Thinking Science Australia: Improving teaching and learning through science activities and reasoning

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Abstract

'Thinking skills' is one of the eight general capabilities explicitly included in the content description and achievement standards of the recently released draft Australian Curriculum: Science. Unfortunately, it is often not clear to teachers how they can successfully teach thinking skills to students and make a difference to their achievement. The significance of this research is that it is providing science teachers and students an opportunity to participate in a program of science activities that has the potential to enhance the students' reasoning capacity. The aim of this paper is to outline the '*Thinking Science Australi*a' project and to examine some of the initial data from this project. Teachers from eleven schools in WA were provided with two days professional development on Thinking Science, a program initially developed in the UK. Data collection involved observation of the implementation of the thinking activities in Year 8 and focus group interviews with teachers about how best to adapt the activities to the Australian school environment. A baseline cognitive test was administered to participating students. Findings from the focus group interviews and the classroom observations (including short video clips) will be presented as well as an overview of the baseline test results.

Words – 199 (200 limit)

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Thinking Science Australia: Improving teaching and learning through science activities and reasoning

Thinking Science Australia is an ARC funded research project between The University of Western Australia and King's College, London to develop a cognitive acceleration program suitable for Australian schools.

Positive impact of cognitive acceleration (CA) programs have been shown to confer considerable benefits upon students in several peer reviewed studies (Adey & Shayer, 1990, 1993, 1994; Adey**,** Robertson & Venville, 2002; Shayer & Adhama, 2007; (General Teaching Council for England, 2001; Higgins, Baumfield and Hall, 2007). Systematic reviews of data, called meta analyses, are used to determine policy and practice in medicine and have been undertaken to examine the effect of thinking skills. Data show that the *Thinking Science* program has a demonstrable impact on student cognition.

'Thinking' lessons can be taught and since they have such far-reaching consequences in terms of raising the achievement of students across the curriculum, then it seems reasonable to suggest that some long-term improvement to intelligence has occurred. So how are these cognitive acceleration programs different from other thinking lessons?

Renowned educators such as De Bono, Gardner and Lane Clarke have contributed to the general discussion about raising awareness of the need for critical thinkers and of the role schools play in facilitating change and development in student thinking. Teachers are urged to encourage their students to use 'thinking hats' to solve problems, spiral different 'thinking types' and ensure that various different intelligences are addressed in students through the design of the curriculum. The 'feel good' factor does not necessarily translate into improved cognition or improved achievement. Howard Gardner commented in a keynote paper at the World Conference on Science and Technology Education recently held in Perth that even though he feels there is much value in the classroom interpretations of his theory of multiple intelligence, "the major scientific work on the plurality of intellect remains to be done" (Gardner, 2007, p. 3).

So, however strong the claims may initially appear, there is no or little evidence for many of the popular approaches used by teachers to encourage students to think in the classroom.

Evidence-based program

The evidence of the effect of the cognitive acceleration through science education (CASE) on students' cognitive growth and academic achievement has been published in a number of forms over the years. The original experiment, with only about 130 students (Adey & Shayer, 1994), as well as more recent work, with over 2000 students from 11 schools (Shayer, 1999; Shayer & Adey, 2002), both demonstrated that students participating in CASE during Year 7 and Year 8 showed improved cognition on Piagetian-based reasoning tasks compared with students in control schools. Moreover, the improvement was sustained and impacted on performance at the (UK) General Certificate of Secondary Education (GCSE) results three years after the intervention program had ended, not only in science, but also in mathematics and

English. The value-added effect translated into an average whole grade improvement in science at GCSE (1.05 grades; 0.6 standard deviations) and similar improvements in mathematics (0.95 grades; 0.5 standard deviations) and English (0.90 grades; 0.57 standard deviations) (Adey & Shayer, 1994).

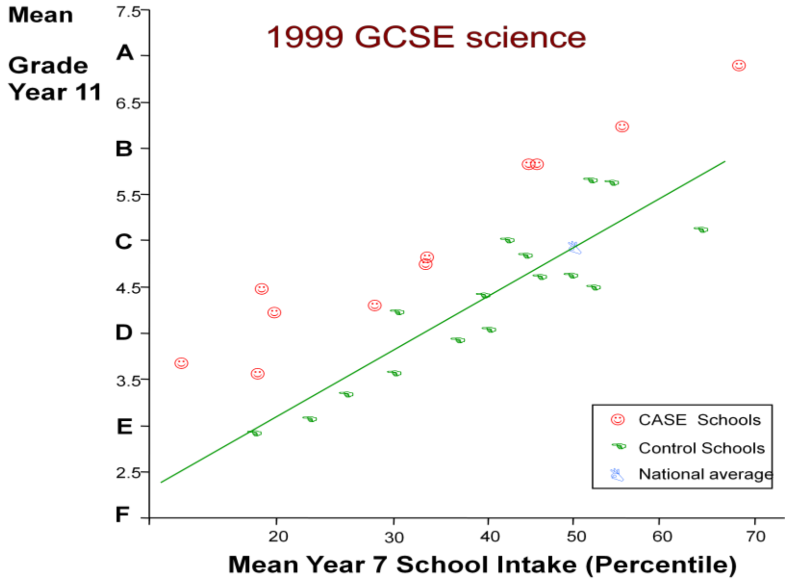


Figure 1 (provided by Philip Adey, King's College London) shows the results from the larger CASE research project (Shayer, 1999) in graphical form. The horizontal axis is the mean student score on a cognitive development test when students entered the school in Year 7. The vertical axis represents the mean science grade for the same students for GCSE, three years after participating in CASE. The CASE schools' value-added can be seen as the vertical distance between the school's point and the regression line for the control schools which runs through the national average.

The cognitive acceleration through science education intervention program is carried out in 30 science lessons over a two-year period (ideally in Years 7 and 8). The program was designed to accelerate students' level of thinking so they would be better able to cope with the demands of the curriculum. *Thinking Science* runs parallel to, but does not replace, other science lessons which give curriculum coverage. The materials are available as a CD or file (Adey, Shayer & Yates, 1995).

Once the early research on *Thinking Science* had been completed a particular methodology and set of curriculum materials were developed and applied to other programs. Currently there are several programs under the auspices of cognitive acceleration including Cognitive Acceleration through Mathematics Education (CAME) and Cognitive Acceleration through Technology Education (CATE) as well as programs for younger children in the early childhood and middle primary years (Shayer & Adey, 2002).

The theory underpinning the cognitive acceleration programs embraces both Piagetian and Vygotskian schools of thought in detailing the stages of cognitive development and specifically targeting problems and requiring 'thinking' to problem-solve in the 'zone of proximal development' so learning as a result of cognitive conflict occurs. Reasoning patterns specifically addressed through the *Thinking Science* activities include: *controlling variables, ratio and proportionality, compensation* and *equilibrium* to analyse process, *correlation, probability, determining criteria for classification, using formal models of thinking and understanding compound variables. Thinking Science* is structured in such a way that the lessons spiral through increasing levels of complexity of these reasoning patterns.

Thinking Science has at its core 5 principles or pillars. The first pillar is ***concrete preparation*** that involves the teacher establishing a problem for the students to consider and to negotiate any associated ideas and terminology needed to understand the problem. The second pillar, ***cognitive conflict*** is a process whereby students are encouraged to think about the problem in a way that challenges their conventional ways of thinking. Students are encouraged to consider a range of possible explanations for the problem. The third pillar, ***social construction*** is the shared development of explanations of and understandings about the problem and potential solutions. Teachers play a role in asking probing questions of students but not offering solutions. Active participation by all students is required, as all are expected to negotiate explanations and solve problems. These processes resonate well with the current interest by educators in pedagogy: group work, problem-solving and challenging teaching. The fourth pillar, ***metacognition***, involves students reflecting on their thinking and articulating their approaches taken to problem solving thus enabling other students to access other ways of thinking and evaluating. Finally, the fifth pillar, ***bridging***, involves applying the ideas developed to other problems in the real world. Associated science lessons can be used to help reinforce and remind students about the range of problem-solving strategies and ways of thinking they develop during *Thinking Science* lessons.

What does a *Thinking Science* lesson look like?

The early part of a *Thinking Science* lesson involves introducing the problem and related vocabulary. For example, in the 'Treatments and Effects' lesson from *Thinking Science* (Adey, Shayer & Yates, 1995), correlation reasoning is used to assess the strength of a relationship between two variables. A concrete experience is provided and students examine pictorial data about carrot plants grown in soil and grown in soil with a treatment. Some control group carrots are larger than treated carrots even though a strong positive correlation exists between the treatment and the size of the carrots. The cognitive conflict is then presented: will all carrots be bigger if we use the treatment? Clearly, understanding correlation depends on an understanding of probability. Other activities in the lesson include examples of negative correlations or where no correlation exists at all. Bridging to everyday life can include use of medication for pain relief etc. Much of this lesson involves whole class discussion, with some time for paired or small group discussion to determine the relationships between variables: teacher input is through specific and Socratic questioning such as 'how do I know?'

Establishing *Thinking Science Australia* in schools

Preparation, delivery and evaluation of thinking lessons need to be well supported. The effective establishment of specific thinking lessons outside the 'normal' curricula depends on a good theoretical understanding and acceptance of the rationale for implementing such lessons into classrooms. For teachers prepared to take on the additional task of delivering lessons which may appear to have little to do with the normal skills, processes and knowledge of everyday curricula, considerable support and 'coaching' in methodology is required. Ideally, this has to be a whole-school agreement, whereby teachers, administrators in schools, technical support and parents are included in the decision to promote thinking in students. To be able to successfully incorporate a program like *Thinking Science* into a school curriculum requires science teachers to be trained in the materials and methodology as well as the underpinning philosophy. At present, we estimate that two days training can successfully cover the underpinning theory as well as address the practical know-how for experienced teachers and this is followed up by PD during the two years. One-off PD sessions do not result in sustained impact and the interactive sessions in this project ensure teachers contribute to, reflect on, try out activities and learn from each other.

One school in regional Western Australia, Pinjarra Senior High School, is identified as an exemplar for the *Thinking Science Australia* program using the cognitive acceleration materials developed at Kings College, London (Adey, Shayer & Yates, 1995). Another school in northern WA adopted the program but delivered this in three terms instead of over two years. Ten other schools in WA, QLD are into their second term of implementing the program with Year Seven, Eight or Nine students.

Methodology

Research Design

The research follows a sequential exploratory design (Cresswell, 2009) with three sequential phases. In 2010 we are in the first phase of conceptualisation. There are three main research questions in this phase.

- how a cognitive acceleration program can best be implemented
    - iterative and primarily qualitative detailed classroom observations and focus group interviews
    - trial and gather feedback about the effectiveness, utility and level of engagement of the cognitive acceleration activities
    - pilot test instruments and analytical procedures
    - give preliminary feedback about the impact of the trialled lessons on thinking ability and science achievement

- how the CA program can complement the new national science curriculum
    - can this be used to inform the schemata and science contexts in which the activities are developed.

- how cutting edge science and modern ICTs can be incorporated into the CA program
    - can (and how?) modern ICTs such as three-D computer-based models, simulations and data loggers be used as tools in the cognitive acceleration activities?

In this paper, we will present quantitative data from baseline tests administered to Year Eight students and qualitative data in the form of transcribed interviews with teachers as a focus group to review and reflect on the activities and the cognitive acceleration program.

Participants

The participants in this research included 1318 Year Eight students from ten high schools in Western Australia and Queensland. Details about the schools and participants are given in Table 1.

Table 1: Information about the schools involved in the research

School type	Location	Number of students
Government	Suburban	98
Government	Regional	172
Catholic	Remote	171
Government	Regional	117
Government	Regional	134
Independent	Suburban	106
Government	Suburban	94
Independent	Suburban	159
Independent	Suburban	97
Government	Suburban	170

Quantitative data on the cognitive level of students

Data have been collected prior to the implementation of the cognitive acceleration program on students' level of cognitive development using a Piagetian Science Reasoning Task (SRT) as developed by Shayer (1978) and a further SRT will be administered to students at the conclusion of the two-year program in December 2010.

The first baseline test is one of a series developed by the team 'Concepts in Secondary Maths & Science' at Chelsea College, University of London some years ago. These were used to investigate the relationship between the optimum Piagetian level (at which students can function) and the understanding of science (which he or she can achieve). Developmental psychologists such as Piaget have identified the change in thinking about 'size' as each of the component parts become more clearly understood by children as they develop.

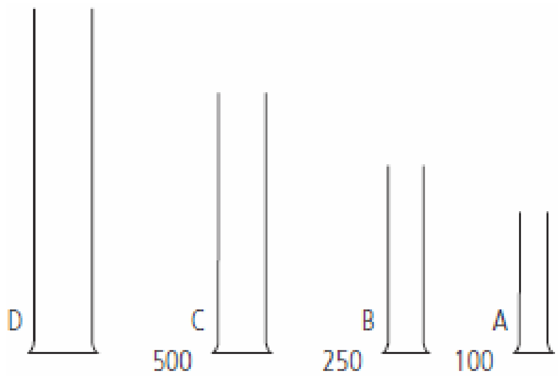
The baseline test

The baseline task is based on volume and heaviness, with questions from the conservation of volume (Piagetian stage 2A) to calculations of density (3A). The theory behind this task is that the components of 'size' - mass, weight, volume and density - are not differentiated clearly from each other. These terms seems to mean the same thing for young children. The first to 'crystallise out' is mass – conservation of substance. A little later (Stage 2A/2B) weight is conserved, and a global, intuitive concept of density it differentiated from weight. Later, volume is conserved, and differentiated from mass and weight (Stage 2B/3A). Finally, with volume and weight consistently differentiated, students demonstrate an understanding of the concept of density as a weight/volume ratio (3A). So, for example, an individual can see that whether something floats is governed by its weight compared with the weight of the same volume of water.

The task is hierarchically constructed, with the questions starting off being at early concrete operations (2A) and progressing with increasing challenge until the last questions which can only be solved using more advanced thinking. Teacher instructions and guidelines are provided with copies of the student answer sheet which has diagrams of the apparatus used and questions. The whole task takes about 50 minutes and is a tiring experience for students.

For example, one of the early questions which tests conservation of volume is pitched at the Piagetian level (2A). Four measuring cylinders are set up at the front of the class as shown in Figure 2.

Figure 2. Representation of the apparatus on the student baseline test: question 2



Teacher instructions: Fill A at the tap. Pour into D. Refill A. Pour into C. Refill A. Pour into B. Refill A. Put all 4 together in line so they can be seen.

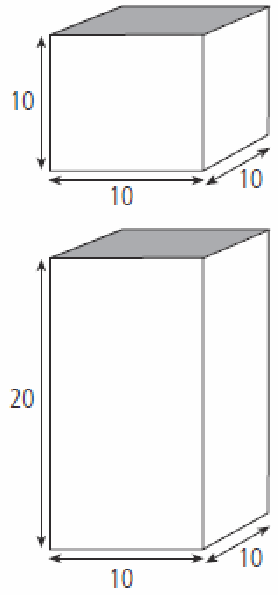
Then put the question to the students:

Do these cylinders all have the same amount of water? YES /.NO
If you answered "NO" write down which has most

Nearly 80% of students in Year Eight scored this correctly.

Another question requires students to make some simple calculations, to consider both mass and volume in thinking about whether a box will float or not. The teacher has a clear box with the dimensions shown as 10cm by 10cm by 10cm.

Figure 3. Representation of the apparatus on the student baseline test: question 12



Teacher instructions: Say this box is so light that you can forget about its own weight and the box is filled with a dry cleaning fluid so that it weighs 1500g. Another box, twice as tall as shown in the diagram, has water and this one weighs 2000g.

Would the small box sink or float when out in water?

SINK / FLOAT

How did you work out your answer?

Teacher instructions: Emphasise that it is very important to show the working or reasoning being used – no credit otherwise – when they have finished show the box again and read the next question. Now imagine what happens when the dry cleaning fluid is emptied out and is filled with alcohol. Now it weighs 850g.

Would the small box sink or float when out in water?

SINK / FLOAT

How did you work out your answer?

For a mark, students need to both choose the correct sink / float option and to justify their answers correctly.

Qualitative survey: teacher focus group

During term two of the implementation of the *Thinking Science Australia* program in schools, teachers were brought together to form a focus group. Representatives from eight schools participated in the focus group discussions. With permission from all participants, interviews were recorded and transcribed. In this paper, we present a snapshot of teachers' responses to three sets of focus group questions.

Do you feel that you have learnt something through the PD process? What did you learn? What (if anything) has changed about your teaching approach?

Have you been able to make connections between what students are doing in the Thinking Science lessons and what you have been teaching them in your regular science lessons?

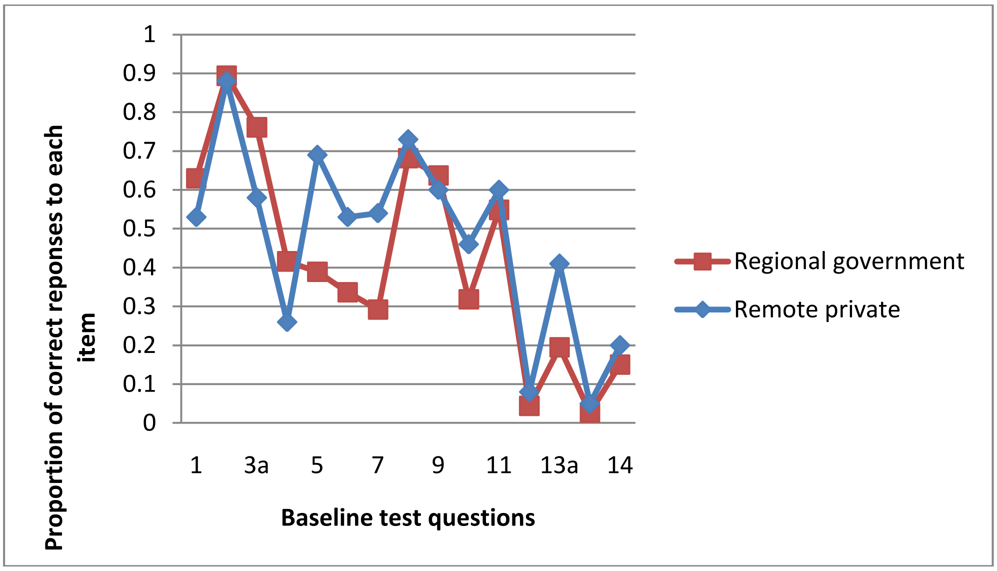
The draft national curriculum has 'thinking skills' as one of ten general capabilities. Do you think that these lessons would be appropriate to achieve this general capability? Why? Why not?

Findings

Quantitative data: the baseline test

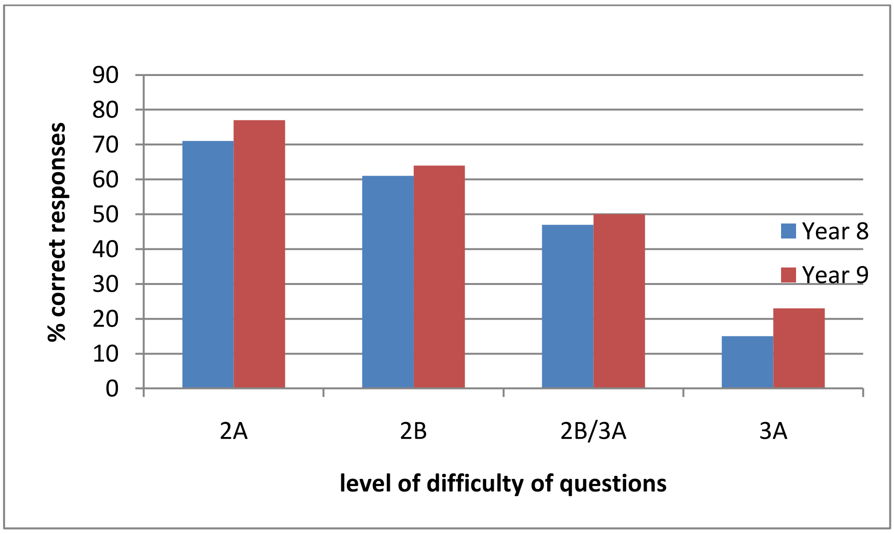
All the baseline tests were scored by two independent markers ad the data entered into an excel spreadsheet. The scoring rules use a 2/3rd success rate as a criterion for being at a particular Piagetian stage and an algorithm is used to compute the final task 'score' which determines the Piagetian level of thinking for each student. Statistical analyses of the data include determining the mean score and standard deviation for each school year group.

Figure 4. Item facilities on the baseline test: the Science Reasoning Task (SRT) II



The data show that more students had correct responses to the questions which were easier, demanding a lower level of reasoning.

Figure 5. The percentage of correct responses for questions of varying difficulty (Years 8 and 9) in one school



The reasons students gave for their choice of floating and sinking were used to score the answer. For a wholly correct answer students had to correctly choose floating or sinking and then provide a valid justification. A selection of student responses is given below.

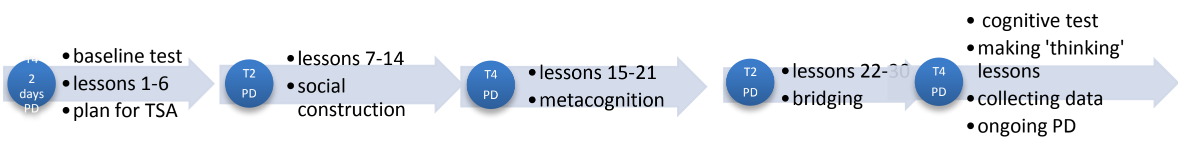
- The sealed box should have air in it
- Water can’t get in the box
- The chemicals in the dry cleaning fluid will keep it afloat. Or the water pressure will force the smaller box to float.
- Cleaning fluid does not [sink] because cleaning don’t weigh much
- The box needs air to float
- Water isn’t that strong and wouldn’t be able to hold the alcohol
- Because the alcohol is heavy in the box
- It will sink because alcohol is more thicker and plus a box it will sink to the bottom
- It will sink as there is no air in the box making it impossible to float as you need air seeking the surface
- Because liquid and liquid apart from water doesn’t float

Schools reports were generated based on the data gather from scoring task II and included reference to activities to address students’ misconceptions.

Sustained professional development over two years

The model of professional development recognises the importance of ongoing support as teachers implement a new program in their classrooms. Yoon et al., (2007) examined nine controlled studies of professional development efforts to determine how much time is necessary for an impact. Yoon and colleagues noted that when efforts were less than 30 hours, they showed no significant effects on student learning. Efforts that ranged between 30 and 100 hours, with an average of 49 hours, showed positive and significant effects on student achievement. The model used for PD for all teachers extends for two years, involves university and school based sessions of examining activities and data, planning improvements and reflecting on pedagoagy.

Figure 6. The professional development model for *Thinking Science Australia*.



The purposes of the professional development days are centred around key issues to meet the needs of teachers working with students. The researchers have been gathering information and data about implementation, the activities and student performance. The main purposes of the professional development are technical, theoretical, managerial, administrative, research and social.

A summary of the professional development day for the first day is shown below.

1. Technical	Structure of the materials and of the programme. Going through the first lot of *Thinking Science* Activities. Gaining familiarity with Task II, Volume and Heaviness.
2. Theoretical	The nature of intelligent thinking: formal operations. Cognitive conflict as a spur to cognitive development.
3. Managerial	Planning a two-year development in science departments; strategies and tactics for managing professional development.
4. Administrative	Recording who will be involved; roles. Setting up visits; who will visit and when.
5. Research	Effects of cognitive acceleration. Growth of the programme
6. Social	Building a community of shared enterprise. A TSA network.

We do not underestimate the value of teachers having the opportunity to talk about teaching, reflect on their practice and consider the value of changing practice. Changing professional practice takes commitment, personal and administrative, accountability ongoing support. Change is difficult, implementing a program is challenging.

Qualitative findings from the focus group

Mid way through term 2, after working with the *Thinking Science* activities for 15 weeks, teachers from each of the 11 schools were invited to participate in focus group debrief. This enabled researchers to gather information about their experiences, the ease or difficulty with the activities, the structure of the lessons and lesson guides and how their students were finding the lessons. This paper presents a selection of responses to questions about the professional development.

Do you feel that you have learnt something through the PD process? What did you learn? What (if anything) has changed about your teaching approach?

> *a lot of other things that I've been to, PD, they're trying to teach you the sort of things that are well out of your normal teaching practice, and it's very hard for them to convince me that they're worthwhile. What I've seen in this case, it really does mirror the way I teach anyway, it just really hones it in with great activities and focuses even more on the thinking, so it's very similar to the way I teach science. and that's, I like that.*

> *I love that at least once a fortnight there is time away from the curriculum and the students get to do the hands-on, and it doesn't really matter if they're right or wrong at the end of the lesson, but that they've had the opportunity to attempt, um, rather than, you know, just read the text and answer the questions, or, you know, do a prac, and... I find that my practicals are a lot more thorough too with going from the aims through to the conclusion, um, and I think they are understanding it a little bit more too, so...*

> *I think they're able to, you know, especially with the fair testing, um, and the ways these lessons are designed, as far as what's introduced and the value that something has and the relationship that it has ...I think all of that reinforces the investigative work that they do, but in a very, you know, hands-*

on practical way that they probably don't even know that they're sort of learning it.

Have you been able to make connections between what students are doing in the Thinking Science lessons and what you have been teaching them in your regular science lessons?

Um, again, it works really well with, you know, the investigation side of things ... but, you know, it also covers, well we're doing, you know, classification at the moment, so it covers a lot of different sort of content that it ties in with so that it's not so, 'OK, this is a Thinking Science lesson, and it's really separated from, you know, what we do in class', so, yes, I think so.

Do you think that these lessons would be appropriate to achieve this general capability [of thinking as identified in the new national curriculum]?

I think problem-solving is really important, you know, and not just in science but in life in general, and the more, you know, opportunities you have to problem-solve, and especially in that sort of environment because you're not sort of like, 'shh, keep your voice down', you know, it's not sort of um, limiting them. There's discussion going on in their groups, you know, even with the pantry you know, well, 'that doesn't go there', and 'why doesn't that go there', 'oh because I think it goes…', so they're talking to one another and working out those problems and sort of like readjusting their own thinking.

... teachers in general find teaching thinking and generating resources for thinking lessons quite hard. It's out of the box. And having these lessons prepared for them really, really helps, yeah. Teaching a thinking lesson is a hard lesson to plan.

... as we all know, to be safe and stick to the textbook and, you know, to actually ask teachers to get out of the box, out of their comfort zone, is hard. Having these generated in advance really helps. And they're all such good activities, the resources, you don't need, you know, super expensive equipment.

What the data tell us

The original data about students' thinking were collected some thirty years ago and a more recent survey shows that the level of reasoning has fallen in the same age groups measured (Shayer, Ginsburg Coe, 2007) in the UK.

Figure 7. Comparing Year Seven students' performance on the baseline test in 1976 and in 2003

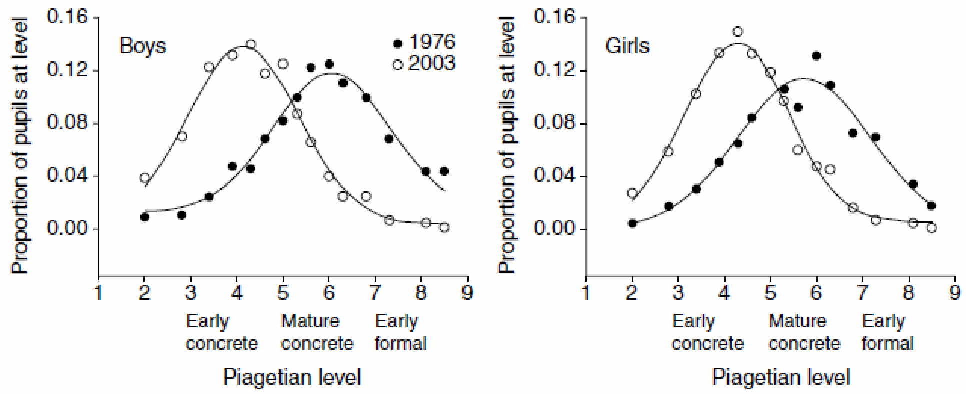
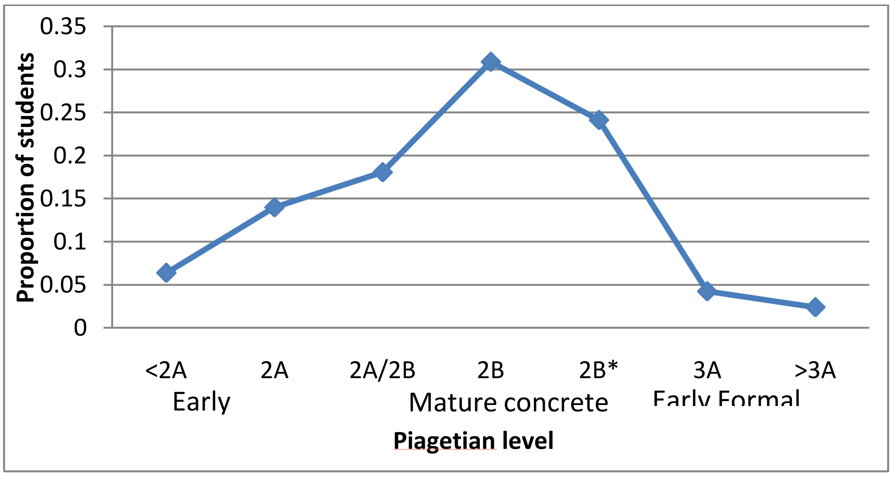


Figure 1. Comparison of performance for boys and girls on *Volume & Heaviness* 1976 to 2003.

The same analysis of the population of Year Eight students sampled in the *Thinking Science Australia* project shows a normal distribution, similar to that shown in Shayer et al. (2007). The mean scaled score is 5.03, which is almost midway between the UK data from 1976 and 2003 for Year Seven students.

Figure 8. Year Eight students performance on the baseline test 2010



There is considerable variation within schools, classes and between schools. Scores from two different schools are given to illustrate the variation between schools and from all schools

Figure 9. How Year Eight students in a low ICSEA school (n = 98) performed. Mean scaled score 4.3, early concrete Piagetian level.

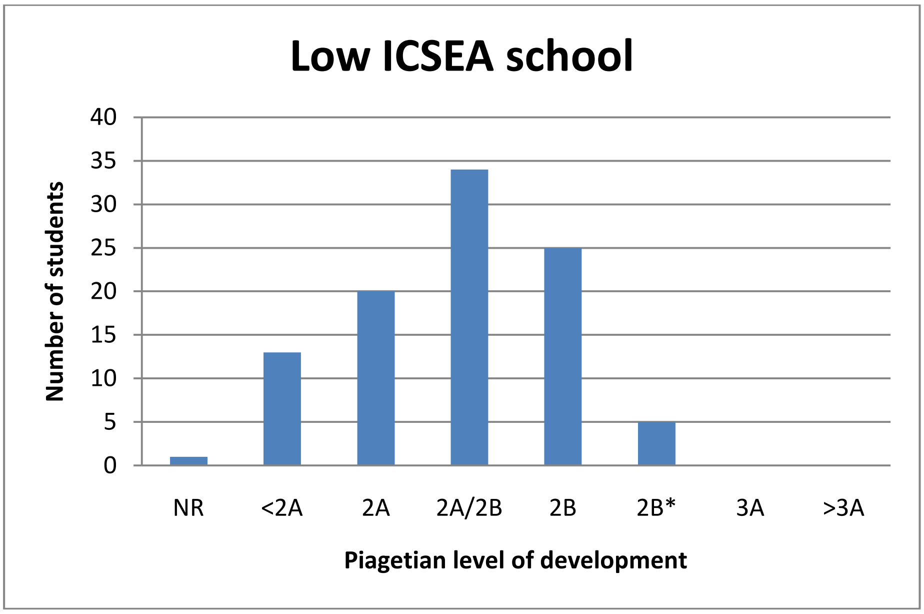


Figure 10. How Year Eight students in a high ICSEA (n = 170) performed. Selective school: high ISCEA. Mean scaled score 6.22, concrete generalization.

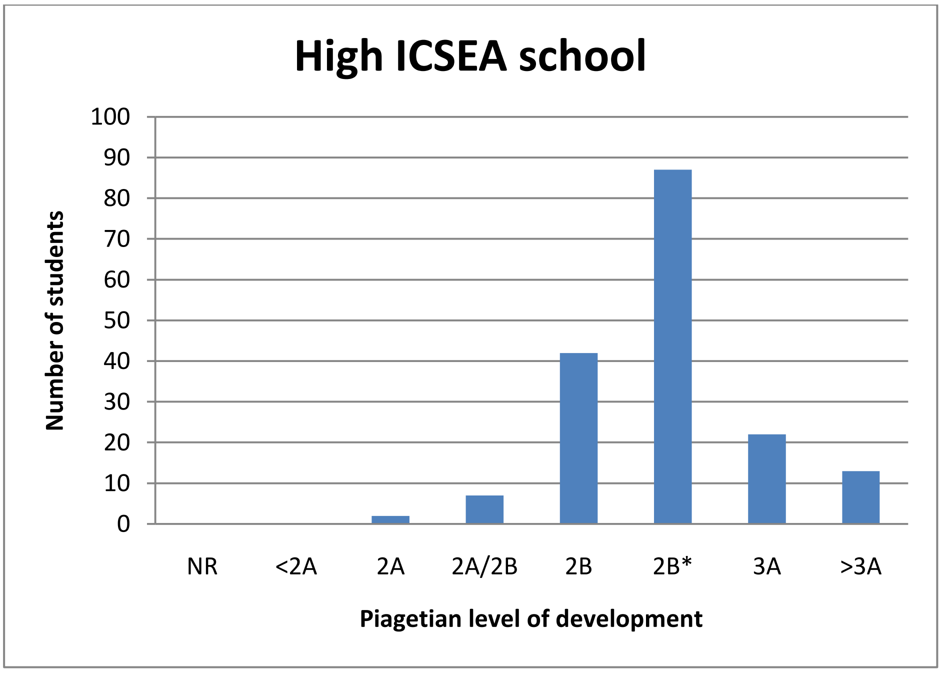


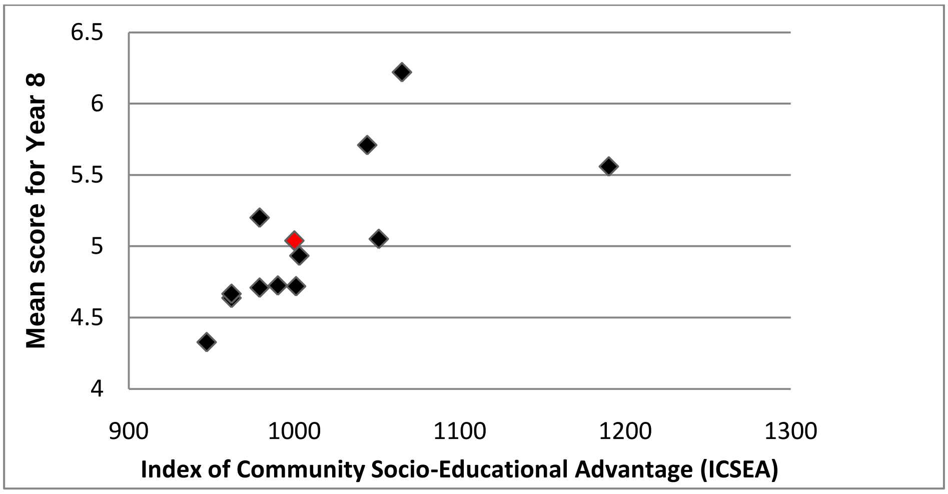
Table 2. Data from all twelve cohorts of Year Eight students showing the mean scaled score, SD and the ICSEA value.

School type	Index of Community Socio-Educational Advantage (ICSEA)	Student number	Mean score	SD
City government	947 [a]	98	4.328	0.9757
Regional government	962 [b]	59	4.638	1.3922
Regional government	962 [b]	113	4.667	1.025517507
Remote private	979 [c]	79	4.71	1.193
Regional government	1001 [d]	117	4.72	1.0599
Regional government	990 [e]	134	4.725	1.288
City private	1003 [f]	106	4.934	1.18
City government	1051 [a]	94	5.052	1.227
Remote private	979 [c]	92	5.201	1.2099
City private	1190 [g]	159	5.56	1.1923
City private	1044 [h]	97	5.71	1.122
City selective	1065 [i]	170	6.221	0.903
		1318	**5.0388**	**1.1474**

[a] Below average of similar schools for all measures: reading, writing, spelling, grammar and punctuation and numeracy
[b] Below all schools for reading, writing, grammar and punctuation and numeracy; substantially below all schools for spelling.
[c] Above average of similar and all schools for reading, writing, spelling, grammar and punctuation
[d] Below average of similar and all schools for all measures: reading, writing, spelling, grammar and punctuation and numeracy
[e] Below average for spelling and numeracy
[f] Above similar schools for writing and for grammar and punctuation
[g] Substantially below similar schools (though above all schools) for numeracy in Years 7 and 9; below similar schools for reading, writing, spelling, grammar and punctuation and numeracy in Year 9 and above in all measures compared with all schools; substantially above in Years 7 in reading and grammar and punctuation.
[h] Above average for grammar and punctuation and for numeracy in Year 7 and 9
[i] Substantially above average for all measures
Data from My School website http://www.myschool.edu.au/ accessed 25 June 2010

The data suggest a correlation between the Index of Community Socio-Educational Advantage (ICSEA) and levels of students' cognitive development. The average ICSEA value is 1000. Most schools have an ICSEA score between 900 and 1100.

Figure 11. The relationship between the mean scaled score on the baseline test and the ICSEA value.

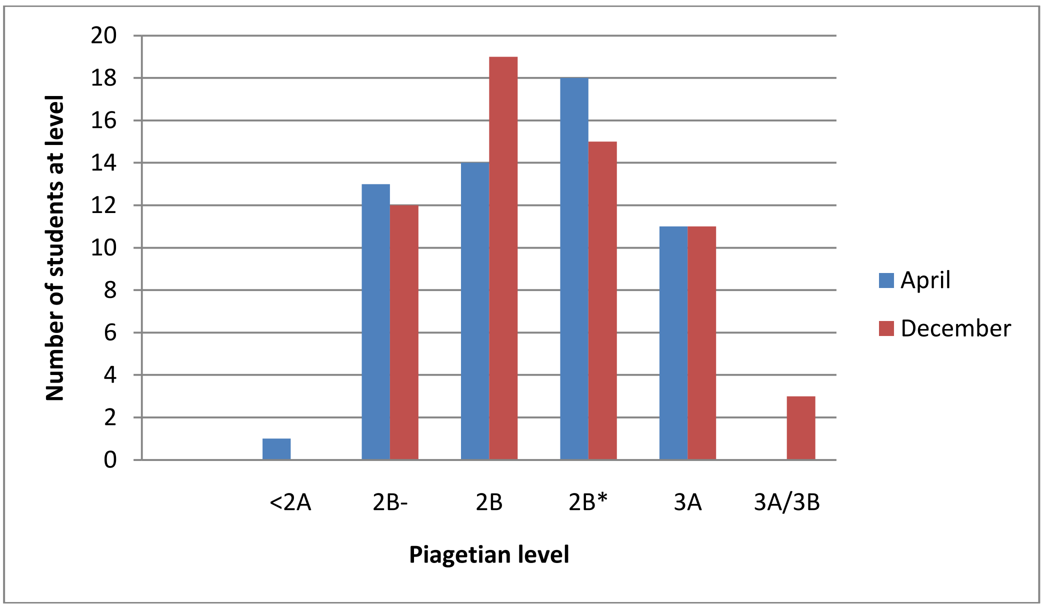


n = 1318
r =0.696907202

A recent report from the Organisation for Economic Co-operation and Development (OECD) used economic modelling to suggest that even small increases in cognitive skills impact a nation's economic growth (OECD, 2010). Poland is cited as an example which improved reading scores between 2000 and 2006 with an economic benefit calculated to be over 2 billion USD.

One school completed the 30 lessons in three terms, so affording us an opportunity to measure levels of cognition over an eight month period. This data is shown in Figure 12.

Figure 12. Matched students in Year Nine (n = 57) after 30 lessons in three terms.



A general shift is seen with more students performing at a higher level in the second test. A control study is planned for 2011.

Thinking Science Australia and the new national science curriculum

The recently published National Science Curriculum structures the proposed curriculum around schemata similar to those of Inhelder and Piaget including comparing, sorting and classifying for Stage 1 (typically 5-8 year olds); cause and effect, patterns, and evidence and explanations for Stage 2 (8-12 year olds); and, equilibrium and interdependence, as well as evidence, models and theories for the Stage 3 (12 to 15 year olds). The consistencies between the proposed structure for the Australian national science curriculum and the schemata used for the UK cognitive acceleration programs highlights the appropriateness and importance of explicit teaching and learning of thinking skills through Piagetian-based schemata. Thinking skills comprises one of ten general capabilities of the new national curriculum as described below.

> *By the end of Year 7, students are able to formulate questions and predictions to be investigated. They can select, with guidance, an appropriate method to investigate their questions (eg **designing a fair test**, survey, information research, use of secondary sources) and conduct investigations safely in groups or individually. They record accurate observations (including **some use of repeat trials**), **show results in tables** or **simple graphs** and make conclusions which are largely consistent with their results. They can **apply the idea of fair testing in relation to controlling, changing and measuring variables***
>
> *By the end of Year 8, students ... distinguish between **types of variables** in designing investigations and routinely record data using correct units, **construct graphs to show trends and patterns** in their results including using ICT with minimal guidance and draw conclusions based on scientific understanding. They use repeat trials in some investigations (eg in force and motion experiments) and suggest alternative methods if required (http://www.australiancurriculum.edu.au/Explore/Science)*

The *Thinking Science Australia* program supports the development of process skills in science, fosters uncertainty and metacognition in students and provides a framework for teachers to develop other thinking lessons.

With respect to the third research question, we are in the infancy of considering the use of IT to support the activities

Phase Two

The purpose of the second phase of the research will be to conduct a quasi-experiment to evaluate the effect of the *Thinking Science Australia* cognitive acceleration program. During this phase the research will focus on the effect of the *Thinking Science Australia* program on students' cognitive development and science achievement.

In order to work with a broad spectrum of Australian school contexts, schools will be selected from all school jurisdictions (government, Catholic, independent) and include both city and country schools and from across Australia. Ten high schools, their science teachers and one cohort of high school students (either Year 7 or Year 8 depending on the school system), (n≈2000) will form the experimental group. Schools will be selected from those whose science teachers have already participated in cognitive acceleration professional development so that they are familiar with the theory and pedagogy required for teaching a cognitive acceleration program. Ten different high schools whose teachers have not participated in the professional development program and a similar cohort of students (n≈2000) will form the control group. The equivalence of the groups will be strengthened as much as possible by matching variables such as year of participating students, size of school, school jurisdiction, location and socio-economic status of the student catchment. The experimental group will implement the *Thinking Science Australia* program within the timeframe of the normal science curriculum for two years. The control group will implement their normal science curriculum for the two year period without the *Thinking Science Australia* intervention. These control schools will be given the option of implementing the *Thinking Science Australia* program after the completion of the research.

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