

# 2011 National Science Teachers Summer School Jan 9 – 14

By Dominica Thomson

Thirty teachers applied and won the privilege of attending the 2011 NSTSS held in January at the Australian National University (ANU) in Canberra. Both Primary and Secondary teachers, in search of an inspiring experience in science, participated in a week of fun filled science activities and excursions. The group of teachers from all states and territories of Australia spent five nights on campus at the ANU. Staying at the ANU gave the experience an authentic 'student' feel and allowed for easy access, mostly on foot, to ANU facilities, the Shine Dome and lots more.

The NSTSS was sponsored by the College of Science at the ANU, the University of Canberra, the Australian Science Teachers Association (ASTA) and the National Youth Science Forum (NYSF). The program included a lecture and demonstration by Professor Hans Bacher on lasers, a visit to the Tidbinbilla Deep Space Tracking Station and the Mt. Stromlo Observatory, an interactive link with the scientists at the Large Hadron Collider near Geneva, laboratory visits in the areas of robotics, forensics and much more. There were many highlights during the week including a guided scientific tour of the National Insect Collection and visits to Geoscience Australia and Questacon to name a few.

Teachers were exposed to the latest advances in science and got a 'peek' into the future in areas such as solar panels and new consumer based applications of the sciences within engineering and plant phenomics. Scientists from all fields gave information freely and shared their own career paths that teachers could then pass on to their own interested students.

New ideas gained were then discussed with reference to the new Australian Curriculum. The trip to Parliament House, for example, was linked to *Science as a Human Endeavour* with links and resources given in the area

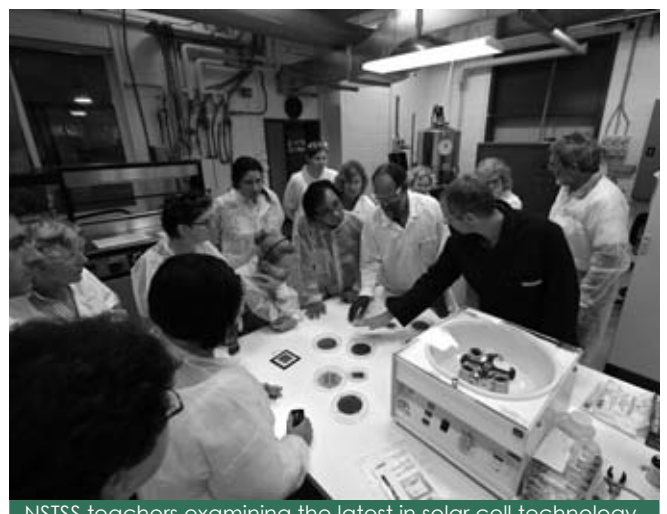
of argumentation when exposing students to ethical implications of science in our world. This idea was epitomized when we observed students involved in the NYSF take part in ethical debates following the



Debra Smith (QLD) engaging in forensic chemistry at the University of Canberra.



Dominica Thomson and John Flint at CSIRO Discovery.



NSTSS teachers examining the latest in solar cell technology at ANU School of Information Sciences and Engineering.

# Schools and teachers supporting student open investigations

By David Symington and Russell Tytler

**This paper draws on a study of the BHP Billiton Science Awards to explore the ways in which open investigation work occurs in schools. The research used interviews with teachers and students and state organisers to develop a picture of what happens on the ground in running student open investigations, and to trace how schools have built a culture of investigation. The paper explores how schools develop and maintain practices that effectively support students' engagement in open investigation work in Science.**

## INTRODUCTION

In an earlier paper from our group (Hubber, Darby & Tytler, 2010), we reported on some of the findings of a study related to the national BHP Billiton Science Awards and associated state-level award schemes, involving the engagement of students in open scientific investigations. The data in the earlier paper showed that involving students in open investigations has a range of positive outcomes. However, teachers can find open investigative work challenging and, to date, relatively few schools are seriously involved in this form of activity. There have been from time to time, at different levels, and in different Australian states, curriculum requirements for open investigative work. Currently, a much greater emphasis on inquiry skills in the new Australian Science Curriculum (ACARA 2009) promises to increase the significance of this activity in the curriculum. It can be anticipated that there will be a need to develop a deeper understanding of, and teacher professional development material related to, how schools and teachers can go about open investigative work, yet there is a dearth of research that would tell us how best to do this.

Most of the impetus for ongoing open inquiry work has been associated with open research categories of science competitions run by the state science teacher associations and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) CREST initiative. These feed into the national BHP Billiton Science Awards, a peak competition funded by BHP Billiton and administered by CSIRO. The authors were part of a team involved in an evaluation of the impact of the awards scheme. In the course of this evaluation, we explored the experience of students in conducting open research, and the way schools developed and sustained processes to support students in this. In the previous paper (Hubber, Darby & Tytler, 2010), we explored the question: 'What is the experience of students engaged in open investigation in school science?' The research question driving the current analysis is:

- How do schools develop and maintain practices that effectively support students engaged in open investigation work in science?

## METHODS

The methodology employed for the larger study was mixed method. The data collection consisted of a combination of questionnaire (predominantly online) and interview data. Only a subset of the interview data will be drawn on for the current analysis. The interviewees included: science coordinators/teachers in schools well represented in the awards (seven secondary, three primary), teacher award winners (seven), students recently involved in the research competitions (three), and state organisers of state awards competitions (two). The interviews were semi structured and explored the experience of the interviewee with research investigations and the award scheme. Written notes were taken of the interviews, which were also audio-taped for backup and to establish quotes. In three cases of substantial interviews which were developed into case studies in the report and which are well represented in this paper, the notes and transcripts were sent for member checking.

In order to make the evaluation manageable within time and budgetary restrictions, we focused our attention on two Australian states with different characteristics which had substantial involvement in the award scheme. The interview data from each of the groups of interviewees were analysed to establish emergent themes. These themes were further checked in each case by at least one and in the case of the current analysis two other team members and refined after discussion. Quotes have been selected that best illustrate the themes.

## FINDINGS

In the interviews, there are stories of teachers building investigative work into their practice in different ways. There are some schools that over time have become very successful at building a culture of open investigation work. Here we will report the different themes that emerged regarding the ways in which a culture of open investigations can be established. The discussion section teases out the nature of the culture that is established, and the student experience resulting from participation in this culture. The paper should be read as a description of what is happening in exemplar cases, rather than as representative of schools' and teachers' practice more generally.

## Building student capacity to conduct research

There are a number of key moments in any open research investigation, and students need to be supported at each of these. Schools developed approaches to help students with research topics and questions, experimental design and analysis, and communication.

Building the capacity to identify suitable investigable questions is important, and challenging. There is variation in the way teachers assist students with this task. The website of the State STS awards was mentioned by one teacher as very useful for ideas. In schools where there is a tradition in such work, students are pointed to the topics explored by previous students. One teacher talked about the importance of the local context in providing a source of research questions, and of science fairs generating interest and motivation to pursue these:

*This is a low socioeconomic area. I thought after uni that all the kids would love science like I did but I found you need to motivate the kids. I entered kids in the (local) Science Fair to get the kids involved. I found I got them engaged with success. We have developed a unit on scientific inquiry which takes a term in the Year 8 syllabus. This leads into the Science Fair projects. I pick out articles for the kids to read from the local paper, agricultural magazines and New Scientist, which might lead to project topics. The project starts at school but if it is going well they get going at home. 50% of the kids are from farms and a lot of the projects are on agricultural topics. (HR, secondary teacher)*

At Ridley School, where Sean appreciates the difficulty of students choosing topics, he has topics 'up his sleeve' for those students who cannot think what to do. In preparation for the awards, Sean hands out a twenty page booklet which includes examples of projects from past years. Students choose projects but he provides support. He opens up the school labs until 6 pm one day a week and states 'near the deadline I have twenty to thirty kids at a time'. He spends much energy supporting students to come up with and refine their ideas; connecting them with scientific professionals is a significant part of the process.

Some schools involved in this form of activity build science investigation work into their curriculum. For example, at Moriah School, teachers embed research work in the curriculum and build expertise over time in a deliberate way, starting with, but going well beyond, simple variable control ideas. Students are encouraged to focus on a topic related to what they have done in class, and to find a mentor. In the following example the longitudinal nature of inquiry increases in complexity over time, as students' research practices increase in their level of sophistication.

*Experimental design skills are important and every year it improves. We start in Year 7 looking at designs with one independent and one dependent variable. In Year 7 and 8 they frequently work with one hypothesis. By Year 9, students are doing more sophisticated designs, longer term, with multiple hypotheses. It may be that the outcome of the first hypothesis may be re-entered as a question in a second area of exploration and they may do that two or three times so that they've now got a more longitudinal study that has a number of hypotheses that may answer a number of questions. Sometimes they do an extended version of the project the following year. (Alison, Moriah School)*

Simon (university student), reflecting on his experience of being part of the research culture at Ridley School, recognised the active role of teachers in developing this research capacity over time. Teachers were enthusiastic and supported students to 'have a go at the science awards and have a go at some proper research'. They inspired students to persist with their investigations, and supported them by providing ample opportunities to develop 'good research skills'.

*In my case, the teacher would always say "Where are you up to?", encouraging you to keep going and keep chipping away at the project. That was very important because when you're a student, you're a little fish in a big ocean and you always need a lot of encouragement, even if you don't get a good result. Our school would always say that a good project is not necessarily one that comes up with a good result but a good project is where you have developed good research skills. They wouldn't necessarily look at the results, but whether you had put the effort into proper research technique. The school prepared you with these research skills. Every time you do an experiment they take you through the scientific method of: background research, aim, hypothesis, methods, results, conclusion. That was drilled in at all class experiments and it became a second language on how to write up experiments, so that when you did your own research you were quite savvy in how to communicate your results.*

(Simon, university student)

## Building a research culture through interaction

Support through providing opportunities for interaction with others was also evident. In some schools, students were mentored by older 'more expert' students who had been through the process. For example, one secondary school has Year 11 and 12 students working closely with primary school students.

*I teach in a Year 11 and 12 college – in a regional area ..... During the Science week project - we have nineteen primary schools and five high schools that attend working on hands-on activities - over sixty activities last year.... The Year 11 and 12 students lead the project (primary students come to the secondary school). The focus is very much on our students leading the project, so while teachers may set it up ... our students actually lead the activities. (Teacher award winner 1)*

Darren, who completed his first open-ended CREST science investigation in Grade 5, received mentoring from Grade 6 'CREST partners' who helped them by sharing their experiences, brainstorming ideas, and assisting with designing the investigation. Other students received mentoring from scientists from local industry who assisted students in generating ideas and met on a semi-regular basis.

The awards themselves provided opportunities for students to interact with students from other schools, which, for students in isolated areas was important.

*It matters a great deal because of our relative isolation. They get to see what other kids are doing. They can compare and see the standard. Very important! At the event you see them going and talking to other kids when they have break and they learn from one another.*

(L, rural secondary teacher)

Almost every teacher interviewed talked about linking their students with practising scientists. This often occurred through the Scientists in Schools scheme, run by CSIRO, and these initiatives need to be seen as linked. One of the very important features of the awards and of running scientific investigations is the way they encourage this movement across the school-community boundary, bringing authentic science practice into the classroom via a variety of science professionals. Some teachers have cultivated contacts over the years, even partnerships with the scientific research community and with local science professionals who supported their work with students.

*It's also good to have people in the community to draw on. We've had great help from CSIRO Marine and Atmospheric Research labs in (state capital), who have given students samples of material to work with and detailed notes to base their methods on. Likewise university departments have been helpful. Also people related to students who have expertise – they may not be people from big industries, but people like bee keepers, or agricultural advisors, or people with farms or people working with the Department of Primary Industries - they might take samples and test them for students. Over the years I've developed a lot of contacts and I use them. These people also act as role models for students in areas in which they might find themselves in a few years time. It really is good for students to have contact with such people, so they can see the value of the sciences. Or it might be that we have people come into class as guest speakers, from organisations such as the Department of Primary Industries or Waterwatch, perhaps taking in crayfish, as was the case back when we were doing the work on them. In this way you can expose the species (then endangered) to as many as 200 students even though the project only involved six students.*

(Alison, Moriah School)

Sean spends a lot of energy supporting students to come up with and refine their ideas, and connecting them with scientific professionals is a significant part of the process.

*It's important to get them to do good background research in the area so they know what's been done before. Then the big job is trying to get them their first contact... hook them up with someone... by email... to help them with their idea, to get started. Kids have all sorts of projects that I wouldn't have a clue about. At the moment I've got a kid who wants to work on dissolved oxygen in water. .... Wants to remove all the micro-organisms so I'm trying to find them a contact. Who can we talk to who's developed a membrane so we can filter... That's the big thing... once they've got a contact - someone who's knowledgeable in their area perhaps someone in the school, they know they're doing proper science. If they've gone out and made that contact, they really get into it. If a teacher feeds them ... like I want you to do this... and this is the next step, it's not much use.*

Sean talked about the building of an understanding of the nature of open investigative approaches and what was possible. He told the story of the student who developed a device to protect against heat in cars. That student was the first to do a really substantial project and the project provided the inspiration for the path the school subsequently took:

*It was a prototype. It provided a model for research projects... what is possible, what is inspiring.*

## Building teacher capacity to establish and sustain a research culture

There was general acknowledgement of the challenges for teachers beginning to involve students in open research projects, centred on insecurity of knowledge, a comfort with the status quo, the workload implications, and a need to develop management skills. It was argued that while the initial step is a large one, the task becomes easier as time progressed. Teachers need professional support as they take the first steps, and interviewees advocated targeted professional development as one means of achieving this. One primary teacher who acts as science leader in his primary school, described the slow process of encouraging teachers who feel they don't have the expertise to run investigations. One-on-one help, and modelling, are strategies used. The curriculum requirement to undertake investigations has been an important support.

*It can be very daunting. Teachers believe it needs a lot of knowledge and it needs to be scientifically based and it's getting over that hurdle where science investigations are led by kids... and it doesn't matter if you fail or if things go astray. It's a lot of that mindset of Science being specialised... teachers feel they need a degree in Science to teach it and it's not true... It's providing a model. I go into their classrooms and provide a model of the process. Find where the teacher is at and find how I can help. (M, primary teacher)*

In some schools the scope and sequence planning for investigative work provided an easy entry for teachers in lower grades who would run controlled rather than open investigations, building confidence through this. In one primary school, the running of open investigations and award entry was part of a ten year professional development plan to raise the quality of science teaching and learning and draw in the entire school community:

*We feel now that we have a culture of parents, students, teachers all working together to ensure that the kids get the best possible grounding in science and scientific literacy that they possibly could. It is a whole school initiative. And has been running — Next year will be the end of the last phase, making it a ten year initiative.*

(Teacher award winner 5)

Another successful innovation has been the institution of regional science fairs that explicitly target schools with a view to maximising participation. In these cases the reporting requirements are sometimes not as stringent as in the state competitions, but participation rates can grow quickly and standards build by virtue of teachers and students being exposed to the projects from more experienced schools.

*From 2000-2003/4 I started mentoring students in small groups and individuals and they did well in the awards... We had some really good successes and staff got interested in making this accessible to all students, so we embedded research in the curriculum. We also organised a science fair which grew from forty entrants in 2003 to eighty entries in 2004. The university-based judges got interested and the university offered a partnership which led to our regional science fair – it's a really fine science fair with over 400 students from eighteen schools involved this year. In the past couple of years, projects from the fair formed the lion's share of entries in the state awards and a lot were nominated for BHP. (Alison, Moriah School)*

Alison talked about the need to mentor teachers who become involved in investigative projects by developing support materials with the purpose of raising teachers' confidence in running individual research projects, and enlisting the expertise of scientists from a local university. She claims that, 'the sort of PD necessary to support this is difficult to come by', suggesting that the responsibility for building teacher capacity falls on schools. She listed the characteristics of a teacher who can run open investigations successfully. They need:

- A strong background and good knowledge of contemporary science;
- Interpersonal skills and the capacity to provide challenge and support individuals;
- A capacity to multi task – hands-on management skills; and
- Enthusiasm for learning with students:  
*Teachers need to be lifelong learners themselves, interested and with the tenacity to stay with a project. It gets easier as you build up a battery of approaches.*

## DISCUSSION AND CONCLUSION

While the research does not claim to be representative of all teachers' and students' experience, certain patterns emerged as well as some compelling stories, concerning the building of a culture of open investigative work.

### Schools establishing a culture of research

The development of processes supporting open investigative work in these schools was not conceived of as a technical issue but rather as a pedagogical orientation and set of beliefs about the benefits for students of autonomous inquiry. There were challenges described for teachers in taking up this work, but many of the schools involved in the awards system had put in place a process, often driven by enthusiastic teachers, to establish the practice within the curriculum. There was evidence that a commitment to open investigation was related to experience with collaborative pedagogies. The approaches of these schools to supporting students was varied and pervasive, including the development of written resources, of a structured inquiry curriculum that took students from simple to more complex investigative designs, and of varied mentoring arrangements. In many cases, these developments were driven by individual teachers with a commitment to and a passion for investigative work.

The awards schemes and science fairs were often, but not always, instrumental in the sustaining of this work in schools. This occurred through the exposure of students and teachers to student work which provided ideas for further work, a sense of what quality investigation looks like, and a realisation of the potential enthusiasm and learning of students. It is interesting (and probably fundamentally inevitable) that an award system that is built around the notion of supporting individual excellence has spawned the creation of a community culture centred on student autonomy in research. That is not to say that only students working in such school environments can develop significant research capabilities. Previous research (Tytler 1992) has demonstrated the importance of family and friends in many students' experience of open investigative projects.

In the case of schools which were advanced down this track of commitment to student open investigation, a culture had been established which supported students in a variety of ways, that have a number of points of intersection with the notion of 'communities of practice' (Lave & Wenger 1991; Lave 1996). These include:

- A variety of mentoring arrangements; from older students, previous years' researchers, teachers committed to working together, parents and friends, and science professionals, organised by teachers or as part of the scientists in schools scheme;
- The development of histories of practice through the accumulation of successful, documented projects (in some cases specialising in particular lines of inquiry);
- Established methods of inducting students into investigative practices, both through formal curriculum arrangements and through targeted support focused on quality outcomes; and
- A commitment to knowledge building based on significant, contextual questions.

In these schools we see the establishment of a culture that encompasses beliefs about, and commitments to, scientific exploration and knowledge building. They involve questions situated in real contexts, involving conceptual refinement. Students become participants in a set of practices that transcend technical knowledge and skills. For instance, one of the defining features of these schools is their commitment to a moral purpose driving the projects. Thus Alison tended to focus on sustainability issues and students completed projects of social relevance. Sean talked about the need for nurturing and the fact his school "is ... a caring school. You need to support and mentor students". He has a belief in projects that have a moral purpose: "We emphasise the beneficial nature of projects ... that is innovative and helps a need.... We try to think of bigger projects than the dynamics of a falling ball".

In terms of the nature of the student projects, there is evidence from the teacher interviews of students adopting flexible, responsive approaches to their investigations and engaging in imaginative problem solving around issues of design. They are far richer than stock-in-trade exercises in variable control that pass for 'scientific method' in many curricula, but which have been widely critiqued (Tytler & Swatton 1992; Watson, Goldsworthy & Wood-Robinson 2002; Windschitl 2004). Alison's description of growth in experimental sophistication captures some of this authenticity of practice. The other dimensions that have become of increasing interest in framing science curricula, evidenced in the Australian national curriculum (ACARA, 2009) are those of student dispositions, and appreciation of the human dimensions of science. This concern with dispositions is linked with a movement in some state curricula to identify broader student capabilities that are represented in science such as creativity and imagination, problem solving, communication, and persistence. These were all mentioned by teachers as outcomes of investigative projects.

## IMPLICATIONS

This study has identified the development in some schools of a supportive culture of student open investigative work. These were largely driven by teachers with a knowledge and passion for this collaborative and creative aspect of science learning. The science awards play an important role in encouraging and sustaining these teachers' practices, as well as their students' commitment. The presence of the awards is important for supporting innovation of this kind.

An important aspect of almost all these schools' practice was the link made to the wider scientific community. Given the support and encouragement offered by science professionals and scientific organisations to students and teachers undertaking this work, there is a need not only to support this (through schemes such as scientists in schools) but to find ways of better linking schools and the science community.

Finally, a challenge was identified concerning the support of teachers and schools beginning down this track of open investigative work. There are a number of skills required of teachers, and of schools, in providing for open investigation, and there is a need for professional development resources to be developed to support this. Our research found only one example of a formal professional development approach, run by the Queensland STA. This was reported to have been successful for primary teachers. While clearly there is a need for across-school professional development of teachers, in the cases identified by this research this seems to have occurred informally, in a school setting, drawing on the expertise of teacher enthusiasts. The experience of teachers in this study could be drawn upon to devise an effective resource for practising teachers and for teacher education, to support the development of practices in schools supporting open investigative work in science. We would advocate that ASTA should consider taking a lead in developing such resources.

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