"I can feel it making my brain bigger": *Thinking Science Australia*

By Heath Dullard and Mary Oliver

"I can feel it making my brain bigger": from a Year 8 student at Pinjarra Senior High School (SHS) halfway through the two-year *Thinking Science* Program. Pinjarra was a pilot school for the program in 2009/10 and a growing number of schools in Western Australia (WA) are implementing this program in Years Seven to Nine as part of the school science curriculum. *Thinking Science Australia* is being coordinated from the Graduate School of Education at The University of Western Australia (UWA) and supports teachers, schools and students from the north to the south of WA, and from Queensland, New South Wales, and Victoria. This article will give the reader a brief overview of *Thinking Science Australia* and look at its implementation at Pinjarra SHS.

Introduction: What is Thinking Science?

The *Thinking Science* program is more than just the thirty lessons delivered over two years, typically 7/8 or 8/9 (see Oliver, Meczes & Venville, 2008). The activities of each of the lessons are short, devised to stimulate thinking and problem solving but demand periods of attention and focused discussion. Lessons are devised around developing reasoning skills that underpin science teaching and learning: control of variables, proportionality, classification, ratios, probability, correlation, formal models, compound variables and equilibrium. The lessons were developed at King's College London by Philip Adey, Michael Shayer and Carolyn Yates and were the first of the Cognitive Acceleration programs to emerge from King's College. Many teachers in Australia have worked in the UK and may be familiar with the Cognitive Acceleration through Science Education (CASE) or its Mathematics counterpart CAME. More recently, the *Let's Think* cognitive acceleration programs included thinking lessons for students from the early years up to the late stages of high school (for example, see Venville, Adey, Larkin, & Robertson, 2003).

The program is designed to improve students' thinking skills through a specific pedagogy that challenges students at all levels and helps them think about their own thinking. *Thinking Science* is an evidence-based program that has been used extensively in the United Kingdom with quantitative data showing not only improvements in students' science grades, but also cross curricula improvements in Mathematics and English long after the intervention period of the cognitive acceleration. It is believed that the program improves students' overall cognitive ability and therefore improves results across the board.

The Evidence

In 1999, a team from King's College gathered data from schools running the *Thinking Science* program and compared it with data from control schools. The results compared students' performance on a national Year 7 test with their Year 11 GCSE results.

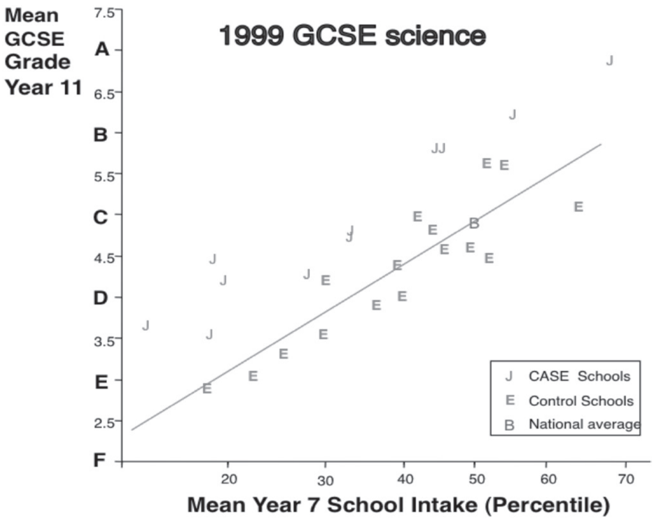

Figure 1: Shows the results from the larger research project (Shayer, 1999) in graphical form. The horizontal axis is the mean student score on a cognitive development test when students entered the school in Year 7. The vertical axis represents the mean science grade for the same students for GCSE, three years after participating in the *Thinking Science*, often referred to as 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. (provided by Philip Adey, King's College London)

The data from the UK showed improved mean performance of all schools involved in the *Thinking Science* program (Adey & Shayer, 1990; Shayer, 1999). There was a 1.05 grade increase for students in science who completed the program – this means a C student became a B student, a B student became an A student and so on. Students also showed a 0.95 grade increase in Mathematics and a 0.90 increase in English examinations in Year 11. These data were compelling enough for teachers at Pinjarra to be interested in exploring how to bring this program to the students at Pinjarra SHS.

Why Thinking Science?

Pinjarra teachers and administration have long valued the importance of higher order thinking skills in improving student performance.

> *As a teacher, I have been constantly looking for new and innovative ways to incorporate thinking skills into my science class. When I read an article in 2008 SCIOS (Oliver et al., 2008) describing the Thinking Science program (then called CASE), I was immediately interested. The fact that the program was evidence based and well structured appealed to me.*

After discussions with UWA, the Science department and school administration, Pinjarra became the pilot school for *Thinking Science Australia*.

Photograph 1: Learning about a fair test and controlling variables.

Implementation

The program has been successfully implemented at Pinjarra with the 2010 Year 9 cohort being the first to finish the program. The lessons are part of the Years 8 and 9 science program and new teachers to the school are trained in delivering the lessons. A number of teachers experienced at working with Thinking Science have reflected on the changes to their teaching as they become familiar with the principles underpinning the program (Oliver, Venville & Adey, 2011a, b). If teachers do indeed change how we teach, it follows that we need support to manage the changed pedagogy in our classrooms. There is considerable variety in the professional learning opportunities available to teachers and with schools looking to the 'bottom line' there is an expectation that professional learning will match school values and goals with improved and measurable student outcomes.

Recently, one of the program developers and internationally renowned educational researcher, Professor Philip Adey, presented a lecture at the University of Western Australia (UWA) and supported the professional learning for teachers. Professor Adey came to Pinjarra Senior High School to see first hand how the program was running at the school and this gave teachers an opportunity to reflect on the model of implementing an intervention program for students as a result of sustained professional learning support.

Discussion with Philip showed that there are several key factors for effective professional learning:

- A sound program, with well researched theoretical underpinnings, evidenced-based and appropriate materials.
- The quality of the professional learning needs to empower teachers through modelling pedagogy, time to develop new skills, reflect on changes to practice and needs to be sustained over a long time; a one day professional learning is unlikely to translate into teacher change even if it is stimulating.
- Developing collegiality comes about when all teachers are working together, supporting each other through changes, become classroom coaches, share and reflect upon pedagogy, rationale and administering the program.
- The school administration has been central to the successful implementation of *Thinking Science* at Pinjarra. With the program embedded in the school plan, the school Principal visiting classes and 'nursing' the program, the vision of improved student achievement is maintained and highly valued as an outcome.

Philip Adey has undertaken research on effective professional development programs and reflected on the essential components to support the implementation of a new program in schools and developed a model of successful professional learning. The 'ingredients', both external and internal to the school, are all necessary to allow teachers to develop professionally and to change or improve practice.

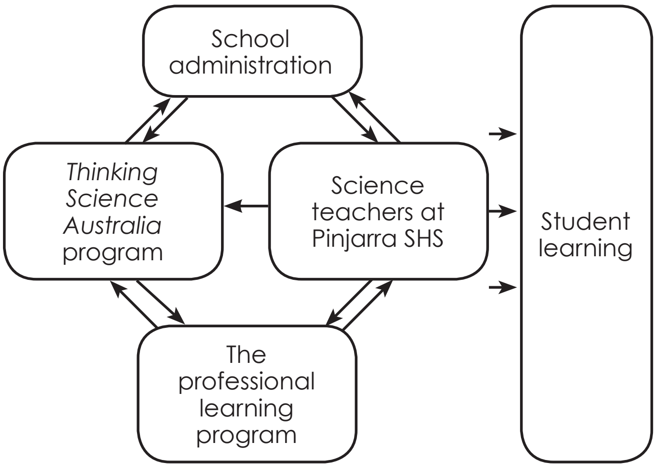

Figure 2: A model of successful Professional Learning. Adapted from Adey, Hewitt, Hewitt, & Landau, 2004.

It is interesting to note all aspects of the diagram were important in successful implementation of the program at Pinjarra. One point that is important to make is the need for ongoing professional learning, or professional development. UWA provides two year professional learning as part of the *Thinking Science Australia* program. This gives teachers the opportunity to engage with the curriculum materials in the lessons, explore the theoretical basis for the pedagogy used in the lessons and builds a community of professionals with growing expertise in helping students become better thinkers. Additionally, the professional learning program supports teachers in developing collegiality within departments, enabling teachers to develop classroom coaching skills and demonstrate competencies across a range of National Professional Standards for Teachers (see http://www.teacherstandards.aitsl.edu.au/).

I have spoken to a number of teachers who had been given the program to teach in the United Kingdom (UK) with little or no professional learning and the program floundered at the school with teachers and students both disliking it.

This is also reflected in the research where teachers who do not 'buy into' the need for a changed pedagogy can have a detrimental effect on student learning (Endler & Bond, 2008).

Pinjarra

Pinjarra is located about 100 km south of Perth CBD. It is a co-educational school with enrolments from outlying towns and farming communities. The school lies in a region of falling socio economic status and this is reflected in the Index of Community Socio-Educational Advantage (ICSEA) developed by the Australian Curriculum, Assessment and Reporting Authority (ACARA). Variables used to determine the ICSEA are derived from the Australian Bureau of Statistics (ABS) and include parental occupation and education level, location of the school (rural, regional metropolitan), proportion of students with languages other than English and proportion of Indigenous students. The average ICSEA value is 1000 and the distribution of students according to parental income is given on the MySchools website (www.myschool.edu.au). The case study school has an ICSEA of 947 with the distribution of parental income heavily skewed towards the bottom half, with 57% in the lowest quartile. This population of between 550-700 students from Years 8-12, is considered to be typically under-represented in mainstream tertiary education with 8% of students from the 2010 graduating cohort going on to university.

The Research Questions

1. What changes were there to the students' level of thinking over the two year program?

2. Were there any changes to student achievements as measured by the WAMSE data?

Method of Data Collection

Piagetian Science Reasoning Tasks (SRT) were used to determine the cognitive level of students before and after the two year program of *Thinking Science* lessons. These have been well documented, used and validated to gauge the cognitive level of students (Shayer, Adey, & Wylam, 1981). Over the last thirty years, these tests have been used to amass data on students' levels of thinking. These paper and pencil tests are based on a classroom demonstration of a specific reasoning concept. Such tasks are available to determine conservation of volumes, mass and density; equilibrium and balance and the pendulum. Using Rasch scaling, results from the tasks can be used to determine the cognitive level of students and data using these tests, have been reported elsewhere (Adey & Shayer, 1990). The 'volume and heaviness' test was administered to all Year 8 students prior to the implementation of the *Thinking Science* program and the test 'equilibrium and balance' on completion of the lessons at the end of Year 9. As the number of schools taking part in the program has grown, so too has the need to standardise this process. These tests are now available on video and power point for schools. Teachers in their normal science classes administered the tests and researchers at UWA scored the papers, cross checking for reliability and consistency.

The Pedagogy

The *Thinking Science* lessons all have the same pedagogy, which engages students in the activities and develops their thinking skills. The pedagogy of each lesson comes within the framework of five headings or pillars. While these pillars are not new to education, the combination of them and their regular use in the classroom is believed to be the reason for the program's success. Although these are described as if the lessons are linear in sequence, in practice, experienced teachers navigate between them, setting up the conflict, opportunities for focused construction and small group or whole classroom 'thinking' and bridging.

The 5 Pillars

1. *Concrete Preparation*
   Each lesson has a short 'hands on' activity that allows students of all abilities to be involved in the lesson. All equipment is readily available and inexpensive.

2. *Cognitive Conflict*
   Once the context for the lesson has been established there is then a conflict or problem presented to the students. This is what engages them if something does not work as they think it should or they are unable to explain something. Students then need to try to solve the problem or explain the observation.

3. *Social Construction*
   All activities are completed in small groups. Students work together and help each other in their group as well as other class members. The teacher acts as a facilitator and does not give students the answers. The fact that students must construct their own understandings and solutions greatly increases their understanding of the concepts covered.

4. *Metacognition*
   The end of each lesson sees students reflect on what they have learnt during the lesson. How did they solve the problem? How does this solution relate to other situations? Metacognition is often referred to as 'thinking about thinking' and is an important step in improving thinking skills.

5. *Bridging*
   The final pillar is using what is learnt in *Thinking Science* lessons in other science lessons. For example; fair testing is covered in a number of the lessons, when investigations are being planned and evaluated, the teacher may first ask students to recall what they learnt about a fair test in their *Thinking Science* lesson. There are many bridging possibilities and some more examples will be given under 'The Curriculum' section. While the program is not designed to teach content, there are many examples where the content relates directly to the curriculum. For example, two lessons towards the end of the two year program relate to density. Directly after this, the Year 9 class were scheduled to learn about convection current, so the *Thinking Science* lessons related directly to the 'content' of the science program.

I found this also happened at the start of the program when I was teaching the scientific method. While it may be possible to link the Science curriculum with the lessons, it would be difficult as they change quickly and we did not link them at Pinjarra. However, many of the topics covered offer an excellent introduction to topics that students will study later in their schooling.

The following is a summary of the content covered in the 30 lessons: variables, fair tests, relationships between variables, classification, ratios, probability, correlation, sampling (capture/recapture) formal models (kinetic theory – states of matter, chemical change, dissolving), pressure, density, equilibrium and moments. The fact that students have constructed their own understanding about the above contexts means that they are more likely to retain them and be able to apply their understandings in the future. There are also many areas where a *Thinking Science* lesson can bridge to a regular science lesson.

Photograph 2: Learning about proportionality: wheelbarrows and ratios.

The Results

For the first time in Western Australia, we have been able to measure cognitive gains over the two-year period and compare these gain scores made with control data. Additionally, we have been able to use tests such as the scores on the Science state-wide Western Australian Monitoring Standards in Education (WAMSE) and national, the National Assessment Program-Literacy and Numeracy (NAPLAN) to determine gains between Years 7 and 9. Data are available elsewhere on the effect of the *Thinking Science* program by looking at cognitive gains made over the course of the program (Oliver, Venville & Adey, *in press*). Some of these data are presented in this paper (with permission from the International Journal of Science Education).

PIAGETIAN REASONING TASKS		GAINS
Case study students	mean	0.94
(n = 68)	SD	0.95
Comparison control	mean	0.46
(n = 120)	SD	1.09

Table 1: Cognitive gains made by students.

WAMSE SCIENCE		GAINS
Case study students	mean	48.4
(n = 68)	SD	40.9
Matched DET schools	mean	39.3
(n = 12,000)	SD	46.8

Table 2: Gains made by students on WAMSE (Science) between Years 7 and 9.

These data show that students have made considerable cognitive gains as a result of the *Thinking Science* intervention (Oliver, Venville & Adey, in press). There were also gains to the students' achievement in the WAMSE Science tests with males performing better than female students and the school having the best ever recorded science results in Year 9.

Discussion

The *Thinking Science* lessons were delivered as part of the science curriculum so that less 'content' lessons were delivered in Years 8 and 9, but with improved performance by the students. Clearly, further follow-on work needs to verify the long term effect of the intervention. Students reported positive experiences with these lessons, citing the usefulness in their 'regular' science lessons, when working scientifically and in promoting thinking about data.

The change in approach to teaching impacts teachers and students. Teachers allow and expect students to reflect on and think about data; it engages students, as they are required to think and solve problems in order to get the answers.

> *After using this pedagogy for 30 lessons over 2 years, I have noticed that I have integrated parts of it into my own teaching. I now try to allow students to construct their own knowledge and give them conflicts to engage them. I have moved away from giving the answers first but rather allow students to struggle with an explanation and discuss answers with their peers.*

It is a firm belief amongst the developers of *Thinking Science* that the program does change teacher pedagogy, which may explain some of the positive results. Implementing a program where teachers watch each other teach, offer feedback on very specific parts of lessons (for example, questioning to promote students thinking or metacognition, increasing 'wait time', setting up groups) fosters the development of collegiality about teaching practice. This practice is evident in other cultures where there has been a deliberate effort to improve teaching quality as suggested by improvements in students' performance in PISA data (Jensen, 2012). Perhaps it is this aspect that has been seen as the most powerful driver of improvements in students' achievement. There is currently research being undertaken by colleagues in NSW as to how and whether the program has an effect on teacher pedagogy.

Lyn Beazley, the Chief Scientist of Western Australia commented that,

> *As Chief Scientist of Western Australia, I have had the privilege to learn about the Thinking Science program and to experience it first hand in a school setting. I have been so impressed: the program really sets the students thinking 'outside the box' about science in a constructive, enjoyable and rewarding way. Moreover, the teachers see the benefits of being in a program that delivers improved student performance, now being confirmed for a wide range of skills by independent testing. The program may also introduce a new teaching style into their skill set. Well done everyone involved in Thinking Science. It is addressing the need for a society with science awareness and the ever growing skills shortage for scientists, technologists and engineers faced by WA.* (Beazley, pers. comm.)

How to get involved

Teachers across the state involved in delivering the professional learning, teaching lessons, coaching peers and adapting materials for their own use and others, are keen to promote the *Thinking Science Australia* program. We are regular presenters at science education forums, such as CONASTA and ASERA. The website has links to further material at: *http://www.education.uwa.edu.au/tsa.*

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