Primary Connections* Reference Group which included members with expertise in educational assessment. Feedback was incorporated into the next versions of the instruments. The instruments were then trialled with two classes each of Year 3-7 students at one school which had adopted *Primary Connections* in most classes. Analysis of these scripts identified aspects of one task that were ambiguous and feedback from the trial was used to revise the task. The final forms of the tasks are attached as Appendix 2. The final forms of the test had good reliability with Cronbach alphas of greater than 0.7. The full test for Year 5-7 has a Cronbach alpha of 0.841, the literacy items component of the test had a Cronbach alpha of 0.752 and the process skills items a Cronbach alpha of 0.761. The seven-item attitude scale had a Cronbach alpha of 0.852.

The characteristics of the assessment tasks and the target populations are summarised in Figure 2.

Task	Attributes assessed	Target population
Draw Your Thumb	Observation, recording observations as a labelled diagram, make comparisons between observed objects	Years 3-7
Shoe Size	Make measurements, record measurements as a table, make simple interpretations of data, construct a bar graph (the graph was only constructed by Year 5-7 students)	Years 4-7
Rolling Ball	Identify a variable for investigation, make a prediction, write the question, plan the investigation and a table to record the results	Years 5-7
Attitude scale	Attitudes/responses to school science	Years 4-7

Figure 2: Assessment tasks, their attributes and target populations

Year 3 students only completed the Draw Your Thumb task, Year 4 students completed the Draw Your Thumb task, a limited form of the Shoe Size task and the Attitude scale, and students in Years 5-7 completed all of the tasks.

The test scripts from the pilot were used to develop a coding manual for scoring the scripts. Given that the evaluation was based on developmental view of learning and performance, the tasks were constructed to be open in the sense of allowing students to respond at the level at which they were capable. The coding scheme therefore used a polytomous approach which gave no credit, partial credit or higher levels of credit depending on the level of performance demonstrated. Two researchers then dual coded a sample of scripts from the pilot so that discrepancies in coding could be used to identify aspects of the coding scheme that were not sufficiently clearly defined. This process continued until the two coders consistently produced agreed codes.

Four pre-service science education students were recruited to code the scripts from the evaluation. The students completed a training session which involved an explanation of the research approach, the design of the tasks and the design of the coding scheme. The coders worked through coding a set of scripts that had previously been coded by the researchers and discrepancies in coding helped identify aspects of the coding that were problematic. After further explanation of the coding scheme and further trial codings, the coders reached the point of consistently producing agreed codes. Throughout the coding process, each coder focused on one of the assessment tasks and one of the researchers dual marked batches of scripts for each coder to ensure that consistency of coding was maintained. The final form of the coding guide is attached as Appendix 3.

Procedure

Once the research design for the evaluation had been endorsed by the *Primary Connections* Reference Group, instrument piloting and the development of coding schemes were completed. A notional sampling frame was established to support the recruitment of a sample stratified by science program, year level and socioeconomic index band. Ethics clearance was first obtained at jurisdictional level and then at school level. Teachers and then students were then invited to participate in the study. Active written consent was sought from parents for the participation of students in the testing program. The tests were administered by the classroom teachers following a detailed protocol provided by the researchers and completed scripts were returned by mail to the research team for coding and analysis

Sampling and Demographic Data

The sampling frame for the study was limited to the two jurisdictions in which there was widespread implementation of *Primary Connections* in schools i.e., Western Australia and Queensland. Schools were recruited within these jurisdictions to gain access to teachers and classes that had either used *Primary Connections* for their science program or were teaching science using other programs. *Primary Connections* classes were taught by a teacher who had received a minimum of two-days of *Primary Connections* teacher professional learning and had included a minimum of two *Primary Connections* units in their program for the year. Most *Primary Connections* classes had taught only two units during the year. There is no assumption of fidelity of implementation of the *Primary Connections* teaching and learning model by the teachers of the *Primary Connections* classes. Many teachers would have taught the *Primary Connections* units for only the first or second time.

Comparison classes were recruited from a pool of schools that were teaching science using other programs. Comparison classes were recruited from teachers who volunteered to participate in the study and were therefore likely to be confident about their science teaching. Data gathered from these classes in the evaluation indicated that the students enjoyed their science lessons.

It was recognised that students' general literacy levels would influence their ability to respond to the tests and that socioeconomic index provides a proxy for general literacy levels within schools. *Primary Connections* and comparison classes were therefore recruited within each jurisdiction based on a notional sampling frame that was stratified by year level and socioeconomic index band. The notional sampling frame was based on recruiting 200 students from eight teachers' classes in each of Years 3-7 from both *Primary Connections* and from comparison classes.

Table 1: Notional sampling frame

Stage	Year	Primary Connections classes		Comparison classes	
		Number of teachers	Number of pupils	Number of teachers	Number of pupils
1	3	8	200	8	200
2	4	8	200	8	200
	5	8	200	8	200
3	6	8	200	8	200
	7	8	200	8	200

Socioeconomic index bands used by Queensland Department of Education Training and the Arts and by the WA Department of Education and Training were used to identify pools of *Primary Connections* and comparison schools within similar bands and these schools were approached to participate in the study. The recruitment process progressed in a number of stages: selection of pools of schools matched on socioeconomic index bands; recruitment of schools from the pools; recruitment of classes from schools; and, recruitment of students within classes which required active written parental consent. Given the staged nature of the recruitment process and the need for parental consent for participation it was not possible to recruit a sample that had equal numbers in the cells of the notional sampling frame.

More schools, classes and students were recruited from WA than Queensland, from *Primary Connections* than comparison schools and from Years 4, 6 and 7 than from Years 3 and 5. In total, 1467 students participated in the testing program and these were recruited from a total of 26 schools. The characteristics of the sample are outlined in the following section.

Demographic Data

The characteristics of the sample are described first in terms of jurisdictions, science program, year level and gender, and then in terms of socioeconomic index band, ATSI and LBOTE backgrounds.

<u>Jurisdictions, science program, year level and gender</u>

The numbers of schools and students recruited from each jurisdiction are summarized in Table 2 and the breakdown of student numbers by jurisdiction and year group is summarized in Table 3.

Table 2: Numbers of students and schools by jurisdiction

Jurisdiction	Number of students	Number of schools
WA	1113	18
Queensland	354	8
Overall	1467	26

More students and schools were recruited from WA than Queensland and less students were recruited at Year 3 and 5 than at Year 4, 6 and 7 (Table 3).

Table 3: Number of students by jurisdiction and year group.

Jurisdiction	Year 3	Year 4	Year 5	Year 6	Year 7	Total
WA	251	189	142	290	241	1113
Queensland	0	124	79	62	89	354
Overall	251	313	221	352	330	1467

More students were recruited from *Primary Connections* classes (905, 62%) than from comparison classes (562, 38%) and the breakdown of numbers by year level is presented in Table 4.

Table 4: Numbers of students by type of science program and year group.

Science program	Year 3	Year 4	Year 5	Year 6	Year 7	Total
Primary Connections classes	189	176	150	199	191	905
Comparison classes	62	137	71	153	139	562
All classes	251	313	221	352	330	1467

Of the 1467 students who participated in the testing program, 747 (51%) were male and 710 (49%) were female. Males and females were evenly distributed between *Primary Connections* and comparison classes (Table 5).

Table 5: Numbers of students by type of science program and gender.

Gender	Primary Connections classes	Comparison classes
Male	460 (51%)	287 (51%)
Female	436 (48%)	274 (49%)
No gender given	9	

<u>Key finding 1</u>. A total of 1467 students recruited from 26 schools participated in the assessments. More students were recruited from *Primary Connections* classes than from comparison classes. Males and females were distributed equally between the *Primary Connections* and comparison groups.

<u>Socioeconomic index band, ATSI and LBOTE backgrounds</u>

WA DET and QLD DETA classify schools by jurisdiction specific socioeconomic index bands. Pools of schools were identified within High (Bands 6-8) and Low (Bands 2-4) bands in WA and within High (Bands 9-10) and Low (Bands 7-8) bands in QLD. Classes and students were recruited to ensure the *Primary Connections* and comparison samples had similar proportions of students from schools classified as high and low socioeconomic index. These data are reported in Table 6. Overall the *Primary Connections* sample had a slightly lower proportion (66%) of students from high socioeconomic index schools than the comparison sample (70%).

Table 6: Number and per cent of students sampled from schools classified as high and low socioeconomic index

Socioeconomic index	WA		QLD		Total	
	Number	Per cent	Number	Per cent	Number	Per cent
Primary Connections classes						
High	486	65	110	71	596	66
Low	264	35	45	29	309	34
Total					905	
Comparison classes						
High	256	71	137	69	393	70
Low	107	29	62	31	169	30
Total					562	

When students completed the assessments, they recorded on their answer booklets whether they were of Aboriginal or Torres Straits Islander descent (ATSI) or not, and whether someone in their home spoke a language other than English (Language Background Other than English, LBOTE) or not. The numbers of students who were ATSI, not ATSI, LBOTE and not LBOTE in the samples are reported in Tables 7-9.

Table 7: Numbers of students of Aboriginal and Torres Straits Islander (ATSI) descent

ATSI	Year 3	Year 4	Year 5	Year 6	Year 7	Total
ATSI	11	32	28	27	14	112
Not ATSI	240	279	193	317	313	1342
No response						13
Overall	251	311	221	344	327	1467

One hundred and twelve Indigenous students participated in the testing program representing 8% of the total. Three hundred and six LBOTE students participated in the testing program representing 21% of the total.

Table 8: Numbers of students with a Language Background Other Than English (LBOTE)

Language background	Year 3	Year 4	Year 5	Year 6	Year 7	Total
LBOTE	45	65	45	73	78	306
Not LBOTE	205	247	176	275	251	1154
No response						7
Overall	250	312	221	348	329	1467

The proportion of ATSI and LBOTE students in the *Primary Connections* and comparison groups are reported in Table 9. The comparison group had a higher representation of both ATSI and LBOTE students than the *Primary Connections* group.

Table 9: Numbers of students by science program, ATSI and LBOTE background

Variable	Primary Connections classes	Comparison classes	Total
ATSI	47 (5%)	65 (12%)	112 (8%)
LBOTE	135 (15%)	171 (30%)	306 (21%)

Key finding 2. A slightly higher proportion of students in the *Primary Connections* group came from schools with a low socioeconomic status index than the comparison group. Eight per cent of the students who participated in the assessments identified as Indigenous and 21% identified as being LBOTE. The comparison group had a higher proportion of Indigenous and LBOTE students than the *Primary Connections* group.

Coding of Student Responses
The coding guide provided for coding of components of task performance at various levels of performance. Each component was considered an item for data coding. For example, Year 5-7 students were asked to identify the relationship between shoe size and length from their table of data. The coding scheme (Figure 3) allocated '2' for a response that described the relationship in algebraic terms, '1' for a general description of the relationship and '0' for other responses that gave no evidence of being able to identify and describe the relationship between the variables.

Shoe Size task, Year 5-7 , Item 15, processes of science		**Interpreting data: identifies relationship between variables**
Code 2	Identifies algebraic relationship	Shoe length is shoe size plus 10 cm
Code 1	Describes simple relationship	Shoe length increases with shoe size or higher shoe sizes are longer or the bigger the shoe size the longer the shoe or shoe size goes up by 1cm each time [I (P&E) Level 3]
Code 0	Other	

Figure 3: Coding scheme for the science process skill of identifying relationships between variables from a table of data about shoe sizes and lengths

Data Analysis
Given that different year groups completed different tasks, initially data was aggregated for Year 3 students in *Primary Connections* and comparison classes, for Year 4 students and for Years 5-7 students. Per cent students scoring at each level of performance and item means were calculated for each item. Mean scores for items on each task were aggregated for science processes and for literacies of science. Performance of *Primary Connections* and comparison classes on science processes and literacies of science were compared using two-tailed t tests for independent samples. To determine the magnitude of the impact of *Primary Connections* on students' achievement of literacies of science and science processes, Cohen's *d* effect sizes were calculated as a difference between the mean scores for *Primary Connections* and comparison groups divided by the pooled standard deviation for the means (Cohen, 1988). Values of <0.2 are considered small, 0.2 – 0.5 moderate and >0.5 substantial. Data were also available for student gender, ATSI and LBOTE status and therefore comparisons were also made for these groups drawn from *Primary Connections* and from comparison classes to determine the impact of the program on various groups of students.

Results

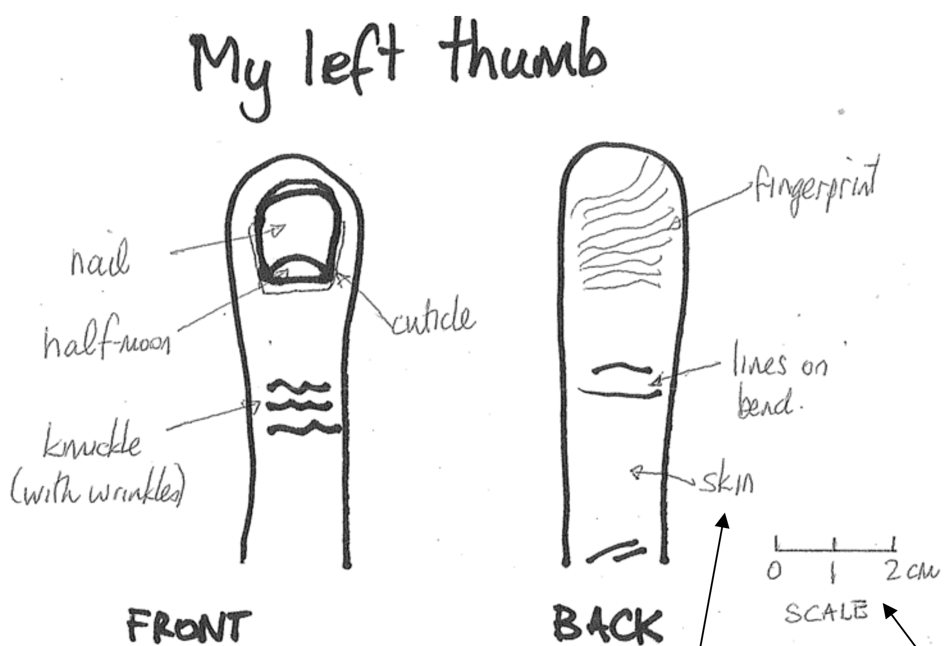
Results for student performance are reported by task and sub-task. Comments are provided summarising and interpreting performance, and where appropriate linking levels of performance to progress map outcome levels. The tasks were designed to be open ended to allow students to respond at their level of competence and consequently the results show the number of students demonstrating various levels of performance. It should be noted that the higher levels of performance on these tasks do not represent expected levels of performance for students of this age group and some of the performance levels would only be expected of typical lower secondary students.

Task 1: Draw Your Thumb Task

This task was attempted by students in Years 3 to 7. Students observed and drew a scientific labelled diagram of their thumb. They were then asked to compare their thumb to the finger next to the thumb. This task assessed process of observing and comparing observations and the literacies associated with representing observations as a labelled diagram. Figure 4 below illustrates the key components of a scientific labelled diagram.

Title
All diagrams need a title. The title should describe the diagram to the viewer.

Accuracy
Accuracy of diagram depends on accurate observation and having skills to represent the observations as a labelled diagram. Accurate diagrams are a good size and accurately represent the main features of the object as a scientific diagram.



Amount of information
This was an open task and therefore students decided how extensive their representation would be. Simple representations of the thumb showed just one view of the thumb while extended representations either show more than one view of the thumb or show how the thumb is attached to the palm of the hand.

Labelling
Labelling is required to identify and communicate features of the thumb to the viewer of the diagram. Labels should connect to the diagram with a line that touches or points directly to the part being labelled.

Thumb size
Scientific diagrams need to include some form of scale so that the viewer has an indication of the size of the object represented in the diagram.

Figure 4: Components of a scientific labelled diagram of a thumb

Data for students' performance on the Draw Your Thumb task for the Year 3 to 7 students are summarised in Tables 10-12. Table 10 reports performance of the Years 3 and 4 students on the Draw Your Thumb task. Data for literacies of science are reported in italics and data for processes of science are reported in normal font. Levels of performance for each aspects of the task are reported for students from *Primary Connections* classes (PC) and for students from comparison classes (Not PC).

Table 10: Performance on the Draw Your Thumb task for Year 3 and 4 students from *Primary Connections* classes and from comparison classes

Aspect	Performance standard	Per cent of students	
		PC	Not PC
		(n = 365)	(n = 199)
Title for diagram	*No title is provided*	*74*	*94*
	Simple title	*23*	*6*
	Descriptive title	*3*	*0*
Accuracy of diagram	Diagram does not effectively communicate the features of the thumb	58	61
	Diagram shows some features	34	31
	Diagram is accurate	8	8
Amount of information recorded	*No information recorded*	*2*	*2*
	Simple representation of thumb	*67*	*87*
	Provides extended representation	*31*	*11*
Labelling of diagram	*No labels*	*18*	*31*
	Limited or inaccurate labelling	*64*	*58*
	Effective labelling	*18*	*11*
Size of thumb	*No indication of size*	*99*	*100*
	Some indication of size	*1*	*0*
Compares thumb and forefinger	No valid differences	22	33
	Identifies one or two valid differences	55	52
	Identifies three or more valid differences	23	15

Note. *Literacies of science are in italics,* processes of science are in normal font

Most of the Year 3 and 4 students did not give their diagram a title, produced a diagram that was not sufficiently accurate to effectively communicate features of their thumb, provided simple rather than extended representations, provided limited or inaccurate labelling, gave no indication of the size of their thumb, however, they were able to identify one or two valid differences between their thumb and forefinger. On all aspects a higher proportion of students from *Primary Connections* classes demonstrated the higher levels of performance than the students from comparison classes.

Table 11: Performance on the Draw Your Thumb task for Year 5, 6 and 7 students from *Primary Connections* classes and from comparison classes

Aspect	Performance standard	Per cent of students	
		PC	Not PC
		(n = 540)	(n = 363)
Title for diagram	*No title is provided*	*71*	*79*
	Simple title	*21*	*17*
	Descriptive title	*9*	*4*
Accuracy of diagram	Diagram does not effectively communicate the features of the thumb	25.6	28
	Diagram shows some features	44	51
	Diagram is accurate	30.6	21
Amount of information recorded	*No information recorded*	*1*	*0*
	Simple representation of thumb	*50*	*75*
	Provides extended representation	*49*	*25*
Labelling of diagram	*No labels*	*10*	*23*
	Limited or inaccurate labelling	*46*	*54*
	Effective labelling	*44*	*23*
Size of thumb	*No indication of size*	*98*	*99*
	Some indication of size	*2*	*1*
Compares thumb and forefinger	No valid differences	24	20
	Identifies one or two valid differences	37	43
	Identifies three or more valid differences	39	37

Note. *Literacies of science are in italics,* processes of science are in normal font

Most of the Year 5-7 students did not give their diagram a title, drew diagrams that did communicate features of a thumb and many were accurate, provided simple or extended representations, labelled their diagram, gave no indication of size, however, they did identify valid differences between their thumb and forefinger. On all aspects except comparison, a greater proportion of students from *Primary Connections* classes achieved higher levels of performance than students from comparison classes.

Table 12 shows data aggregated for Year 3-7 students and reports mean scores for each aspect of the Draw Your Thumb task. For all aspects, the mean scores attained by students from *Primary Connections* classes were higher than those attained by students from comparison classes. Similarly, the overall mean scores for literacies of science and for processes of science were higher for students from *Primary Connections* classes than for students from comparison classes.

Table 12: Per cent of Year 3-7 students at various performance standards for each aspect of the thumb task and mean scores on aspects for students from *Primary Connections* and from comparison classes

Aspect	Performance	Primary Connections classes (n =905)		Comparison classes (n =562)	
		Per cent	Mean score on aspect	Per cent	Mean score on aspect
Title for diagram	*No title is provided*	*72*	*0.34/2*	*84*	*0.18/2*
	Simple title	*22*		*14*	
	Descriptive title	*6*		*2*	
Accuracy of diagram	Diagram does not effectively communicate the features of the thumb	39	0.82/2	40	0.76/2
	Diagram shows some features	40		44	
	Diagram is accurate	21		16	
Amount of information recorded	*No information recorded*	*1*	*1.41/2*	*1*	*1.19/2*
	Simple representation of thumb	*57*		*79*	
	Provides extended representation	*42*		*20*	
Labelling of diagram	*No labels*	*13*	*1.21/2*	*26*	*0.93/2*
	Limited or inaccurate labelling	*53*		*56*	
	Effective labelling	*34*		*18*	
Size of thumb	*No indication of size*	*99*	*0.01/1*	*100*	*.00/1*
	Some indication of size	*1*		*0*	
Compares thumb and forefinger	No valid differences	23	1.10/2	24	1.05/2
	Identifies one or two valid differences	44		47	
	Identifies three or more valid differences	33		29	
Mean total score for processes of science			**1.92/4**		**1.81/4**
Mean total score for literacies of science			**2.97/7**		**2.30/7**

There was no clear developmental pattern in titling diagrams. Students were not prompted to provide a title. The younger students were able to provide a simple title if they recognized the need for one. Very few students provided a descriptive title. There was a trend to increased levels of proficiency in accuracy of diagrams which requires good observational and representational skills. Less than 10% of the Year 3 and 4 *Primary Connections* students produced accurate diagrams while almost one-third for the Year 5-7 *Primary Connections* students did so. *Primary Connections* students were more likely to provide extended representations that included either more than one view of the thumb or how the thumb was attached to the palm of the hand. Older students and *Primary Connections* students were much more likely to provide effective labelling of their diagram than younger students.

Literacies of titling and labelling of diagrams are crucial for effective communication of information about the object that has been observed. Very few students recognized the need or had the skills to communicate to the reader the size of the thumb by including a scale. The majority of students were able to observe their thumb and forefinger, identify differences and record them. There was a developmental trend in older students identifying more differences than younger students. Making such comparisons is at Level 2 of the processing data aspect of Investigation on the National Scientific Literacy Progress Map (MCEETYA, 2005).

<u>Key finding 3</u>. On the Draw Your Thumb task most students did not give their diagram a title or a scale to indicate the size of their thumb. Older and *Primary Connections* students were much more effective in drawing accurate diagrams, providing extended representations and effectively labelling their diagrams than younger students and students from comparison classes. Most students were able to identify valid differences between their thumb and forefinger and thus demonstrate Level 2 of the processing data aspect of investigating.

Task 2: Shoe Size Task

The Shoe Size task required students to make measurements of the length of shoe prints, record the measurements in a table and make some simple interpretations of the data. Students in Years 5-7 were also asked to plot a bar graph of the results and make more complex interpretations of data.

Part 1: Measuring Shoe Size and Recording Results as a Table

Numerical data should be recorded in tabular form so that the data are represented in a structured manner so that a reader can identify and comprehend the data. Figure 5 below illustrates the key components of a scientific table.

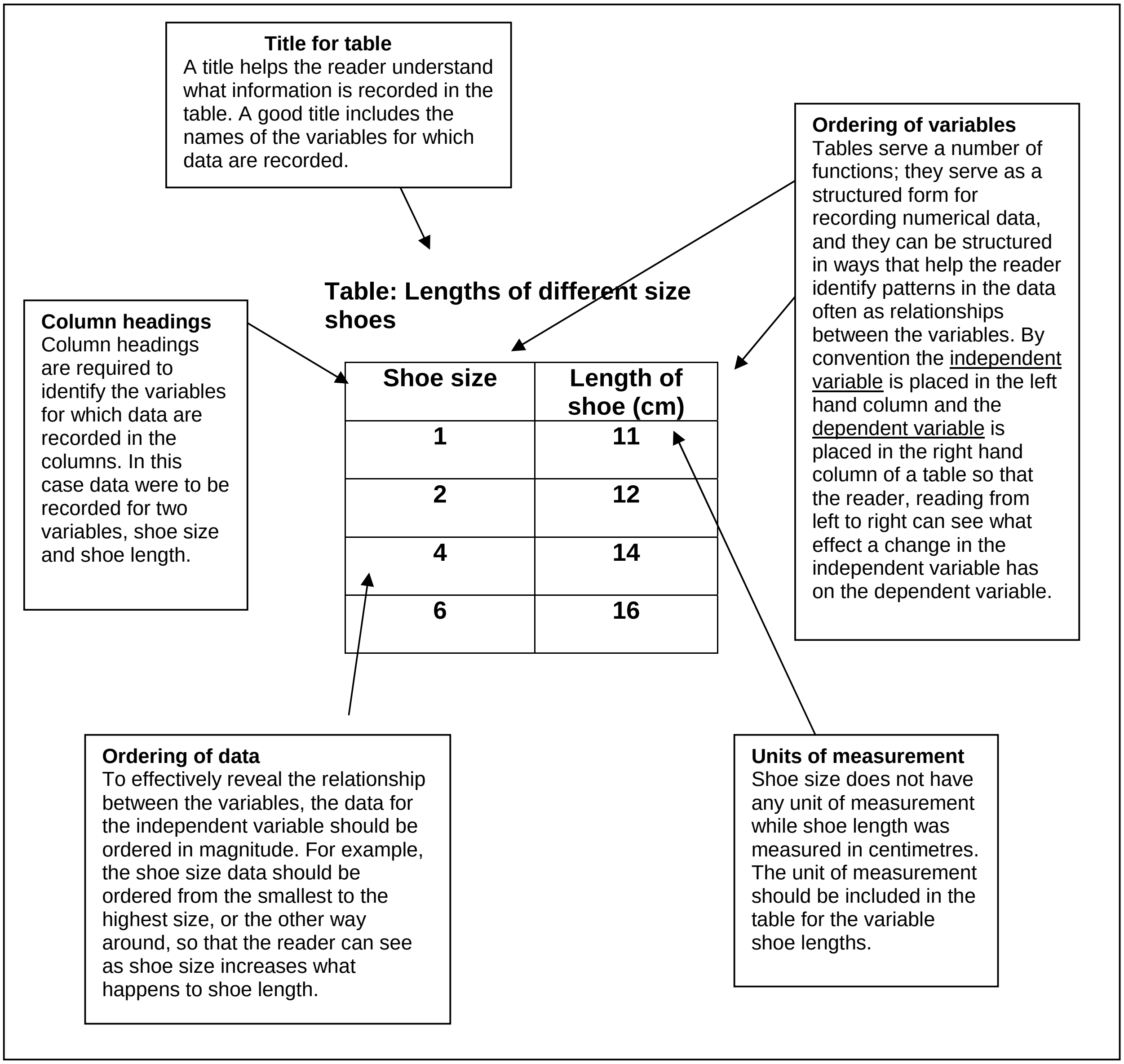


Figure 5: Key components of a results table

Performance of students on the Shoe Size task is reported in Tables 13-18.

Table 13: Performance on the Shoe Size task for measuring and constructing a table for Year 4 students from *Primary Connections* classes and from comparison classes

Aspects of measurement and table construction	**Performance standard**	**Primary Connections classes (n = 176)**		**Comparison classes (n = 137)**	
		Per cent	**Mean score**	**Per cent**	**Mean score**
Accuracy of measurements	Other	16	1.59/2	28	1.34/2
	Measurements are somewhat inaccurate	9		10	
	Measurements are accurate	75		62	
Results recorded in a table	*Non-tabular form*	*38*	*0.62/1*	*42*	0.58/1
	Tabular form	*62*		*58*	
Title for table	*No title*	*90*	*0.10/2*	*99*	*0.02/2*
	Simple title	*10*		*0.5*	
	Descriptive title	*0*		*0.5*	
Column headings for table	*No column headings*	*73*	*0.41/2*	*79*	*0.28/2*
	1 column heading	*13*		*15*	
	2 column headings	*14*		*6*	
Units included in table	*No units included*	*30*	*0.70/2*	*50*	*0.50/2*
	Units included	*70*		*50*	
Ordering of data	*Data not ordered*	*53*	*0.47/1*	*67*	*0.33/1*
	Data in order of magnitude	*47*		*33*	
Ordering of variables	*Variables not ordered*	*36*	*0.64/1*	*49*	*0.51/1*
	Variables are ordered by column	*64*		*51*	

Note. *Literacies of science are in italics,* processes of science are in normal font

Making measurements using standard units of measurements is at Level 3 of the conducting investigations aspect of investigating while recording numerical data in tabular form is at Level 3 of processing data (MCEETYA, 2005). Most of the Year 4 students made accurate measurements (all four measurements were within 0.4 cm of the true value) and recorded their measurements in tabular form with units of measurement, however, most did not give their table a title nor did they include column headings for the variables recorded in the table. The students were more likely to order the independent and dependent variables from left to right in the table than to order the data in order of magnitude for the independent variable. On all aspects, students from *Primary Connections* classes performed at higher levels than students from comparison classes.

Performance of the Year 5-7 students on the measurement and table construction aspects of the Shoe Size task was very similar to that of the Year 4 students. Only on the inclusion of column headings in tables did the older students clearly out-perform the younger students. Data are reported for the Year 5-7 students in Table 14.

Table 14: Performance on the Shoe Size task for measuring and constructing a table for Year 5, 6 and 7 students from *Primary Connections* classes and from comparison classes

Aspect of table construction	Performance standard	Primary Connections classes (n = 540)		Comparison classes (n = 363)	
		Per cent	Mean score	Per cent	Mean score
Accuracy of measurements	Other	12	1.67/2	18	1.56/2
	Measurements are somewhat inaccurate	9		8	
	Measurements are accurate	79		74	
Results recorded in a table	*Non-tabular form*	*34*	*0.66/1*	*44*	*0.56/1*
	Tabular form	*66*		*56*	
Title for table	*No title*	*92*	*0.12/2*	*96.5*	*0.04/2*
	Simple title	*4*		*3*	
	Descriptive title	*4*		*0.5*	
Column headings for table	*No column headings*	*56*	*0.76/2*	*69*	*0.50/2*
	1 column heading	*11*		*12*	
	2 column headings	*33*		*19*	
Units included in table	*No units included*	*31*	*0.69/1*	*26*	*0.74/1*
	Units included	*69*		*74*	
Ordering of data	*Data not ordered*	*54*	*0.46/1*	*62*	*0.38/1*
	Data in order of magnitude	*46*		*38*	
Ordering of variables	*Variables not ordered*	*35*	*0.65/1*	*42*	*0.58/1*
	Variables are ordered by column	*65*		*58*	

Note. *Literacies of science are in italics,* processes of science are in normal font

The majority of Year 5-7 students made accurate measurements using standard units demonstrating Level 3 of the conducting investigations aspect of investigating. A majority also recorded their numerical data in tabular form demonstrating Level 3 of the processing data aspect of investigating (MCEETYTA, 2005). In the context of this task, ordering the independent and dependent variables from left to right and ordering the data for the independent variable by magnitude are critical for effective communication of the data and for identifying the relationship between the variables. The Year 5-7 *Primary Connections* students performed best on these aspects of the task, however, less than half ordered their data by magnitude and only two-thirds ordered the variables correctly from left to right.

Part 2: Shoe Size and Length – Graphing Data

Students in Years 5-7 were also asked to plot a bar graph of their results for shoe sizes and lengths. Figure 5 below illustrates the key components of a bar graph. Data for Year 5-7 students' performance on the graphing task are summarised in Table 15.

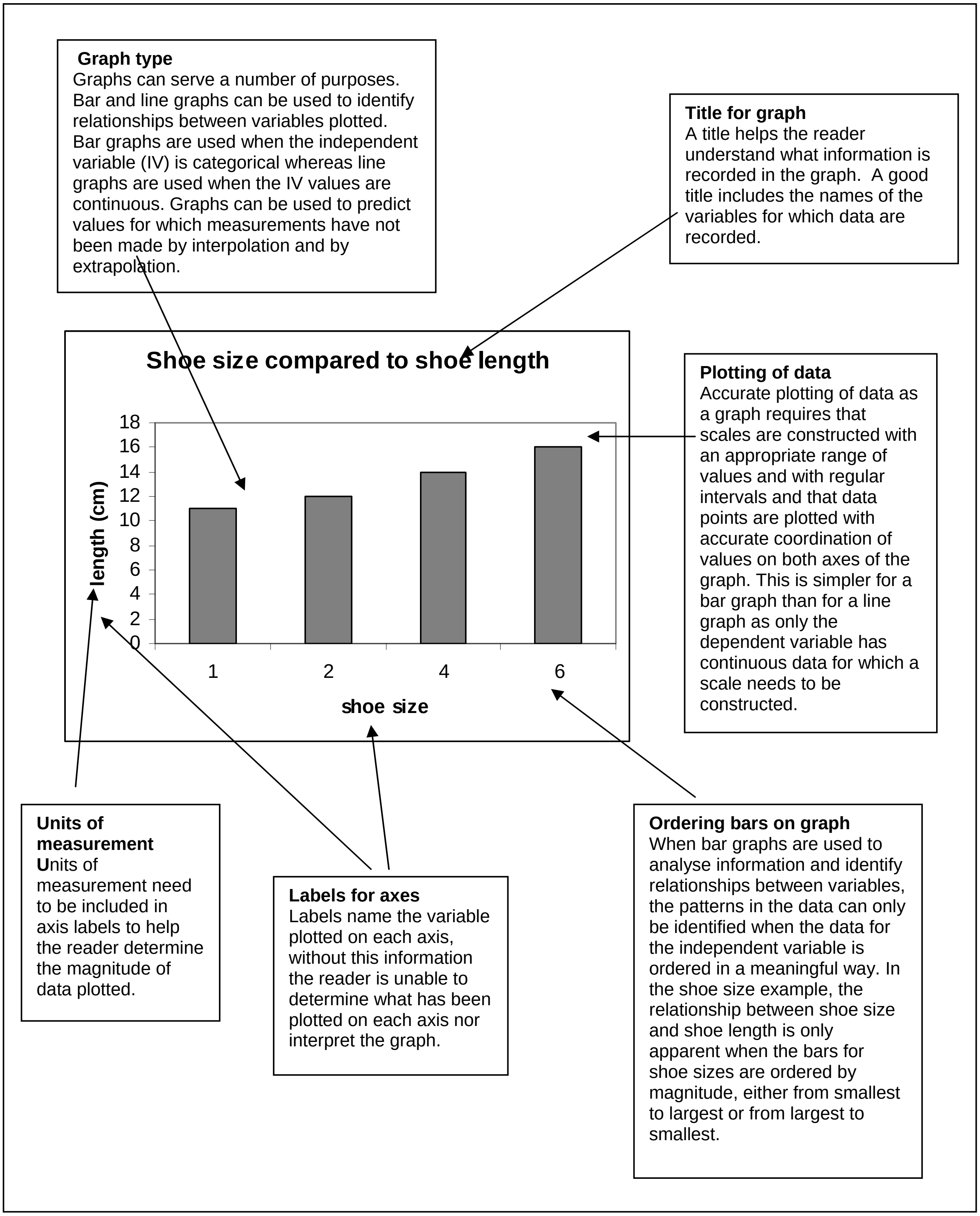


Figure 6: Key components of a bar graph

Table 15: Performance on graphing shoe size data for Year 5 - 7 students from *Primary Connections* classes and from comparison classes

Aspect of graph construction	Performance standard	Primary Connections classes (n = 540)		Comparison classes (n = 363)	
		Per cent	Mean score	Per cent	Mean score
Understands what a bar graph is	*Other type of graph*	*8*	*0.92/1*	*6*	*0.94/1*
	Plots a bar/column graph	*92*		*94*	
Graph title	*No title*	*72*	*0.38/2*	*78*	*0.28/2*
	Simple title	*18*		*17*	
	Descriptive title	*10*		*5*	
Labels axes	*Not correctly labelled*	*48*	*0.86/2*	*58*	*0.64/2*
	Labels one axis	*18*		*21*	
	Labels both axes	*34*		*21*	
Units of measurement on graph	*No units*	*59*	*0.41/1*	*54*	*0.46/1*
	Units included	*41*		*46*	
Plotting of data	Inaccurate plotting	35	1.16/2	52	0.89/2
	Plotting accurate	13		8	
	Plotting and scale accurate	52		40	
Ordering of bars on graph	*Not ordered*	*39*	*1.12/2*	*53*	*0.88/2*
	Ordered high to low	*9*		*6*	
	Ordered low to high	*52*		*41*	

Note. *Literacies of science are in italics,* processes of science are in normal font

Most students were able to plot a bar graph, however, most did not give their graph a title, did not label the axes of the graph and did not include the units of measurement with the axis label for the dependent variable shoe length. A significant number of students did not plot their data points accurately, particularly from the comparison classes, however, most students from *Primary Connections* classes plotted data points accurately on accurately constructed scales. A majority of students from *Primary Connections* classes ordered the bars on their graph in order of magnitude of the independent variable (shoe size) which enabled the reader to identify the relationship between the independent (shoe size) and dependent (shoe length) variables. A majority of students from comparison classes did not order the bars by magnitude. Plotting bar graphs is at Level 3 of the processing data aspect of investigating (MCEETYA, 2005).

Part 3: Interpretation of Shoe Size Task Results

<u>Year 4 students</u>

Students were asked to state how long a size 2 is. This required them to either measure the shoe outline or look up their results in the table. Students were then asked to determine how much longer a size 4 shoe was than a size 2 shoe. This required students to read the shoe lengths from the table and subtract the length of the size 2 shoe (12 cm) from the length of the size 4 shoe (14 cm) and give an answer of 2 cm. This task involved a simple comparison which is at Level 2 of the processing data aspect of investigating. Students were also asked to predict/determine what size shoe Katy should wear if her feet were 11.5cm long. Data for performance on the interpretation tasks for the Year 4 students are summarised in Table 16.

Table 16: Performance on interpretation of Shoe Size task results for Year 4 students from *Primary Connections* classes and from comparison classes

Aspect of data interpretation	Performance standard	Primary Connections classes (n = 176)		Comparison classes (n =137)	
		Per cent	Mean score	Per cent	Mean score
Reading data: reads length of shoe from table	Length incorrect	7	1.77/2	14.5	1.56/2
	Length correct with no units	10		14.5	
	Length correct with units	83		71	
Interpreting data: comparison of shoe lengths	Difference not correct	29	1.36/2	37	1.14/2
	Correct difference with no units	5		12	
	Correct difference with units	66		51	
Interpretation of data to answer question	Incorrect answer	43	0.57/1	47	0.53/1
	Correct answer	57		53	

Most of the Year 4 students were able to read their table of data, identify the length of a size 2 shoe and report its length with units of measurement. A majority of the students was able to compare the length of size 4 and size 2 shoes and report the correct difference with units of measurement and were able to compare the length of Katy's feet with the shoe lengths and identify the size of shoe that would fit her feet. These students demonstrated attainment of Level 2 of the processing data aspect of investigating. Students from *Primary Connections* performed better than students from comparison classes on all three aspects of this task.

<u>Year 5, 6 and 7</u>

This section of the task was slightly different for Year 5, 6 and 7 students than for the Year 4 students.

Students were asked to determine how much longer a size 4 shoe was than a size 2 shoe. This required students to read the shoe lengths from the table and subtract the length of the size 2 shoe (12 cm) from the length of the size 4 shoe (14 cm) and give an answer of 2 cm. This task involved a simple comparison which is at Level 2 of the processing data aspect of investigating.

They were then asked to identify the relationship between shoe size and shoe length. This required students to describe the relationship in terms of shoe length increasing as shoe size increases (Level 3 / processing / investigating) or to describe the relationship in algebraic terms, shoe length is shoe size plus 10, which is at Level 3 of the Reasoning Mathematically aspect of the Working Mathematically outcome in the Western Australian Mathematics Progress Maps (Curriculum Council, 2005).

Students were also asked to predict/determine the length of a size 3 shoe for which they did not have data. This required students to interpolate from the pattern in the graph. Data for performance on the interpretation tasks for the Year 5-7 students are summarised in Table 17.

Table 17: Performance on interpretation of Shoe Size task results for Year 5, 6 and 7 students from *Primary Connections* classes and from comparison classes

Aspect of data interpretation	Performance standard	Primary Connections classes (n =540)		Comparison classes (n =363)	
		Per cent	Mean score	Per cent	Mean score
Interpreting data: comparison of shoe lengths	Difference not correct	24	1.46/2	18	1.61/2
	Correct difference with no units	6		3	
	Correct difference with units	70		79	
Interpretation of data: identifies relationship between variables	No valid relationship	55	0.59/2	58	0.54/2
	Describes simple relationship	32		30	
	Identifies algebraic relationship	13		12	
Interpreting data: interpolates from existing data to predict length of a shoe	Incorrect prediction	27	1.38/2	26	1.41/2
	Correct prediction with no units	9		7	
	Correct prediction with units	64		67	

A large majority of the Year 5-7 students was able to compare the lengths of two shoes and report the correct difference with units of measurement (Level 2 /processing data / investigating). A majority of students were, however, unable to identify and describe the relationship between shoe size and shoe length; only one-third were able to explain that as shoe size increased so did shoe length (Level 3 / processing data / investigating) and only one-tenth identified the relationship in algebraic terms (Level 3 / Reasoning mathematically / working mathematically).

Mean literacies of science and science processes scores for Year 4 and for Years 5-7 students are reported in Table 18. On these measures, students from *Primary Connections* classes outperformed students from comparison classes.

Table 18: Mean literacies of science and science processes scores on the shoe task for Year 4 and Years 5-7 students from *Primary Connections* classes and from comparison classes

Component and Year group	Primary Connections classes (Yr 4 n=176; Yrs 5-7 n=540)		Comparison classes (Yr 4 n=137; Yrs 5-7 n=363)	
	Mean score	Sd	Mean score	Sd
Literacies of science				
Year 4	*2.93/8*	*1.917*	*2.22/8*	*1.962*
Years 5-7	*7.04/16*	*3.755*	*5.99/16*	*3.284*
Processes of science				
Year 4	5.30/7	1.764	4.58/7	2.085
Years 5-7	6.26/10	2.616	6.00/10	2.739

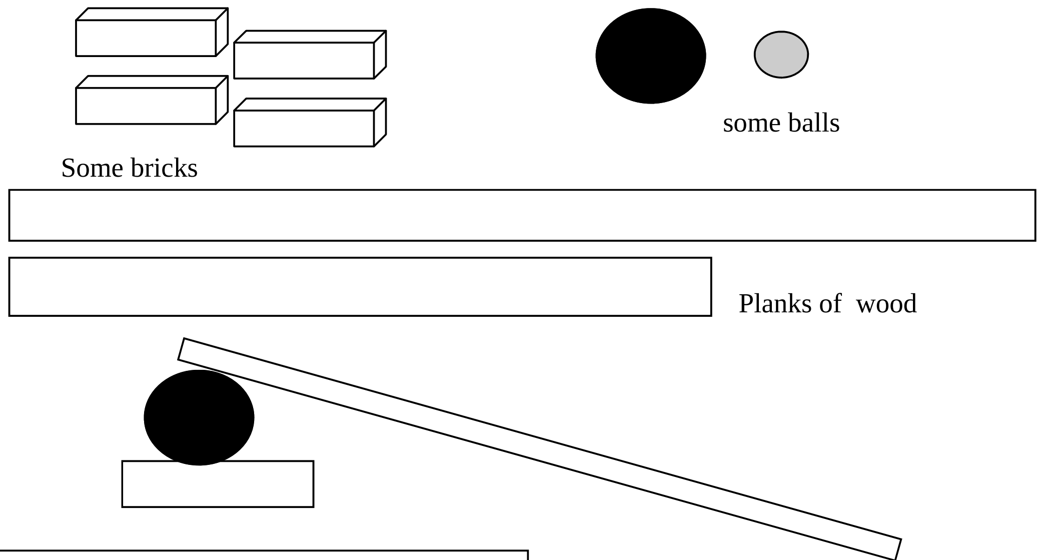
Key finding 4. On the Shoe Size task most Year 4 and Year 5-7 students could make accurate measurements (Level 3 / conducting / investigating) and record data in tabular form with units of measurement (Level 3 / processing / investigating), and construct a bar graph (Level 3 / processing / investigating). Most did not give titles to tables or graphs or give column headings in tables, however, they were not prompted by the task. Ordering variables in the table, data by magnitude in the table and ordering bars on the graph were critical for identifying patterns in the data. Students from *Primary Connections* classes outperformed students from comparison classes on these aspects and were also more successful with accurate plotting of data on the graph. A majority of Year 4 and Year 5-7 students were able to successfully complete the Level 2 data interpretations (comparisons), however, a majority of Year 5-7 students was not able to successfully complete the Level 3 data interpretations (identify relationships between variables). Almost two-thirds of Year 5-7 students were able to interpolate within the data to predict an unmeasured shoe length. Students from *Primary Connections* classes outperformed students from comparison classes on overall means for literacies of science and science processes.

Task 3: Rolling Ball Task

Only Year 5-7 students completed the Rolling Ball task which required students to demonstrate competencies associated with the planning and conducting aspects of investigating. Students were given a diagrammatic representation of a fairly familiar context of rolling balls down a slope. Students were required to identify a variable that might affect how far a ball will roll (independent variable), then predict what affect the variable would have on distance rolled (the dependent variable), and then write a question for the investigation. Following this, students were asked to identify the variables they would change, measure and keep the same in their investigation, and then construct a table that they would use to record their results. Constructing the table gave students an opportunity to demonstrate their awareness of the need to conduct repeat trials and average the results.

Figure 7 shows details of the planning task. Data for students' performance on the planning task for Year 5-7 students are summarised in Table 19.

What to do:
Kim and Lee were planning how to investigate things that affect how far a ball will roll when placed on a slope. They were trying out some equipment shown in the diagram below.
Imagine you are working with Kim and Lee on this investigation.



1. Identify **one thing** that you could investigate that might affect how far a ball will roll.
Answer: any one of size of ball, type of ball, length of plank, number or height of bricks, angle of plank

2. What effect do you think this **thing** would have on how far a ball will roll?
Answer:
It will change/affect the distance the ball rolls or the speed/rate the ball rolls

3. Write the question that you would be trying to answer if you did this investigation.
Answer: A good question will relate the dependent variable to the independent variable. For example: "Will the ball roll further if there are more bricks stacked up? "
OR "The more bricks the further the ball will roll".
A poor question will not relate two variables. For example: "What effect will the number of bricks have?"

Figure 7: Question and sample answers for planning the Rolling Ball investigation

Table 19: Performance on the Rolling Ball investigation for Year 5, 6 and 7 students from *Primary Connections* classes and from comparison classes

Aspect of investigation planning	**Performance standard**	**Primary Connections classes (n =540)**		**Comparison classes (n =363)**	
		Per cent	**Mean score**	**Per cent**	**Mean score**
Identifies an independent variable	Other	19	0.81/1	18	0.82/1
	Identifies a potential independent variable	81		82	
Makes a prediction	Other	38	0.62/1	40	0.60/1
	Makes a prediction ie says how the independent variable is expected to affect the dependent variable	62		60	
Writes a question for investigation	Other	39	0.94/2	37	0.87/2
	Question is incomplete	27		38	
	Complete and accurate question	34		25	
Identifies a variable to change	Other	41	0.59/1	50	0.50/1
	Names the independent variable given previously	59		50	
Identifies the variable to measure	Other	28	0.72/1	44	0.56/1
	Names the distance rolled/speed it rolls	72		56	
Identifies variables to keep the same	Other	34.5	1.01/2	36	0.91/2
	Names one variable to be kept the same	29.5		37	
	Names two variables to be kept the same	36		27	
Creates table to record results	*Other*	*40*	*0.91/2*	*52*	*0.66/2*
	Table has a column for the Independent Variable (IV) or the Dependent Variable (DV) (not both)	*28*		*30*	
	Table has columns for IV and DV	*32*		*18*	
Table allows for repeat trials and average	Other	81	0.27/2	89	0.14/2
	Table allows for repeat trials	12		8	
	Table allows for repeat trials and average	7		3	

Note. *Literacies of science are in italics,* processes of science are in normal font

Most students were able to identify an independent variable (Level 2 / planning / investigating) and to make a prediction about its effect on the dependent variable (Level 3 /planning / investigating), however, students found it far more difficult to write a question for their investigation (Level 3 / planning / investigating). One-third of the Year 5-7 students from *Primary Connections* classes were able to write a complete and appropriate question while only one-quarter of students from comparison classes were able to do this. Students were asked to complete a supplied table to show which variables they would change, measure and keep the same to make it a fair test. A majority of students were able to identify the variables to change and measure and at least one variable to keep the same (Level 3 /planning / investigating), about one-third of students identified two variables that would be kept the same (Level 4 /planning / investigating),

The students were asked to create a table that they would use to record results from their investigation. This was included in the task to determine whether students were aware of the need to conduct repeat trials and average results. Figure 7 illustrates the components of a results table required for recording results from this investigation.

Column headings
The table should have headings for the independent variable and the dependent variable.

Allows for repetition
Table allows for repetition of test for each value of independent variable and averaging of results

	Distance ball travelled (cm)			
Height of ramp (cm) (No of bricks)	Trial 1	Trial 2	Trial 3	Average
1				
2				
3				
4				

Figure 8: Key components of a results table for the Rolling Ball task

One-third of *Primary Connections* students were able to construct a table with columns for both the independent and dependent variables, one-fifth demonstrated an awareness of the need for repeat trials (Level 4 / conducting / investigating) and seven per cent constructed a table that provided a column for averaging results from the repeat trials (Level 4 / processing data / investigating). To a certain extent performance on the table construction part of this task was dependent on successful performance on earlier parts of the task (e.g., identification of independent and dependent variables) and the low success rate can be partly attributed to this. The task also required students to construct a response to an item at the end of the test and consequently some students may not have attempted the task due to fatigue.

Overall mean scores for literacies of science and for science processes on the Rolling Ball task are reported in Table 20. Students from *primary Connections* classes outperformed the students from comparison classes on both these measures.

Table 20: Mean literacies of science and science processes scores on the Rolling Ball task for Year 5-7 students from *Primary Connections* classes and from comparison classes

Component	Primary Connections classes		Comparison Classes	
	Mean	Sd	Mean	Sd
Literacies of science	*0.91/2*	*0.846*	*0.66/2*	*0.768*
Processes of science	4.96/10	2.586	4.39/10	2.388

Key finding 5. On the Rolling Ball task, a majority of the Year 5-7 students were able to identify an independent variable to test, make a prediction and could identify a variable to change, measure and keep the same in an investigation. Students found it far more difficult to write a complete and appropriate question for their investigation, plan a table for recording results for both independent and dependent variables and to allow for repeat trials and averaging of results. Most students were successful on the Level 2 tasks (variable identification) and the easier Level 3 tasks (make a prediction, identify one variable to keep the same), however, they found the harder Level 3 tasks (formulating a question for investigation) and the Level 4 tasks (identifying more than one variable to keep the same, planning for repeat trials, averaging of results) far more difficult. Overall, students from *Primary Connections* classes outperformed students from comparison classes on literacies of science and on science processes.

Comparison of Groups on the Tasks

Performance on the tasks by students from *Primary Connections* classes and from comparison classes has been reported using descriptive statistics. This has illustrated the various levels of performance by students on each aspect of the tasks and has revealed the relative ease with which students from each group has been able to complete the aspects of tasks. Tables 21-23 report the findings of two-tailed t tests for independent samples conducted to test whether the mean scores for students from *Primary Connections* classes were significantly higher than the mean scores for students from comparison classes.

Given that the Year 3 cohort only completed the Draw Your Thumb task, overall mean task scores were calculated for the students from *Primary Connections* classes and from comparison classes. The mean task score for the *Primary Connections* group (4.46) was significantly greater (p. <.05) than the task mean score for the comparison group (3.39). The effect size for the impact of *Primary Connections* on students' achievement of literacies and processes of science was substantial (Cohen's d = 0.68). Given that the Year 3 cohort was a relatively small sample (n = 251) no comparisons were made between Indigenous, LBOTE and other sub-groups.

Table 21: Means of combined literacies and processes of science scores for Year 3 students from *Primary Connections* classes and from comparison classes

	Groups	n	Scores /11	
			Mean	Sd
Year 3	PC	189	4.46*	1.849
	Not PC	62	3.39*	1.251

Note. * p<.05; ** p<.01; Cohen's d = 0.68

The Year 4 cohort completed both the Draw Your Thumb task and a limited version of the Shoe Size task. Overall mean scores were calculated for literacies of science and for science processes over the two tasks (Table 22). The mean literacies of science score for the *Primary Connections* group (5.23) was significantly greater (p. <.01) than the literacies of science mean score for the comparison group (3.93) and the effect size was substantial (Cohen's *d* = 0.56). The mean science processes score for the *Primary Connections* group (6.72) was significantly greater (p. <.01) than the science processes mean score for the comparison group (5.79) and the effect size was moderate (Cohen's *d* = 0.40). Given that the Year 4 cohort was a relatively small sample (n = 313) no comparisons were made between Indigenous, LBOTE and other sub-groups.

Table 22: Means of literacies and processes of science scores for Year 4 students from *Primary Connections* classes and from comparison classes.

Year 4	**Group**	**n**	**Literacies of science /15**		**Processes of science /11**	
			Mean	**Sd**	**Mean**	**Sd**
	PC	176	5.23**	2.370	6.72**	2.135
	Not	137	3.93**	2.251	5.79**	2.522
	Effect size (Cohen's *d*)		0.56		0.40	

Note. ** p<.01;

The Year 5-7 cohort completed the Draw Your Thumb task, the Shoe Size task and the Rolling Ball task. Overall mean scores for literacies of science and for science processes were calculated for various groups over the three tasks.

The *Primary Connections* mean literacies of science score for Years 5-7 students (11.18) was significantly higher (p. < .01) than the mean (9.15) for the comparison group and the effect size was substantial (Cohen's *d* = 0.47). The *Primary Connections* mean processes of science score (13.42) was significantly higher (p. <.01) than the mean (12.48) for the comparison group, however, the effect size (Cohen's *d* = 0.19) was smaller than for the impact of *Primary Connections* on achievement of literacies of science.

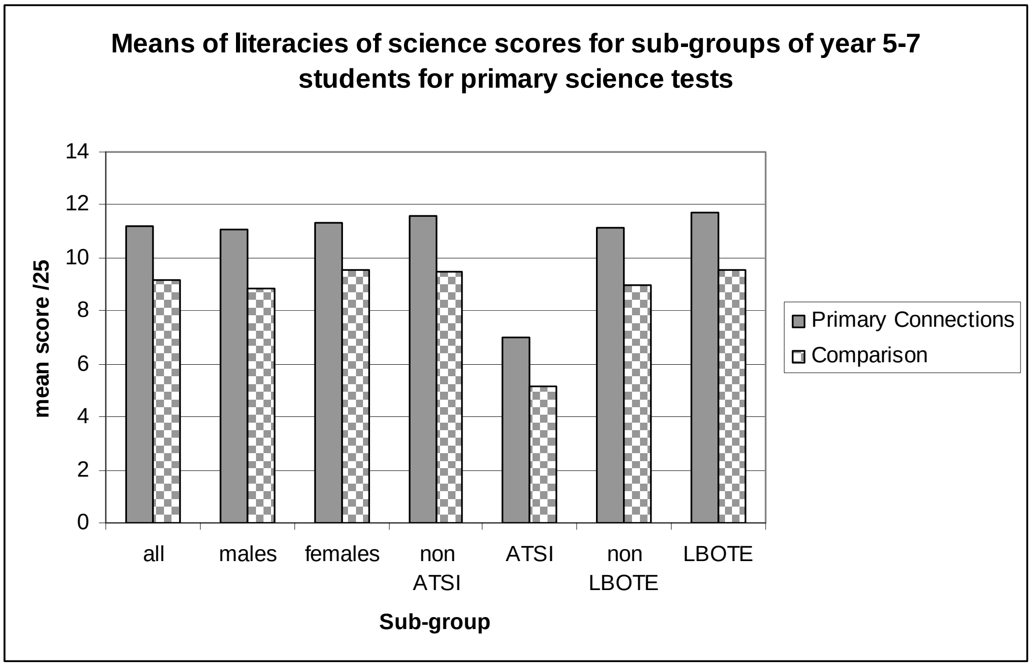
Given the larger size of the Year 5-7 cohort (n = 903) it was considered reasonable to also compare the performance of various sub-groups (Table 23).

Table 23: Means of literacies and processes of science scores for Years 5-7 students from *Primary Connections* classes and comparison classes

Year 5, 6 and 7	Compare	n	Literacies of science /25		Processes of science /24	
Group			Mean	Sd	Mean	Sd
All	PC	540	11.18**	4.66	13.42**	4.87
	Not PC	363	9.15**	3.96	12.48**	4.87
	Effect size (Cohen's *d*)		0.47		0.19	
ATSI only	PC	41	7.02**	2.554	10.59**	5.153
	Not PC	28	5.14**	2.940	6.68**	5.150
LBOTE only	PC	77	11.72**	4.500	13.39	4.899
	Not PC	119	9.52**	4.305	12.56	5.392
Non ATSI	PC	492	11.58**	4.619	13.70*	4.764
	Not PC	331	9.48**	3.864	12.94*	4.537
Non LBOTE	PC	458	11.12**	4.663	13.46**	4.851
	Not PC	244	8.97**	3.782	12.44**	4.599
Non ATSI and non LBOTE	PC	419	11.48**	4.65	13.67*	4.80
	Not PC	221	9.15**	3.71	12.89*	4.28
Males only	PC	280	11.07**	4.494	13.27**	4.815
	Not PC	201	8.87**	3.949	12.07**	4.891
Females only	PC	260	11.31**	4.825	13.58	4.926
	Not PC	161	9.54**	3.954	13.02	4.802

Note. * $p<.05$; ** $p<.01$;

The mean literacies of science and science process scores for all sub-groups from the *Primary Connections* and comparison classes are illustrated in Figure 9.



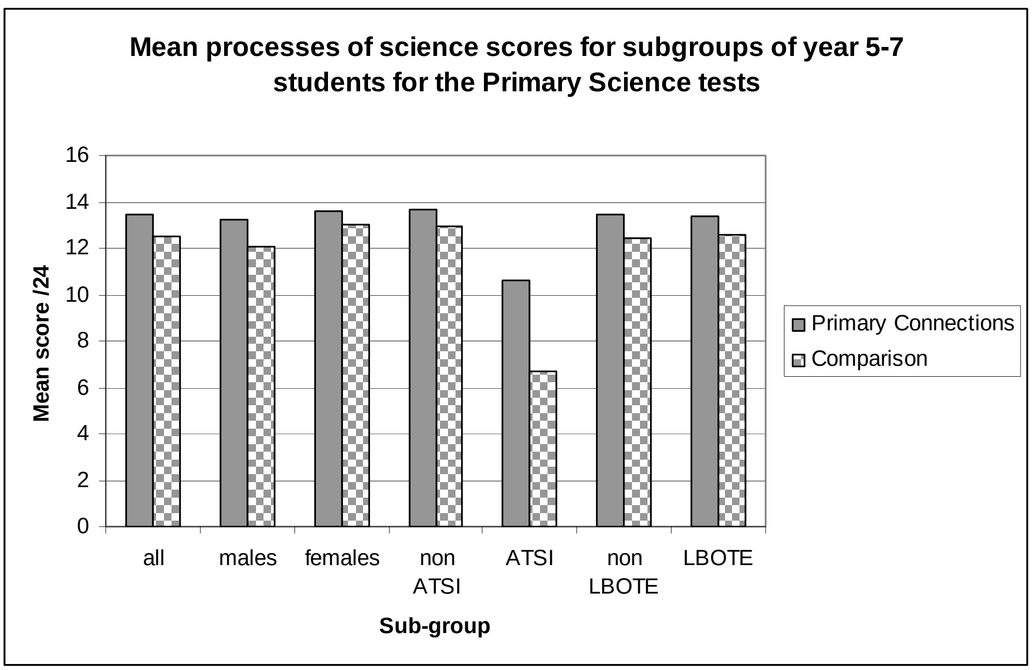


Figure 9. Mean literacies of science and science process scores for Year 5-7 sub-groups

Students who identified as Indigenous were a relatively small group and comparisons between the performance of Indigenous students from *Primary Connections* classes with Indigenous students from comparison classes should be considered with caution as sampling effects are likely to influence findings. The mean literacies of science score for ATSI students from *Primary Connections* classes (7.02) was significantly greater (p. <.01) than the literacies of science mean score for ATSI students from comparison classes (5.14). The mean science processes score for ATSI students from *Primary Connections* classes (10.59) was significantly greater (p. <.01) than the science processes mean score for ATSI students from comparison classes (6.68).

Students who identified as LBOTE were a relatively small group and comparisons between the performance of LBOTE students from *Primary Connections* classes with LBOTE students from comparison classes should be considered with caution as sampling effects are likely to influence findings. The mean literacies of science score for LBOTE students from *Primary Connections* classes (11.72) was significantly greater ($p < .01$) than the literacies of science mean score for LBOTE students from comparison classes (9.52). The mean science processes score for LBOTE students from *Primary Connections* classes (13.39) was not significantly different ($p = 0.279$) from the science processes mean score for LBOTE students from comparison classes (12.56).

'Mainstream students' i.e., those that did not identify as Indigenous or LBOTE from the *Primary Connections* classes had a significantly higher ($p < .01$) literacies of science mean score (11.48) than the students from comparison classes (9.15). Mainstream students from *Primary Connections* classes also had a significantly higher ($p < .05$) mean processes of science score (13.67) than students from comparison classes (12.89).

Both males and females from *Primary Connections* classes attained significantly higher ($p < .01$) mean literacies of science scores than students from comparison classes, and males from *Primary Connections* classes attained a significantly higher ($p < .01$) mean science processes score than male students from comparison classes.

Key finding 6. Year 3 students from *Primary Connections* classes performed significantly better than students from comparison classes on the Draw Your Thumb task. Year 4 students from *Primary Connections* classes performed significantly better than students from comparison classes on literacies of science and science processes on the Draw Your Thumb and the Shoe Size tasks. Year 5-7 students from *Primary Connections* classes performed significantly better on literacies of science and science processes on the Draw Your Thumb, Shoe Size and Rolling Ball tasks than students from comparison classes. Both Year 5-7 Indigenous and LBOTE students from *Primary Connections* classes performed significantly better on literacies of science than Indigenous and LBOTE students from comparison classes. Year 5-7 Indigenous students from *Primary Connections* classes performed significantly better on science processes than Indigenous students from comparison classes. Year 5-7 students who were neither Indigenous or LBOTE from *Primary Connections* classes performed significantly better on literacies of science and science processes than students who were neither Indigenous or LBOTE from comparison classes. Both Year 5-7 male and female students from *Primary Connections* classes performed significantly better on literacies of science than male and female students from comparison classes. Year 5-7 male students from *Primary Connections* classes performed significantly better on science processes than male students from comparison classes.

Effect sizes indicate that the impact of *Primary Connections* on students' achievement of literacies of science and processes of science is substantial.

Relationships between literacies of science and science processes

Scientific literacy is a multidimensional construct (refer to Figure 1) and two components of this construct, science literacies and processes, are often applied together during science investigations to gather data, represent data, interpret data, argue claims based on evidence and to communicate findings. Developing understandings within science is dependent on first learning how to interpret and construct science texts (Norris & Phillips, 2003). Similarly, the successful performance of some processes of science, such as data interpretation may be dependent on first representing data appropriately. To explore this potential relationship between literacies and processes of science a cross tabulation analysis was conducted for graphing data and identifying relationships between variables. On the Shoe Size task, Years 5-7 students were asked to measure the length of shoes of various sizes, plot a bar graph of shoe size against shoe length and identify the relationship between shoe size and shoe length. It would be expected that those students who constructed a conventional bar graph where the bars were ordered by magnitude of shoe size would more easily identify the relationship between the variables. These data are presented in Table 24.

Table 24. Relationship between ordering bars on a graph by magnitude and identification of the relationship between the variables plotted on the graph.

		Relationship between variables			**Totals**
		No relationship identified	Descriptive relationship identified	Algebraic relationship identified	
Ordering of bars on graph	Bars not ordered	263	94	47	404
	Bars ordered from high to low	40	26	6	72
	Bars ordered from low to high	204	159	64	427
	Totals	507	279	117	903

Of the 404 Year 5-7 students who did not order the bars on their graphs by magnitude, only 141 or 35% were able to identify a relationship between the variables plotted on the graph either as a descriptive relationship or as an algebraic relationship. Of the 72 students who ordered the bars on their graph by magnitude from high show sizes to low shoe sizes, 32 or 44% were able to identify the relationship between the variables. Of the 427 students who ordered the bars on their graph by magnitude from low to high, 223 or 52% were able to identify the relationship between the variables.

This is one example that illustrates the close relationship between literacies and processes of science. In this example, mastering the conventional representational form of the bar graph facilitates students' identification of the relationship between the variables plotted on the graph. Success on the process of analysing data is enhanced by mastering the literacy of science. This close relationship between literacies and processes of science is illustrated by the high Cronbach's alpha of 0.841 for the Year 5-7 test of literacies and processes showing that the items are homogeneous and the test has high internal consistency. A Pearson correlation coefficient was also calculated for the relationship between the 567 Year 5-7 students' total test scores on literacies of science and their total test scores on processes of science. A significant correlation ($r = 0.582$; $p. < .01$, two tailed) was found between these two variables.

<u>Key Finding 7</u>

A significant correlation exists between students' literacies of science scores and processes of science scores, and in the specific example of graphing and analysing data, performance on the process of identifying relationships between variables is dependent on the science literacy of constructing a graph of conventional form to display the data and reveal the relationship.

Attitudes Towards School Science

Students from Years 4-7 responded to an attitude scale comprising items related to school science. Students also responded to an item about the frequency of science lessons. Students responded to all items on a five-point rating scale based on the frequency of the attribute occurring in students' science lessons. For the item *I enjoy learning in science lessons* students could select from the following responses: *Never*, *Rarely*, *Sometimes*, *Often* or *Always*. Students' responses to statements about frequency of science in their classes and attitude to science for Years 4-7 students are summarised in Tables 24-26.

Student Perceptions about Frequency of Science Lessons

Some students may not always be aware when they are learning science given that it is often integrated with other learning areas and this factor would influence students' responses to the first item *In my class I do science every week*. Fifty-seven per cent of students from *Primary Connections* classes reported that they did science every week *Often* or *Always* while only 36% of students from comparison classes reported this frequency of science lessons (Table 24). This finding is consistent with teachers' self reporting of an increased science teaching time when they started teaching with *Primary Connections* (Hackling & Prain, 2005).

Table 25: Students' responses to the statement about frequency of science in their classes

Statement : **In my class I do science every week.**	**Per cent of students with this response**					**Mean frequency score**	**Sd**
	Never	**Rarely**	**Some Times**	**Often**	**Always**		
Per cent of students in *Primary Connections* classes (n=708)	2	9	32	30	27	3.71**	1.026
Per cent of students in comparison classes (n=489)	9	28	27	20	16	3.06**	1.226

Note. Students responded on a five-point scale which was scored: Never = 1; Rarely = 2; Sometimes = 3; Often = 4; and, Always = 5.
**p. <.01

A two-tailed t test for independent samples indicated that the mean frequency score for students from *Primary Connections* classes (3.71) was significantly greater (p. <.01) than the mean frequency score for students from comparison classes (3.06).

<u>Key finding 8</u>. Students from *Primary Connections* classes reported a perception of frequency of science lessons that was significantly greater than that of students from comparison classes.

Attitudes about School Science

Students responded to a seven-item scale which comprised sets of items about: the frequency with which they experienced excitement, enjoyment or boredom in science lessons; how often they find other subjects more interesting than science / how often they like science better than other subjects; how often they are curious in science; and, how often they learn interesting things in science. The students responded to each item on a five-point scale which ranged from *Never*, *Rarely*, *Sometimes*, *Often* to *Always*. The percentage of Year 4-7 students that responded with these frequency ratings for each item are reported in Table 25.

Most students were *Often* or *Sometimes* excited during science lessons, *Always* enjoy learning in science lessons, are *Never* or *Rarely* bored in science lessons, *Sometimes* find other subjects more interesting than science whilst *Sometimes* like science better than other subjects, are *Sometimes* curious during science lessons and *Always* learn interesting things in science. On the whole the students from *Primary Connections* and comparison classes gave a very positive evaluation of their experience of science.

Table 26: Students' responses to statements about school science

Statement	Per cent of students with this response									
	Primary Connections classes (n = 707)					Comparison classes (n= 493)				
	N	R	S	O	A	N	R	S	O	A
I am excited during science lessons	4	14	30	34	19	5	13	34	26	23
I enjoy learning in science lessons	3	7	25	30	35	4	6	24	31	34
I am bored during science lessons	30	35	22	9	4	31	29	27	9	4
I find other subjects more interesting than science	7	17	36	27	12	6	13	43	26	12
I like science better than most other subjects in my school	12	22	33	20	12	17	18	37	17	12
I am curious during science lessons	5	13	34	31	17	7	18	34	23	18
I learn interesting things in science lessons	1	4	17	36	42	3	6	20	32	39

Note. Students responded on a five-point frequency scale: N = Never; R = Rarely; S = Sometimes; O = Often; and, A = Always. The most frequent/modal response for each statement has been highlighted.

Students' responses to the attitude scale were scored from one to five: *Never* = 1; *Rarely* = 2; *Sometimes* = 3; *Often* = 4; and, *Always* = 5. It should be noted that scores were not reversed for negatively stated items. Mean item scores were calculated for each item and these are reported in Table 26. Mean scores were more positive for *Primary Connections* students on all seven items than for students from comparison classes. Two-tailed t tests for independent samples demonstrated that there were significant differences between the two groups of students for two of the items. The mean score for students from *Primary Connections* classes on the item *I am curious during science lessons* (3.41) was significantly higher (p. <.05) than the mean score (3.27) for students from the comparison classes. The mean score for students from *Primary Connections* classes on the item *I learn interesting things in science lessons* (4.14) was significantly higher (p. <.01) than the mean score (3.97) for students from the comparison classes.

Table 27: Students' responses to statements about school science for students from *Primary Connections* classes and from comparison classes

Statement	Students from Primary Connections classes (n = 708)		Students from comparison classes (n = 489)	
	Mean	**Sd**	**Mean**	**Sd**
I am excited during science lessons	3.51	1.055	3.50	1.161
I enjoy learning in science lessons	3.87	1.059	3.86	1.036
I am bored during science lessons	2.22	1.087	2.26	1.213
I find other subjects more interesting than science	3.19	1.087	3.26	1.111
I like science better than most other subjects in my school	2.97	1.188	2.89	1.161
I am curious during science lessons	3.41*	1.077	3.27*	1.065
I learn interesting things in science lessons	4.14**	0.913	3.97**	1.036

Note. Students responded on a five-point scale which was scored: Never = 1; Rarely = 2; Sometimes = 3; Often = 4; and, Always = 5. Scores have not been reversed for negatively stated items.

- p<.05; ** p<.01

Key finding 9. Most students gave a positive evaluation of their experience of science with many enjoying learning in science, rarely being bored, often or sometimes being excited in science, sometimes experienced being curious in science and always learning interesting things. Students from *Primary Connections* classes were significantly more frequently curious during science lessons and learned interesting things in science than students from comparison classes.

Summary of Key Findings

Number	Key Finding	Evidence
1	A total of 1467 students recruited from 26 schools participated in the assessments. More students were recruited from *Primary Connections* classes than from comparison classes. Males and females were distributed equally between the *Primary Connections* and comparison groups.	Tables 1-5
2	A slightly higher proportion of students in the *Primary Connections* group came from schools with a low socioeconomic status index than the comparison group. Eight per cent of the students who participated in the assessments identified as Indigenous and 21% identified as being LBOTE. The comparison group had a higher proportion of Indigenous and LBOTE students than the *Primary Connections* group.	Tables 6-9
3	On the Draw Your Thumb task most students did not give their diagram a title or a scale to indicate the size of their thumb. Older and *Primary Connections* students were much more effective in drawing accurate diagrams, providing extended representations and effectively labelling their diagrams than younger students and students from comparison classes. Most students were able to identify valid differences between their thumb and forefinger and thus demonstrate Level 2 of the processing data aspect of investigating.	Tables 10 - 12
4	On the Shoe Size task most Year 4 and Year 5-7 students could make accurate measurements (Level 3 / conducting / investigating) and record data in tabular form with units of measurement (Level 3 / processing / investigating), and construct a bar graph (Level 3 / processing / investigating). Most did not give titles to tables or graphs or give column headings in tables, however, they were not prompted by the task. Ordering variables in the table, data by magnitude in the table and ordering bars on the graph were critical for identifying patterns in the data. Students from *Primary Connections* classes outperformed students from comparison classes on these aspects and were also more successful with accurate plotting of data on the graph. A majority of Year 4 and Year 5-7 students were able to successfully complete the Level 2 data interpretations (comparisons, however, a majority of Year 5-7 students was not able to successfully complete the Level 3 data interpretations (identify relationships between variables). Almost two-thirds of Year 5-7 students were able to interpolate within the data to predict an unmeasured shoe length. Students from *Primary Connections* classes outperformed students from comparison classes on overall means for literacies of science and science processes.	Tables 13-18
5	On the Rolling Ball task, a majority of the Year 5-7 students was able to identify an independent variable to test, make a prediction and could identify a variable to change, measure and keep the same in an investigation. Students found it far more difficult to write a complete and appropriate question for their investigation, plan a table for recording results for both independent and dependent variables and to allow for repeat trials and averaging of results. Most students were successful on the Level 2 tasks (variable identification) and the easier Level 3 tasks (make a prediction, identify one variable to keep the same), however, they	Tables 19-20

	found the harder Level 3 tasks (formulating a question for investigation) and the Level 4 tasks (identifying more than one variable to keep the same, planning for repeat trials, averaging of results) far more difficult. Overall, students from *Primary Connections* classes outperformed students from comparison classes on literacies of science and on science processes.	
6	Year 3 students from *Primary Connections* classes performed significantly better than students from comparison classes on the Draw Your Thumb task. Year 4 students from *Primary Connections* classes performed significantly better than students from comparison classes on literacies of science and science processes on the Draw Your Thumb and the Shoe Size tasks. Year 5-7 students from *Primary Connections* classes performed significantly better on literacies of science and science processes on the Draw Your Thumb, Shoe Sizes and Rolling Ball tasks than students from comparison classes. Both Year 5-7 Indigenous and LBOTE students from *Primary Connections* classes performed significantly better on literacies of science than Indigenous and LBOTE students from comparison classes. Year 5-7 Indigenous students from *Primary Connections* classes performed significantly better on science processes than Indigenous students from comparison classes. Year 5-7 students who were neither Indigenous or LBOTE from *Primary Connections* classes performed significantly better on literacies of science and science processes than students who were neither Indigenous or LBOTE from comparison classes. Both Year 5-7 male and female students from *Primary Connections* classes performed significantly better on literacies of science than male and female students from comparison classes. Year 5-7 male students from *Primary Connections* classes performed significantly better on science processes than male students from comparison classes. Effect sizes indicate that the impact of *Primary Connections* on students' achievement of literacies of science and processes of science is substantial.	Tables 21-23
7	A significant correlation exists between students' literacies of science scores and processes of science scores, and in the specific example of graphing and analysing data, performance on the process of identifying relationships between variables is dependent on the science literacy of constructing a graph of conventional form to display the data and reveal the relationship.	Table 24
8	Students from *Primary Connections* classes reported a perception of frequency of science lessons that was significantly greater than that of students from comparison classes.	Table 25
9	Most students gave a positive evaluation of their experience of science with many enjoying learning in science, rarely being bored, often or sometimes being excited in science, sometimes experienced being curious in science and always learning interesting things. Students from *Primary Connections* classes were significantly more frequently curious during science lessons and learned interesting things in science than students from comparison classes.	Tables 26-27

Discussion

The purpose of the study was to evaluate the impact of *Primary Connections* on students' development of literacies of science, science processes and their attitudes towards school science. Previous research has demonstrated that the support of *Primary Connections* professional learning and exemplary curriculum materials increased teachers' confidence and self-efficacy for teaching science, improved their teaching practice and increased the time devoted to teaching science which in turn increased students' opportunity for learning (Hackling & Prain, 2005; Hackling, Peers & Prain 2007). A case study of conceptual learning by Year 5 students (Hackling & Prain, 2005) studying a *Primary Connections* unit demonstrated that these Year 5 students made strong conceptual growth during the unit and a large proportion of the students achieved Level 3 within the National Scientific Literacy Progress Map (MCEETYA, 2005) which is the national proficiency standard for Year 6 students. This small-scale study demonstrated the potential of *Primary Connections* to enhance learning outcomes. Given the focus of *Primary Connections* on the development of literacies of science, science processes and student engagement in learning this study addressed four research questions about the impact of *Primary Connections* on students' achievement and attitudes towards school science. The key findings are discussed in relation to these questions.

1. What literacies of science and science processes are Year 3-7 students who have learned science with *Primary Connections* developing, and to what level?

More than one-third of *Primary Connections* Year 3 and 4 students and a large majority of Year 5-7 students were able to observe and draw a scientific diagram that showed some features or accurately communicated features of their thumb. A majority of Year 3 and 4 *Primary Connections* students provided simple representations of the thumb whilst a majority of Year 5-7 students provided extended representations. A large majority of Year 3-7 students were able to label their diagrams and one-fifth of Year 3 and 4 students and almost one half of Year 5-7 students were able to label their diagrams accurately. Most *Primary Connections* students were able to identify valid differences between their thumb and forefinger and thus demonstrate Level 2 of the processing data aspect of investigating. Students were not prompted to give their diagram a title and scale. Of the one-fifth of *Primary Connections* students who did supply a title more gave simple titles rather than descriptive titles. Almost all students did not provide a scale for their diagram. A scale helps the reader determine the size of the object represented in the diagram. Constructing a scale requires some understanding of the representational form and a capacity to reason with relative sizes. Given that students were not prompted to provide a scale it is not possible to determine whether students were unaware of the need to provide a scale or were not able to construct one.

Most Year 4-7 students from *Primary Connections* classes could make accurate measurements of the shoe lengths (Level 3 / conducting / investigating), record data in tabular form with units of measurement (Level 3 / processing / investigating), and construct a bar graph (Level 3 / processing / investigating). Students were not prompted to give their table a title nor were they prompted to provide column headings that named the variables for which data were recorded. Overall, more than 90% did not provide a title and a majority did not provide column headings.

Ordering variables in the table, ordering data by magnitude in the table and ordering bars on the graph were critical for identifying patterns in the data. A majority of Year 4-7 students from *Primary Connections* classes ordered variables and data in their tables and a majority of Year 5-7 students ordered their bars on the graph. A small majority of Year 5-7 students was able to construct appropriate scales and accurately plot their data on the graph. About one-third provided a title and most labelled at least one axis of the graph without prompting.

A majority of Year 4 and Year 5-7 *Primary Connections* students was able to successfully complete the Level 2 data interpretations (comparisons, however, a majority of Year 5-7 students was not able to successfully complete the Level 3 data interpretations (identify relationships between variables). Almost two-thirds of Year 5-7 students were able to interpolate within the data to predict an unmeasured shoe length. Identifying the relationship between the variables shoe size and shoe length from their graph was easier for students who had ordered the bars on their graph by magnitude of the independent variable shoe size. Describing the relationship required students not only to identify the pattern in the data (shoe length increases with shoe size) but also to construct the syntax of a statement to describe the relationship. About one-third of students were able to identify and describe the relationship and it was pleasing to see 13% describe the relationship in algebraic terms (shoe length is shoe size plus 10cm).

The Rolling Ball task gave Year 5-7 students an opportunity to demonstrate their process skills of planning an investigation. A majority of the *Primary Connections* students was able to identify an independent variable to test (Level 2 / planning / investigating), make a prediction and could identify a variable to change, measure and keep the same in an investigation (Level 3). Students found it far more difficult to write a complete and appropriate question for their investigation (Level 3), plan a table for recording results for both independent and dependent variables and to allow for repeat trials and averaging of results (Level 4). Writing a question for investigation was one of the more difficult Level 3 processes and required students to not only identify the independent and dependent variables but also to construct the syntax required to pose a question about the effect of one variable on the other. Given that the Rolling Ball task was at the end of the test and that constructing a table was dependent on success on earlier parts of the task these factors would have contributed to the low success rate on constructing a table for recording results and demonstrating an awareness of the need to make repeat trials and average results.

2. Is the achievement on literacies of science and science processes by *Primary Connections* students greater than that of students from non-*Primary Connections* classes in equivalent schools?

Year 3, 4 and 5-7 students from *Primary Connections* classes outperformed students from comparison classes in terms of their development of literacies of science and science processes. It should be noted that this evaluation was conducted at a relatively early stage of the project before teachers have sufficient familiarity with *Primary Connections* units to have fidelity of implementation of the *Primary Connections* teaching and learning approaches. The comparison classes were recruited from teachers who volunteered to participate in the study and it can be assumed that these teachers would have been reasonably confident about the quality of their science teaching to participate in the study. Students from these comparison classes reported that they enjoyed their science lessons.

Mean scores of *Primary Connections* students for literacies of science and for science processes were significantly higher than the mean scores for other students. Effect sizes calculated to demonstrate the magnitude of the impact of *Primary Connections* on students' achievement were also substantial. It was interesting to note that effect sizes for literacies of science were larger than for science processes. This is not surprising as science teaching in Australian primary schools has traditionally had a strong focus on processes and the major innovation of *Primary Connections* is the linkage made between the teaching of science and literacy and the focus on development of literacies of science.

The strong correlation between performance on literacies of science and science processes revealed by the data are not surprising given that they are applied together in scientific investigations. There is also some dependency between literacies and processes as revealed by the analysis of students' performance on constructing graphs and identifying relationships between variables.

The data also revealed that *Primary Connections* enhanced learning for all students whether they be male, female, Indigenous (ATSI), LBOTE or non-ATSI and non-LBOTE. *Primary Connections* focus on vocabulary building and use of multimodal representation such as combining graphical and textual representations would be expected to be particularly beneficial for LBOTE and Indigenous students many of whom learn science using English as a second language or dialect. Given the educational and socioeconomic disadvantage faced by Indigenous students these findings are particularly significant.

Given that *Primary Connections* students in this study reported more frequent science lessons than other students and the previous research findings that teachers using *Primary Connections* reported increased science teaching time and improvements to their teaching practice, it is not surprising that *Primary Connections* students outperformed students from comparison classes. Teachers reported that when teaching *Primary Connections* units there was greater focus on developing learning outcomes because of the carefully crafted learning sequences in the units (Hackling & Prain, 2005). Literacy focuses in the units and clearly defined literacy outcomes support teachers develop literacies of science and the inquiry-oriented teaching-learning model and inclusion of student-planned investigations support the development of students' science processes.

3. Can progression in learning be identified within the literacies of science and science processes?

The research design involved testing students over the Year 3-7 range and the assessment tasks allowed students to demonstrate their development of investigation skills at Levels 2, 3 and 4 which provided an opportunity to analyse the data from a developmental perspective and map achievements against the scientific literacy progress map so that progression in learning and standards of performance could be identified and described.

It was not possible to analyse the development of some of the literacies of science because they were not prompted by the tasks (e.g., providing titles for diagrams, tables and graphs) and therefore it was not possible to determine whether the failure to provide a title was due to a lack of awareness of the convention, an oversight or slow development of understanding of how to construct a title of conventional form. The Shoe Size task showed that drawing accurately, providing extended representations and labelling accurately improve as students progress through their schooling. Providing an extended representation emerges earlier than effective labelling than accurate drawing on this task. Recording numerical data in tabular form (Level 3) with units of measurement and ordering variables in the table emerge earlier than ordering data by magnitude which in turn emerges earlier than providing column headings in the table. Almost all Year 5-7 students had developed the ability to construct a bar graph (Level 3), however, only half had sequenced the bars appropriately by magnitude of the independent variable.

Developmental trends were evident in the learning of process skills. Identifying an independent variable (Level 2), and easier Level 3 processes of identifying variables to change, measure and keep the same and making a prediction emerged earlier than the harder Level 3 process of formulating an investigable question and the Level 4 processes of planning an investigation in which repeat trials are conducted and results averaged. Level 2 processes of making comparisons between observations and measurements emerged earlier than Level 3 process of analysing data and identifying a relationship between variables. The developmental patterns were broadly consistent with the progression of learning described in the National Scientific Literacy Progress Map, however, it should be noted that the Level 3 processes of identifying and describing a relationship between variables and formulating an investigable question were harder than identifying variables to change, measure and keep the same when planning an investigation as evaluated in the contexts and tasks used in this study.

4. Do *Primary Connections* students have more positive attitudes towards school science than non-*Primary Connections* students?

There are two main findings regarding students' response to school science. The first is that most of the sampled primary students enjoy school science whether they be from *Primary Connections* or comparison classes. This finding provides further evidence to support the integration of science and literacy learning so that interesting science contexts are used to enhance students' engagement in literacy learning. The second finding is that students from *Primary Connections* classes are more frequently curious in science and more frequently learn interesting things in science. The science community places a high value on curiosity as it is a trait associated with inquiry, problem solving and innovation. The opportunity to learn interesting things in *Primary Connections* science lessons would be expected to enhance engagement, achievement and a positive disposition to science. The challenge for science education is to maintain this high level of interest in science engendered in the primary years of schooling throughout the secondary phase of schooling.

Conclusions and Implications

Many educational initiatives advantage some students and disadvantage others. This evaluation has demonstrated that all students whether they be male, female, Indigenous (ATSI), LBOTE or non-ATSI and LBOTE have significantly better literacies of science and science processes in classes where science instruction is based on *Primary Connections* than in comparison classes where science instruction is based on other programs. The impact of *Primary Connections* on students' achievement of literacies of science and science processes is both statistically significant and substantial as evidenced by effect sizes. It is likely that enhanced performance can be attributed to the teachers' increased confidence, self-efficacy, increased teaching time devoted to science and enhanced teaching practice (Hackling, Peers & Prain, 2007). Central design principles of *Primary Connections* such as linking science with literacy, explicit development of science literacies, an inquiry-oriented teaching and learning model and the inclusion of student planned investigations would also be expected to contribute strongly to students' development of literacies and processes of science. The evaluation has also revealed that most of the sampled primary students enjoy learning science; however, those learning science in classrooms with *Primary Connections* report that they are curious and learn interesting things more frequently than students in comparison classes. Given the significant educational disadvantage faced by Indigenous students and the indications from this evaluation that *Primary Connections* enhances these students' achievement, further implementation and evaluation of *Primary Connections* with Indigenous students should be a priority. This study breaks new ground with an innovative approach to evaluation that has demonstrated the significant impact of *Primary Connections* on the types of learning outcomes that the latest science education literature indicate should count as science learning and contribute to scientific literacy.

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Appendices

Appendix 1: Specification grids

Investigation processes and literacies of science

The following table summarises science investigation processes and the literacy products constructed by students to record, display or communicate observations and measurements made in science investigation. The investigation processes are based on the National Scientific Literacy Progress Map (MCEETYA, 2005) and the literacy products are based on the *Primary Connections* developmental map of literacies of science products.

Level	Investigation processes		Literacies of science	
	Planning and conducting	**Processing and evaluating**	**Stage**	**Literacy product**
1	Responds to the teacher's questions, observes and describes	Describes what happened	ES1	Teacher scaffolded diagram, tables and pictograph
2	Given a question in a familiar context, identifies a variable to be considered, observes and describes or makes non-standard measurements and limited records of data	Makes comparisons between objects or events observed	1	Student captioned diagram, students record data in teacher supplied table, student constructed pictograph
3	Formulates scientific questions for testing and makes predictions. Demonstrates awareness of the need for fair testing. Makes simple standard measurements. Records data as tables, diagrams or descriptions.	Displays data as tables or bar graphs, identifies and summarises patterns in science data. Applies the rule by extrapolating or predicting.	2	Student captioned and labelled diagrams, tables with some teacher support, individual student constructed bar and column graphs
4	Identifies the variable to be changed, the variable to be measured and several variables to be controlled. Uses repeated trials or replicates.	Calculates averages from repeat trials or replicates, plots line graphs where appropriate. Conclusions summarise and explain the patterns in the data. Able to make general suggestions for improving an investigation (eg. make more measurements)	3	More complex diagrams and flow charts, individual student tables, simple line graphs with some teacher support

Early Stage 1 and Stage 1 units have outcomes specified at Levels 1 and 2, Stage 2 units have outcomes specified at Levels 2 and 3 and Stage 3 units have outcomes specified at Levels 3 and 4.

Investigation processes and literacies of science assessment tasks

Task	Intended Year group	Expected stage of units being studied	Investigation processes assessed by the task	Literacy processes and product assessed by the task
Draw your thumb	Year 3	Stage 1	Observing and recording observations as a labelled diagram. Observing and comparing.	Captioning and labelling a diagram. Listing differences
Draw your thumb	Years 4-7	Stages 2 and 3	Observing and recording observations as a labelled diagram. Observing and comparing.	Captioning and labelling a diagram. Listing differences.
Shoe size task	Year 4	Stage 2	Measuring length, recording measurements in student constructed table and making simple interpretations of data	Constructing and captioning a simple table for two variables and single measurements of the dependent variable
Shoe size task	Year 5-7	Stages 2 and 3	Measuring length, recording measurements in student constructed table, plotting bar graph, making comparisons of length, identifying the relationship between the variables of shoe size and length, and interpolating from known data	Constructing and captioning a simple table for two variables and single measurements of the dependent variable, plotting and captioning a simple bar graph.
Rolling balls investigation	Years 5-7	Stages 2 and 3	Identifying a variable for investigation, writing a question for the investigation, making a prediction, identifying variables that would be changed, measured and kept the same, designing a table for recording results.	Constructing and captioning a table for recording data for an independent variable and a dependent variable where repeat trials and averaging would be appropriate

Australian Academy of Science

Year 3 Primary Science Test

School name ________________________________

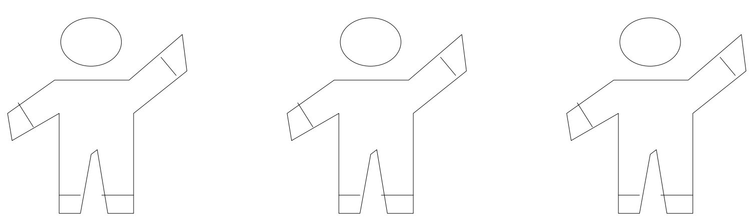
Teacher number ______________________________

I am in year 3 4 5 6 7 (circle one)

I am a Boy (circle one)
Girl

I am Aboriginal or a Torres Strait Islander. Yes
No (circle one)

At home, does anyone speak a language other than English? Yes
No (circle one)



Draw your thumb

What to do

1. Look at one of your thumbs.

   What features can you see?

2. Draw a labelled diagram of your thumb in the space below

3. Now look at the finger next to your thumb.

How are the thumb and finger different?

Write the differences in the space below.

Australian Academy of Science

Year 4 Primary Science Test

School name ___________________________________

Teacher number _________________________________

I am in year 3 4 5 6 7 (circle one)

I am a Boy (circle one)
Girl

I am Aboriginal or a Torres Strait Islander. Yes
No (circle one)

At home, does anyone speak a language other than English? Yes
No (circle one)

Draw your thumb

What to do

1. Look at one of your thumbs.

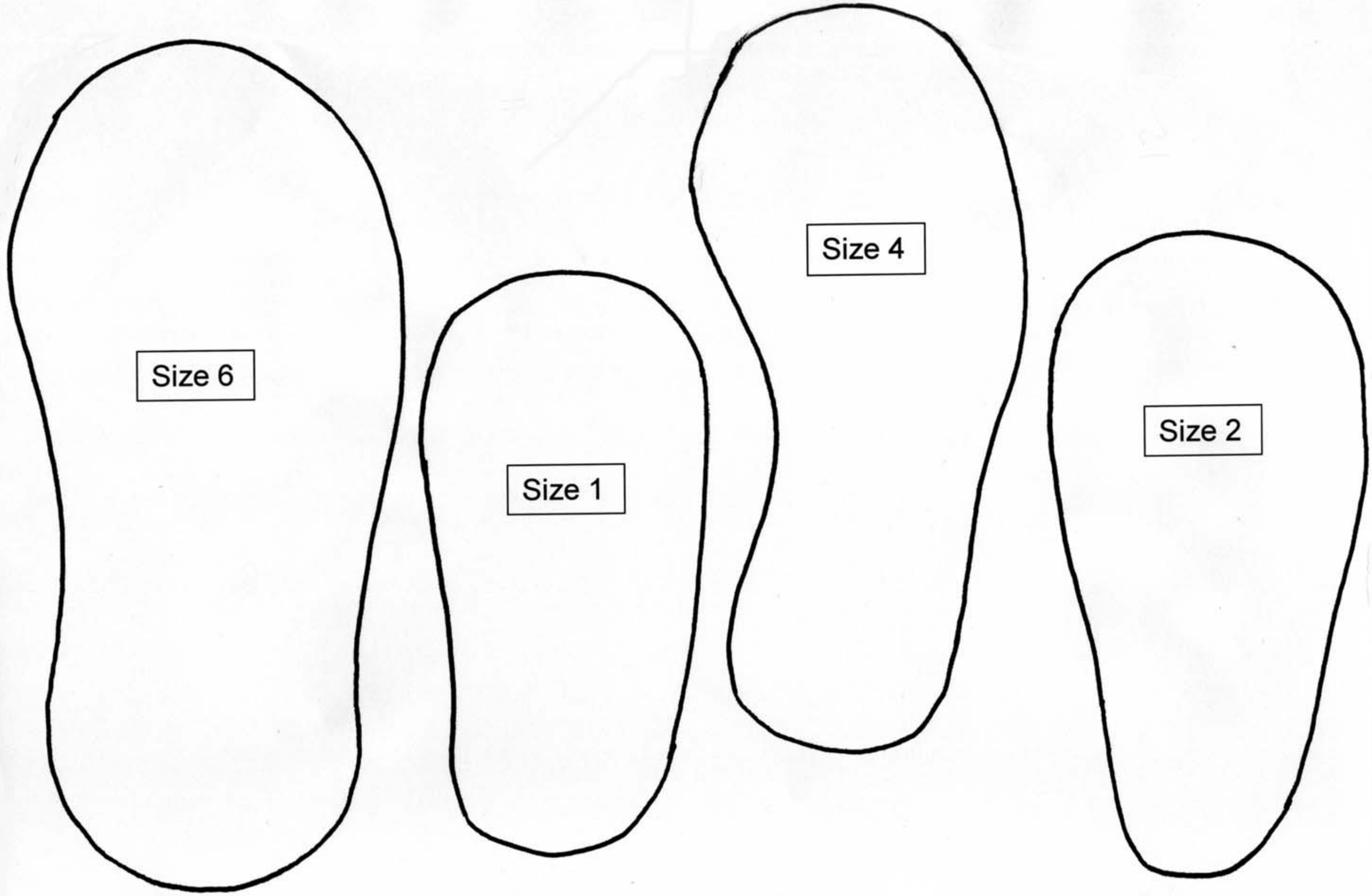
   What features can you see?

2. Draw a labelled diagram of your thumb in the space below

3. Now look at the finger next to your thumb.

   How are the thumb and finger different?

   Write the differences in the space below.



Children's shoes

Activity 2: Shoe Sizes and Lengths

What to do:

Look at the drawings of shoeprints on the opposite page.

Measure the length of each shoe. Write the measurement next to each drawing.

Now, draw a table in the space below and record your results in this table.

4. Using your results, answer these questions

How long is a size 2 shoe? ……………………………………..

B) How much longer is a size 4 shoe than a size 2 shoe?

………………………………………………………………………..

C) Katy's feet are 11.5 cm long. What size shoe should she wear?

…………………………………………………………………………….

…………………………………………………………………………

Activity 3: Science in My Class

Here are some statements about your science lessons at school.

What to do

Read each statement.

Show what you think by putting a circle around the answer that matches what you think. For example:

I eat chocolate cake in science lessons	Never	Rarely	Some-times	Often	Always

If you make a mistake, erase the wrong one and circle the one you want.

There are no right or wrong answers

Now it's your turn.

	Statement	Choose one answer for each statement				
1	In my class I do science every week.	Never	Rarely	Some-times	Often	Always
2	I enjoy learning in science lessons	Never	Rarely	Some-times	Often	Always
3	I am excited during science lessons	Never	Rarely	Some-times	Often	Always
4	I find other subjects more interesting than science	Never	Rarely	Some-times	Often	Always
5	I am curious during science lessons	Never	Rarely	Some-times	Often	Always
6	I am bored during science lessons	Never	Rarely	Some-times	Often	Always
7	I learn interesting things in science lessons	Never	Rarely	Some-times	Often	Always
8	I like science better than most other subjects in my school	Never	Rarely	Some-times	Often	Always

Thank you for doing these activities. Please return this booklet to your teacher.

Australian Academy of Science

Year 5,6,7 Primary Science Test

Booklet 1 (Activities 1 & 2)

School name ____________________________________

Teacher number __________________________________

Student number ______ (your teacher will give you this number)

I am in year 3 4 5 6 7 (circle one)

I am a Boy (circle one)
Girl

I am Aboriginal or a Torres Strait Islander. Yes
No (circle one)

At home, does anyone speak a language other than English? Yes
No (circle one)

Draw your thumb

What to do

1. Look at one of your thumbs.

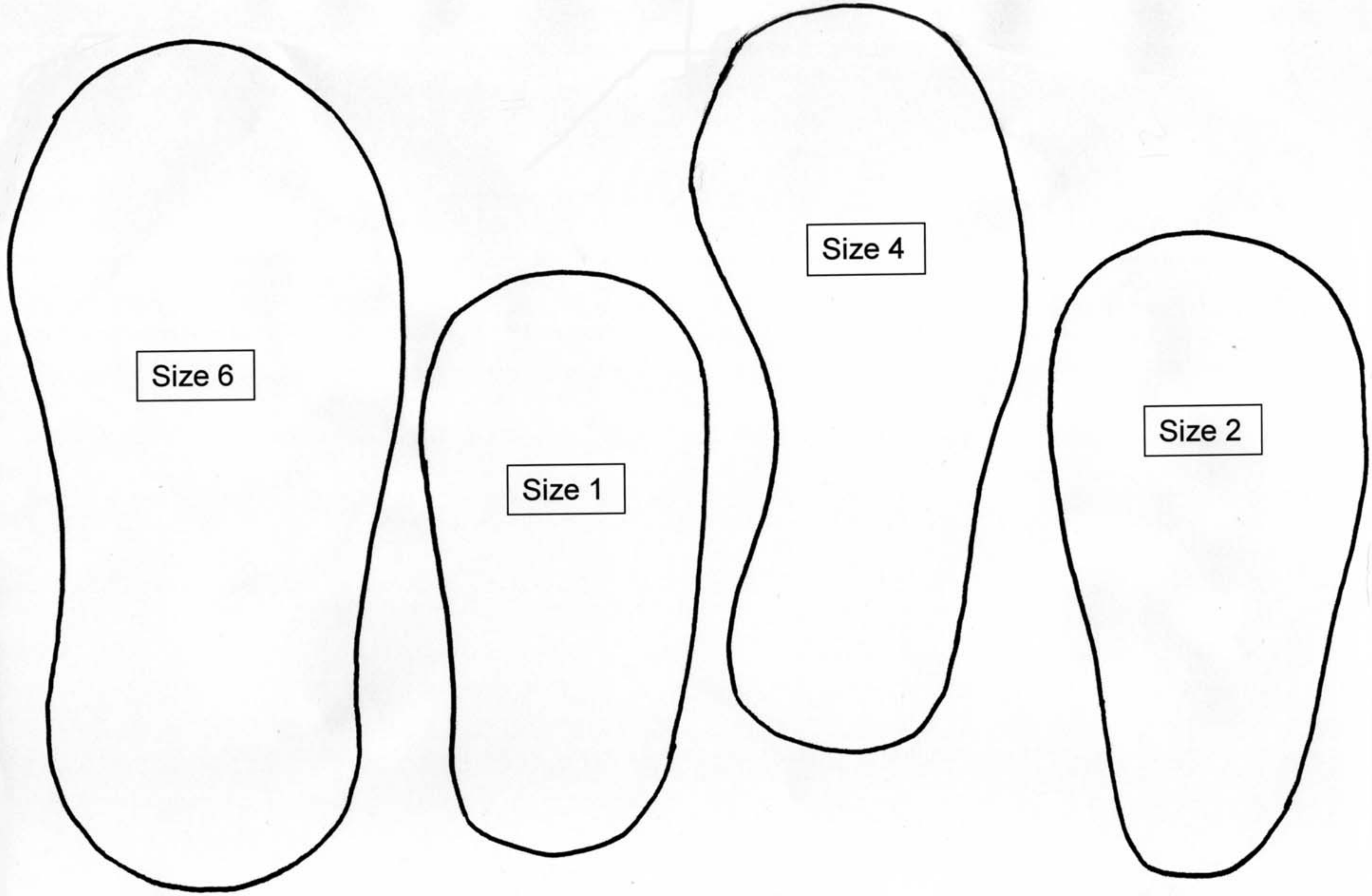
   What features can you see?

2. Draw a labelled diagram of your thumb in the space below

3. Now look at the finger next to your thumb.

   How are the thumb and finger different?

   Write the differences in the space below.



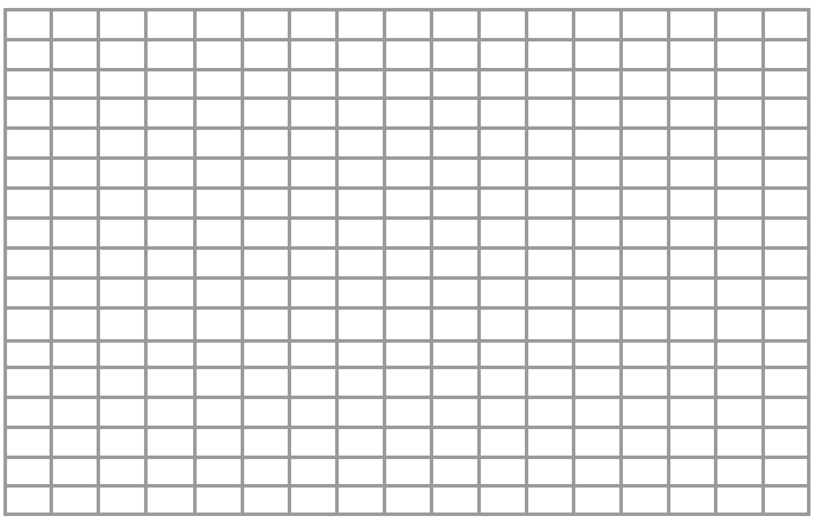
Children's shoes

Activity 2: What is the link between shoe size and shoe length?

What to do:

1. Look at the drawings of shoeprints on the opposite page.
2. Measure the length of each shoe.
3. Record your results as a table in the blank space below

4. Plot your results as a graph in the grid below.



Using your results, answer these questions

5. How much longer is a size 4 shoe than a size 2 shoe? …………………………….

6. What is the link between shoe size and shoe length? ……………………………..
………………………………………………………………………………………………
…………………………………………………………………………………………..…

7. How long would a size 3 shoe be? …………………………………………………..

Australian Academy of Science

Year 5,6,7 Primary Science Test

Booklet 2 (Activities 3 & 4)

School name________________________________

Teacher number ______________________________

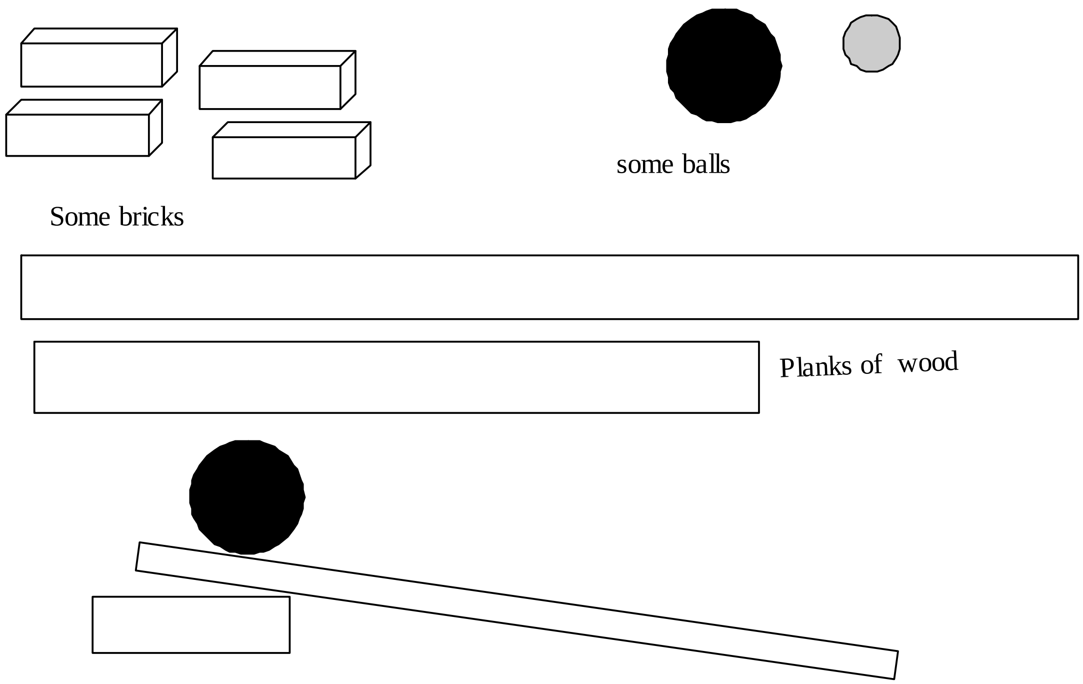
Student number ________ (your teacher will give you this number)

I am in year 3 4 5 6 7 (circle one)

Activity 3: The Rolling Ball Investigation

What to do:

Kim and Lee were planning how to investigate things that affect how far a ball will roll when placed on a slope. They were trying out some equipment shown in the diagram below.



Imagine you are working with Kim and Lee on this investigation.

1. Identify **one thing** that you could investigate that might affect how far a ball will roll.

…………………………………………………………………………….

2. What effect do you think this **thing** would have on how far a ball will roll?

………………………………………………………………………….

3. Write the question that you would be trying to answer if you did this investigation.

……………………………………………………………………………

…………………………………………………………………………..

4. For **this** investigation, complete the table below to show what you would change, measure and keep the same to make it a fair test.

What I would change	What I would measure	What I would keep the same to make it a fair test

5. In the space below <u>draw a table</u> that you would use to record the results from this investigation.

END OF ACTIVITY 3

Activity 3: Science in My Class

Here are some statements about your science lessons at school.

What to do

Read each statement.

Show what you think by putting a circle around the answer that matches what you think. For example:

I eat chocolate cake in science lessons	Never	Rarely	Some-times	Often	Always

If you make a mistake, erase the wrong one and circle the one you want.

There are no right or wrong answers

Now it's your turn.

	Statement	Choose one answer for each statement				
1	In my class I do science every week.	Never	Rarely	Some-times	Often	Always
2	I enjoy learning in science lessons	Never	Rarely	Some-times	Often	Always
3	I am excited during science lessons	Never	Rarely	Some-times	Often	Always
4	I find other subjects more interesting than science	Never	Rarely	Some-times	Often	Always
5	I am curious during science lessons	Never	Rarely	Some-times	Often	Always
6	I am bored during science lessons	Never	Rarely	Some-times	Often	Always
7	I learn interesting things in science lessons	Never	Rarely	Some-times	Often	Always
8	I like science better than most other subjects in my school	Never	Rarely	Some-times	Often	Always

Thank you for doing these activities. Please return this booklet to your teacher.

Appendix 3
Marking Guides for the Assessment Tasks

Marking guide for the 'Draw your thumb' task

Draw your thumb DYT 1 *LIT*		Provides a descriptive title for the diagram
Code 2	Descriptive title	My left thumb or features of my thumb or front view of my thumb
Code 1	Simple title	My thumb or thumb
Code 0	No title	No valid title

Draw your thumb DYT 2 *PROC*		Accuracy of diagram
Code 2	Diagram is accurate	Diagram is a good size and accurately represents main features clearly as a scientific diagram. Must look like a thumb. [I (P&C) Level 3]
Code 1	Diagram shows some features	Some features can be identified from the diagram but shape not exact, nail bed not shown [I (P&C) Level 2]
Code 0	Diagram does not effectively communicate the features of the thumb	Diagram is very small and cramped or out of proportion or misshaped so that it is not clearly a thumb. Nail is just a cap on the thumb

Draw your thumb DYT 3 *LIT*		Amount of information recorded
Code 2	Provides rich representation	Shows how thumb is attached to the palm and/or represents two or more views of the thumb
Code 1	Simple representation of thumb	Draws one representation of the thumb and does not show how it joins to the palm [I (P&C) Level 3]
Code 0	No information recorded	

Draw your thumb DYT 4 *LIT*		Labelling of diagram
Code 2	Effective labelling	Labels are connected to part of thumb with a line or arrow and the line or arrow touches or points directly to the part being labelled, and at least four parts are labelled
Code 1	Limited or inaccurate labelling	Only two or three parts are labelled and/or the labels are not connected accurately to the parts
Code 0	No labels	None or only one label

Draw your thumb DYT 5 *LIT*		Size of thumb recorded
Code 1	Some indication of size	Size may be indicated by an annotation, by a multiple of actual size or by a scale
Code 0	No indication of size	

Draw your thumb DYT 6 *PROC*		Compares thumb and finger
Code 2	Identifies three or more valid differences	For example: Finger is longer, nail on finger is smaller, finger is thinner, finger has three knuckles while thumb has two
Code 1	Identifies one or two valid differences	For example: Finger is longer, nail on finger is smaller, finger is thinner, finger has three knuckles while thumb has two
Code 0	No differences	No differences or not clear (eg. Finger is thin, it is longer)

Marking guide for the 'Year 4 Shoe size' task

Shoe size Year 4 Sh4S1 *PROC*		Accuracy of measurement
Code 2	Measurements are accurate	All (4) measurements are accurate - all within 0.4 cm (11cm, 12 cm, 14 cm and 16 cm)
Code 1	Measurements are somewhat inaccurate	Three measurements are within 0.5 cm [I (P&C) Level 3]
Code 0	Other	Less than 3 measurements accurate.

Shoe size Year 4 Sh4S2 *LIT*	Recording of measurements in a table

Code 1	Tabular form	Measurements are recorded in columns in tabular form [I (P&C) Level 3]
Code 0	Non-tabular form	Measurements are recorded as notes or lists [I (P&C) Level 2]

Shoe size Year 4 Sh4S3 *LIT*		Title of table
Code 2	Descriptive title	Title includes names of both variables e.g. Length of different sized shoes
Code 1	Simple title	Title only includes the name of one variable e.g. Shoe lengths
Code 0	No title	No valid title

Shoe size Year 4 Sh4S4 *LIT*		Column headings
Code 2	2 column headings	Includes both column headings e.g. (Shoe) size or (Shoe) length
Code 1	1 column headings	Includes one column heading e.g. (Shoe) size or (Shoe) length
Code 0	No column headings	*NB. Headings must be at top of table (not embedded), must name variables (measurement, units, etc not allowed)*

Shoe size Year 4 Sh4S5 *LIT*		Units of measurement
Code 1	Units included	Units of measurement (centimetres, cm or cms) are included for shoe length
Code 0	No units included	

Shoe size Year 4 Sh4S6 *LIT*		Ordering of data
Code 1	Data in order of magnitude	Data are ordered by magnitude ie. from highest to lowest values or lowest to highest
Code 0	Data not ordered	

Shoe size Year 4 Sh4S7 *LIT*		Ordering of variables
Code 1	Variables are ordered by column/row	The independent variable (shoe size) is placed in the left column and the dependent variable (shoe length) is placed in the right column OR independent on first line and dependent below for a horizontal table
Code 0	Variables not ordered	

Shoe size Year 4 Sh4S8 *PROC*		Reading data
Code 2	Length correct + units	Correctly reads length of size 2 shoe as 12cm
Code 1	Length correct	Correctly reads length of size 2 shoe as 12 but no units
Code 0	Length incorrect	Length incorrect

Shoe size Year 4 Sh4S9 *PROC*		Comparing data to answer question
Code 2	Correct comparison with units	Size 4 shoe is 2 cm longer than a size 2 shoe
Code 1	Correct comparison, no units	Has 2 but no units
Code 0	Data not compared	Any other answer

Shoe size Year 4 Sh4S10 *PROC*		Interpretation of data to answer question
Code 1	Size 2	Katy should wear size 2 shoes [I (P&E) Level 2]
Code 0	Other	No clear indication of correct size

Marking guide for the 'Year 5-7 Shoe size' task

Shoe size Year 567 ShS1 *PROC*		Accuracy of measurement
Code 2	Measurements are accurate	All (4) measurements are accurate - all within 0.4 cm (11cm, 12 cm, 14 cm and 16 cm)
Code 1	Measurements are somewhat inaccurate	Three measurements are within 0.5 cm [I (P&C) Level 3]
Code 0	Other	Less than 3 measurements accurate.

Shoe size Year 567 ShS2 *LIT*		Recording of measurements in a table
Code 1	Tabular form	Measurements are recorded in columns in tabular form [I (P&C) Level 3]
Code 0	Non-tabular form	Measurements are recorded as notes or lists [I (P&C) Level 2]

Shoe size Year 567 ShS3 *LIT*		Title of table
Code 2	Descriptive title	Title includes names of both variables e.g. Length of different sized shoes
Code 1	Simple title	Title only includes the name of one variable e.g. Shoe lengths
Code 0	No title	No valid title

Shoe size Year 567 ShS4 *LIT*		Column headings
Code 2	2 column headings	Includes both column headings e.g. (Shoe) size or (Shoe) length
Code 1	1 column headings	Includes one column heading e.g. (Shoe) size or (Shoe) length
Code 0	No column headings	*NB. Headings must be at top of table (not embedded), must name variables (measurement, units, etc not allowed)*

Shoe size Year 567 ShS5 *LIT*		Units of measurement
Code 1	Units included	Units of measurement (centimetres, cm or cms) are included for shoe length
Code 0	No units included	

Shoe size Year 567 ShS6 *LIT*		Ordering of data
Code 1	Data in order of magnitude	Data are ordered by magnitude ie. from highest to lowest values or lowest to highest
Code 0	Data not ordered	

Shoe size Year 567 ShS7 *LIT*		Ordering of variables
Code 1	Variables are ordered by column/row	The independent variable (shoe size) is placed in the left column and the dependent variable (shoe length) is placed in the right column OR independent on first line and dependent below for a horizontal table
Code 0	Variables not ordered	

Shoe size Year 567 ShS8 *LIT*		Graph type
Code 1	Plots data as a bar/column graph	Plots a bar/column graph [I (P&E) Level 3]
Code 0	Other	Any other type of graph or representation of the data

Shoe size Year 567 ShS9 *LIT*		Title of graph
Code 2	Descriptive title	Title includes names of both variables e.g. Length of different sized shoes
Code 1	Simple title	Title only includes the name of one variable e.g. Shoe lengths
Code 0	No title	

Shoe size Year 567 ShS10 *LIT*		Labels axes
Code 2	Labels both axes	Labels/names the variables for both axes
Code 1	Labels one axis	Labels/names the variable on one axis only

Code 0	Other	**NB. Labels cannot be embedded in scale markings on axis**

Shoe size Year 567 ShS11 *LIT*		Units of measurement
Code 1	Units included	Includes units of measurement (centimetres, cm or cms) in label of shoe length variable
Code 0	No units included	

Shoe size Year 567 ShS12 *PROC*		Accurate plotting of data
Code 2	Plotting & scale accurate	Scale for length OK and all date plotted accurately (from their data)
Code 1	Plotting accurate	All data plotted accurately (from their data)
Code 0	Other	

Shoe size Year 567 ShS13 *LIT*		Ordering of bars on graph
Code 2	Ordered low to high	Bars ordered with lowest on left
Code 1	Ordered high to low	Bars ordered with highest on left
Code 0	No ordered	

Shoe size Year 567 ShS14 *PROC*		Interpreting data: comparison of shoe lengths
Code 2	Difference correct with units	Calculates difference in lengths, =2cm from their data [I (P&E) Level 2]
Code 1	Difference correct without units	Calculates difference in lengths, =2, no units from their data [I (P&E) Level 2]
Code 0	Other	Difference not correct

Shoe size Year 567 ShS15 *PROC*		Interpreting data: identifies relationship between variables
Code 2	Identifies algebraic relationship	Shoe length is shoe size plus 10 cm
Code 1	Describes simple relationship	Shoe length increases with shoe size or higher shoe sizes are longer or the bigger the shoe size the longer the shoe or shoe size goes up by 1cm each time [I (P&E) Level 3]
Code 0	Other	

Shoe size Year 567 ShS16 *PROC*		Interpreting data: interpolates from existing data to predict length of a shoe
Code 2	Correct prediction with units	Interpolates from data to make a prediction 13 cm [I (P&E) Level 3] Needs to be related to their measurements.
Code 1	Correct prediction no units	Interpolates from data to make a prediction of 13 but no units
Code 0	Other	

Marking guide for the 'Rolling balls' task

Rolling balls RB 1 *PROC*		Identify a potential variable for investigation
Code 1	Identifies a potential independent variable	Size of ball, colour of ball, type of ball, texture of ball, material from which ball made, steepness of slope, number of blocks under ramp, length of ramp [I (P&C) Level 2]
Code 0	Other	

Rolling balls RB 2 *PROC*		Prediction
Code 1	Makes a prediction ie says how the independent variable is expected to affect the dependent variable (distance rolled)	Steeper the slope the further the ball will roll, more blocks the further the ball will roll, larger the ball further the ball will roll etc [I (P&C) Level 3] *Must link to Q1 variable.*
Code 0	Other	

Rolling balls RB 3 *PROC*		Writes a question for the investigation
Code 2	Complete and accurate question	Question names both the IV (named in RB1) and the DV (named in RB2) for the investigation [I (P) Level 3]
Code 1	Question is incomplete	Question only names one of the variables or includes a variable unrelated to the investigation
Code 0	Other	

Rolling balls RB 4 *PROC*		Identifies variable to change
Code 1	Names variable given in RB 1	Names variable given in RB 1 [I (P&C) Level 3]
Code 0	Other	Names another variable or gives more than one variable.

Rolling balls RB 5 *PROC*		Identifies variable to measure
Code 1	Names the distance rolled/speed it rolls	Distance rolled/speed rolled [I (P&C) Level 3] *NB. If includes measuring height of bricks/plank as well as correct DV, that is OK*
Code 0	Other	Names another variable or gives more than one variable.

Rolling balls RB 6 *PROC*		Identifies variables to be kept the same
Code 2	Names two variables to be kept the same	Names two potential independent variables other than the variable named in RB1 or RB2[I (P&C) Level 4]
Code 1	Names one variable to be kept the same	Names one potential independent variables other than the variable named in RB1 or RB2 [I (P&C) Level 3]
Code 0	Other	If IV or DV included then no marks at all.

Rolling balls RB 7 *LIT*		Table includes columns for the independent and the dependent variables
Code 2	Table has columns for independent and dependent variables	Columns are provided for the dependent variable (distance rolled) and the independent variable named in RB1. Must relate to Q1 and Q4 to be valid. [I (P&C) Level 3]
Code 1	Table has column for independent OR dependent variable	Column is provided for the dependent variable OR the independent variable.
Code 0	Other	

Rolling balls RB 8 *PROC*		Table allows for repeat trials
Code 2	Table allows for repeat trials and average	Table provides for recording of measurements from repeat trials and for the recording of the average of the repeat trials [I (P&C) Level 4]
Code 1	Table allows for repeat trials	Table provides for recording of measurements from repeat trials [I (P&C) Level 4]
Code 0	Other	