The student as scientist

A study of the impact of the BHP Billiton Science Awards

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Summary of findings

This evaluation of the BHP Billiton science awards involved an online survey of award nominees and interviews with a sample of teachers, student nominees, teacher award winners, judges and key organisational people.

The aim of the evaluation is to make a judgement about the effectiveness of the BHP Billiton awards in fulfilling their aims, and to make recommendations about their future.

The key themes that emerge from the study are:

1. The student awards scheme sits in a productive relationship to the state awards, which provide an impetus for student entries and which are advantaged by the national profile of the BHP Billiton student awards.
2. There are some very impressive stories of enthusiastic teachers and schools involved in the science awards committed to working with students on investigative projects.
3. The existence of the awards encourages teachers and schools to move beyond normal practical work, which is often described as predictable and illustrative rather than representing scientific experimentation.
4. The requirements for entry into the awards have an impact on what some schools do in their formal curriculum.
5. A minority of teachers and schools are involved in the awards schemes. However, the data gathered suggest that participation in science investigative work is increased where it is embedded in the school’s curriculum.
6. School trajectories tend to start with individual teachers who gradually build their commitment and success, and who work to support and enthuse other teachers.
7. Often, where schools have been involved with the award schemes over a number of years, they have built up a system of supporting students with investigative skills including critical thinking and communication.
8. Such schools, and networks of schools, build the standard of investigative work through the development of a substantive teacher and student culture sustained by the award scheme.
9. Substantial professional learning is required to run school science research projects yet this tends to occur mainly at a local level through sharing teacher expertise. There is an opportunity to tap into this teacher expertise in a more formal and sustained way to produce professional development to support this work.
10. A major aspect of the operation of the science research projects program in schools is the linking of students and teachers with scientists and local science professionals.
11. The award events such as state displays and the BHP judging and camp play a generative role in acknowledging students’ quality work, building student capabilities and standards, and providing motivation to both students and teachers.
12. While there is an absence of quantitative evidence to show that participation in the awards has boosted student engagement with learning or increased participation in science courses and careers, there is universal agreement supported by substantial anecdotal evidence that this is the case. There were also many anecdotes of the activity galvanising disengaged students.
13. While some students have difficulty with aspects of open investigative work, most students respond powerfully to the ownership and independence of open investigations and often characterise this as doing ‘real science’.

14. The teacher awards have gone to teachers with an impressive history of innovation and commitment who have often been successful in initiating and supporting student interest in the student awards. These teachers are very active in utilising the award opportunities and they are very generative in supporting quality school science practice.

15. While the power of an award with very high standards and profile was acknowledged, concerns were raised about the need to have a more layered recognition and award system to encourage teachers and students to participate.

Opportunities and recommendations arising from the study

The study indentified many examples of exemplary practice and innovation on the part of teachers, schools and state science teacher organisations that were encouraged and supported by the BHP awards. We also identified opportunities, arising from the identification of these exemplary practices, for expanding the incidence of science investigative work in schools and a more authentic representation of the nature of contemporary science practices in the curriculum.

Recommendations for BHP concerning the operation of the awards

1. That BHP Billiton continues to support the BHP Billiton science awards through partnership arrangements with CSIRO and the Australian Science Teachers Association (ASTA).

2. That BHP Billiton discuss with CSIRO and ASTA how the nature of the STA and CREST and BHP Billiton awards can best be aligned to meet the twin demands of reward of excellence and grass roots support and encouragement of investigative work, and how the nature of the different levels of award and their communication to students can be most effectively managed to strike the best balance between these competing demands.

3. That BHP Billiton considers expanding the teacher award scheme to give recognition to a greater number of teachers at state level for their involvement with quality student work in the awards schemes.

4. That a revised set of aims for the BHP Billiton Science Awards Program be adopted.

Additional opportunities and recommendations arising from the study

The report has identified challenges, possibilities and effective approaches to developing students’ investigative capabilities in science. This is of particular relevance issue currently, with the emphasis in the Australian Science Curriculum on inquiry and investigative work.

Opportunities exist for utilising the knowledge and practices identified in this report for improving science teaching and learning practices more generally to capture the challenges and excitement of working with science ideas in novel situations. It is acknowledged that there are a number of parties who might see themselves as having a mandate, and the potential to contribute to building on the work described in this report. These include education systems (Government, Catholic, and Independent), CSIRO Education, the Australian Science Teachers Association, and state associations (STAs). It is not appropriate for the report authors to make pronouncements about how this responsibility might be shared or carried out. However, the report findings identify opportunities, with appropriate
Students as scientists: The impact of the BHP Billiton science awards

leadership, for building on current experience within the State STA and BHP Billiton awards to develop a more vibrant school science curriculum generally. The following recommendations focus on these opportunities.

1. That action is taken to ensure that the national curriculum for science includes at least freedom, but hopefully also encouragement, for locally relevant science research projects to be part of the normal classroom program for all students during the compulsory years of schooling. The substance of this study provides a powerful set of arguments for so doing.

2. That steps be taken to initiate and co-ordinate moves for a professional development approach and provision of resources to encourage and support teachers to become involved in open research investigative work. The development of such an approach might involve:
   
   • A national conference / workshop where teachers with expertise in running investigative work can share resources and ideas and develop a strategy for a national approach to professional development.
   
   • The development, possibly in partnership with state STAs, of a professional development resource package for teachers of science to engage their students in investigative work.
   
   • The development, again possibly in partnership with state STAs, of curriculum resources to support the structured introduction of science inquiry skills, based on the experience of teachers and schools involved in the award schemes.
   
   • Support to organise local science fairs as feeder events into the state awards, as a strategy for setting up networks of teachers focused on science inquiry.

3. That relevant bodies will explore ways to use award schemes to encourage quality students and science graduates to consider science teaching as a career option, as an important contribution to raising the quality of science teaching in Australian schools.

4. That some form of recognition be given to people from outside the school system who contribute so much to the learning of school students through their science research projects. This could be done as part of the state award systems.
Introduction

The BHP Billiton awards have been an important part of the Australian science awards landscape for 28 years. The award is a high profile event that builds on the research project division of science prizes run in all Australian states and CREST, and is an avenue to encourage students to participate in this type of science related research work, by virtue of the prize, of the individual recognition it affords, and the profile it generates for this sort of high end student research activity in science.

The aims of the awards and their links with state competitions and CREST.

The stated aims of the BHP Billiton Awards are:

- To improve student communication skills through preparation of reports, posters and dialogue with judges.
- To increase the number of students continuing science at a senior level.
- To improve the view that primary school students have of science.
- To increase the number of students choosing to study science at tertiary level and/or take up careers in science and engineering.
- To increase science teacher professional experience through increasing the amount of inquiry-based science teaching and learning and effective assessment practices in schools.
- To reward outstanding classroom teachers using and, in other ways, supporting open-ended investigations in science classes.

The BHP Billiton Science Awards are managed by a committee with representatives from CSIRO Education, BHP Billiton and ASTA. CSIRO Education manages most of the processes around the awards, although most of the preliminary steps are handled at the state level.

Initially, all science project reports are sent to the state science teachers associations where representatives for the individual teachers’ association choose a finalist for their own state, along with their own categories of winners. Initially there may be hundreds of entries for each jurisdiction which are narrowed down to about thirty and these are forwarded for consideration in the BHP Billiton Awards. Similarly with the Science Teachers Awards – all applications are initially vetted by the state science teachers association. CSIRO liaises with state teacher representatives in terms of gaining applications which align with the criteria for both student and teacher competitions.

The state awards feed into the national awards. The CSIRO CREST awards also feed into the award system. CREST has been operating in Australia since about 1995 when CSIRO introduced it. It was modelled after a UK program of the same name. It is effectively like a structured model of STS but the entries are assessed to determine whether they meet the CREST criteria for the particular category. Teachers like it because if their students complete the work within the criteria they receive their CREST award. They are not competing with other students.

Not all CREST projects are suitable for entry into the BHP Billiton awards as CREST is a non-competitive award scheme in which groups can enter, as well as individuals. For the BHP
Billiton awards, only silver or gold class CREST recipients will be chosen as possibilities. Approximately 30 projects are sent forward to be considered for the BHP Billiton Awards.

**The purpose of the evaluation**

The evaluation was designed to assess the impact of the Billiton Awards in achieving the aims listed above. Given that the awards are closely linked with and encourage a range of science research project competitions and events at state level, the evaluation focused on the effectiveness of the broader setting of the competition in the states in promoting the aims, and separately on the role played by the Billiton awards in encouraging and supporting student research projects in Australia and impacting on individuals who enter the awards.

All students across, primary, intermediate and senior levels are included in this evaluation. In particular, the evaluation aimed to assess:

1. the effect on the communication skills of students who present at the Billiton awards (b, f)

2. the impact of science research competitions on the engagement of students with science (a, b, c, d)

3. the impact of involvement in science research projects on students’ investigative skills and their appreciation of the nature of science (a, b, c, d, f)

4. the impact of science research competitions on students’ views of school science and science more generally (a, b, c, d)

5. the impact of science research competitions on enrolment patterns in school science (c, d)

6. the impact of involvement in science research competitions, on students’ career intentions in relation to science (a, b)

7. evidence of any increase in numbers of students enrolling in science related tertiary courses, due to involvement in science research competitions. (c, d)

8. level of awareness of teachers and students, of the BHP Billiton awards (a, b, c, d)

9. the impact of involvement in student research projects on teacher pedagogy and assessment practices more generally. (c, d)

10. the attitude of teachers involved in the program towards open ended science investigations (c, d, e)

11. perceptions of schools concerning the worthwhileness of science research investigation initiatives (c, d, e, g)

**Methods used in the evaluation**

The methodology employed was mixed method. The data collection consisted of a combination of questionnaire (predominantly online) and interview data. The interviews were semi structured and explored the experience of the interviewee with research investigations and the Billiton awards, and their perceptions of the benefits, challenges and long and short term impact of this initiative. The informants whose knowledge and perceptions was sought include: students involved in research competitions, students reaching the final of the Billiton

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1 The letters refer to the instruments, outlined in the next section, through which the particular aspect will be assessed.
awards, teachers involved in running research project competitions, science coordinators who might be able to throw some light on enrolment trends, the teacher award winners, state organisers of these competitions including the Billiton organisers, and judges.

Some of the outcomes were difficult to establish in an evaluation of this size, and timeline, and indeed difficult in principle. With regard to the questions regarding the effect of the awards on uptake of science courses and careers, for instance, the gathering of hard data that was convincing and took into account the many variables that would impact on such choices would be a major undertaking in its own right. To pursue this question, we sought anecdotal evidence through questioning of student aspirations, retrospective accounts of entrants who are now in tertiary education, of teacher experience of trends within their school, . The findings are indicative, and the argument circumstantial.

In order to make the evaluation manageable within time and budgetary restrictions we focused our attention on two states with different characteristics: New South Wales and Tasmania.

**The evaluation design**

The following instruments were used to pursue the evaluation questions.

a. An online survey sent to all students who were involved in the Billiton competition over the last three years.

b. Phone interviews with a sample of Billiton award nominees from the last two years.

c. Phone interviews with a sample of teachers involved in science competitions from the two states, who had students enter the Billiton awards.

d. Phone interviews with award winning teachers

e. Phone interviews with state science association representatives, and CREST representatives

f. Phone interviews with the judges from the 2008 Billiton awards.

g. Interviews with key players in the award system (CSIRO, CREST, ASTA)

Letters of invitation were sent to these groups of people, inviting them to return consent forms and details through which they could be contacted by phone. It proved surprisingly difficult to get responses from these letters, perhaps because of the wording of the Plain language statement, or because we were asking for teachers’ attention at a very busy time of year, or because the teacher invitations went through the principals. The CSIRO team helped with the mail outs and subsequently with phone and email contacts.

The identity of the participants is protected. In four cases, that of the Case Studies of Stuart Garth and Ann Burke, and students Christina and Ian, permission was sought and granted from these teachers and students and the teachers’ schools for waiver of anonymity. It was felt that these were such positive stories, and identifiable through details of their stories in any case, that this was the most appropriate course of action. Stuart, Ann, Ian and Christina ‘member checked’ their interview data for accuracy.
In the end, the following informants were surveyed or interviewed for their views:

- Student nominees surveyed: 65
- Student nominees interviewed: 3
- Secondary teachers involved in the awards: 7
- Primary teachers involved in the awards: 3
- Award winning teachers: 7
- State association representatives: 2
- Judges: 5
- Key players (CSIRO, CREST, ASTA): 3

Two of the teachers interviewed were also award winners but the questions of them related to their school practice and were different to those asked of the other award nominees.

The interviews were conducted by telephone and were guided by the interviewers to ensure that the interviews covered what had been identified as the key issues for that particular group. The interviews for each group of study participants, for example, award winning teachers, was conducted by a different member of the study team, except for the group of primary and secondary teachers whose interviews were divided between two of the study team. The interviews ranged from 20 minutes to an hour in length.

The interviews were recorded in addition to the notes taken by the interviewer. Typed copies of the interviews or the interview notes were circulated amongst the members of the study team.

The team members produced a summary of the findings of their interviews and these were circulated and used in the writing of the final report. The key themes, recommendations and the draft report were circulated amongst the team to ensure that they truly reflected the data gathered and the inferences drawn by the team from the data.

**Patterns of participation in the awards and the evaluation**

The BHP Billiton Science Awards scheme is a substantial undertaking. It has attracted in excess of 80 primary and 170 secondary entries per year over 2007-2009 period, with more than 50 primary and 70 secondary awards given each year. In the states in which the in depth analysis was carried out for this evaluation, New South Wales and Tasmania, approximately 30 primary students and 25 or more secondary students have received awards each year. There have thus been many students who have participated in the awards over this period, and earlier.

**The online survey**

Students who were nominated, either by their state science teacher organisation or through the CREST awards, for the BHP Billiton Awards for the Years 2007, 2008 and 2009 were invited to participate in an online survey. The survey attracted 65 respondents. This represents a response rate of approximately 20% of those persons who were invited to participate.
survey had multiple pathways depending on levels of award and level of participation in the awards but the main questions are given in Appendix A.

In the following analyses, the profile of students participating in the survey is compared with the profile of all Australian students nominated in the awards.

**Gender**

Table 1 shows equal representation by gender and this is consistent with the gender ratio of all students nominated for the award in the last two years (2008-09)\(^2\).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Response Percent</th>
<th>Response Count</th>
<th>Percent Nominated students in (2008-09)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>50.8%</td>
<td>33</td>
<td>47%</td>
</tr>
<tr>
<td>Female</td>
<td>49.2%</td>
<td>32</td>
<td>46%</td>
</tr>
</tbody>
</table>

**State location of nominated student**

Table 2 shows that the distribution of responses of surveyed students from each state/territory varies widely but is broadly consistent with the distribution of nominated students from each state/territory for the years 2007-2009. The last column shows there is a significant difference in the distribution of CREST award nominees across each states/territories with Queensland being significantly represented.

<table>
<thead>
<tr>
<th>Location</th>
<th>Response Percent</th>
<th>Response Count</th>
<th>Percent Nominated students (2007-09)</th>
<th>Percent CREST award nominees (2007-09)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>13.8%</td>
<td>9</td>
<td>10.4%</td>
<td>8.4%</td>
</tr>
<tr>
<td>New South Wales</td>
<td>24.6%</td>
<td>16</td>
<td>24.0%</td>
<td>11.6%</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>0.0%</td>
<td>0</td>
<td>1.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Queensland</td>
<td>20.0%</td>
<td>13</td>
<td>15.2%</td>
<td>69.5%</td>
</tr>
<tr>
<td>South Australia</td>
<td>13.8%</td>
<td>9</td>
<td>9.9%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Tasmania</td>
<td>7.7%</td>
<td>5</td>
<td>11.6%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Tasmania</td>
<td>10.8%</td>
<td>7</td>
<td>13.9%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Western Australia</td>
<td>9.2%</td>
<td>6</td>
<td>14.0%</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

\(^2\) Gender data for 2007 was not available when this report was compiled.
Origin of entry

Table 3 gives three categories of entry to the awards being the state Science Teachers Association (STA), CREST and direct entry\(^3\) for those students who were surveyed and all nominated students in the years 2007-09. The significantly greater percentage of STA awardees surveyed is consistent with greater proportion of STA awardees when compared to the CREST awardees for all nominated students in the years 2007-09.

<table>
<thead>
<tr>
<th>Award</th>
<th>Response Percent</th>
<th>Response Count</th>
<th>Percent of nominated students (2007-09)</th>
</tr>
</thead>
<tbody>
<tr>
<td>My state’s Science Teachers Association (STA) awards</td>
<td>72.6%</td>
<td>45</td>
<td>77.3%</td>
</tr>
<tr>
<td>CREST awards</td>
<td>27.4%</td>
<td>17</td>
<td>10.9%</td>
</tr>
<tr>
<td>Direct entry</td>
<td></td>
<td></td>
<td>11.8%</td>
</tr>
</tbody>
</table>

Year(s) of participation in the STA/CREST awards and nomination in the BHP Billiton Awards

Only those students who were nominated for the 2007-2009 BHP Billiton Awards were asked to participate in this survey. The data in Table 4 (Graph 1) therefore show that there are significant numbers of students who entered the STA/CREST awards in several years (Note that students participated in the STA/CREST awards during the year prior to them being a BHP Billiton award nominee). In addition, there were several students who were nominated for the BHP Billiton Award in more than one year. This is reflected in the data in Table 5 (Graph 2). Table 6 (Graph 3) shows the number of years of participation in the STA/CREST awards and the number of times students were nominated for the BHP Billiton Awards. This table indicates that around half of the respondents to the survey had more than one year of participation in the STA/CREST Awards and around a quarter of them had been nominated for the BHP Billiton Awards more than once.

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\(^3\) This category was only available in 2007 and so was not given as an option for the surveyed students.
### Table 4 Year of participation in STA/CREST award of the surveyed student

<table>
<thead>
<tr>
<th>Year of participation</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>3.2%</td>
<td>2</td>
</tr>
<tr>
<td>2001</td>
<td>4.8%</td>
<td>3</td>
</tr>
<tr>
<td>2002</td>
<td>8.1%</td>
<td>5</td>
</tr>
<tr>
<td>2003</td>
<td>8.1%</td>
<td>5</td>
</tr>
<tr>
<td>2004</td>
<td>16.1%</td>
<td>10</td>
</tr>
<tr>
<td>2005</td>
<td>19.4%</td>
<td>12</td>
</tr>
<tr>
<td>2006</td>
<td>38.7%</td>
<td>24</td>
</tr>
<tr>
<td>2007</td>
<td>58.1%</td>
<td>36</td>
</tr>
<tr>
<td>2008</td>
<td>50.0%</td>
<td>31</td>
</tr>
</tbody>
</table>

### Graph 1 Year(s) of participation in the STA/CREST awards of the surveyed students
Table 5 Year(s) in which surveyed students were nominated for the BHP Billiton science awards

<table>
<thead>
<tr>
<th>Year</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.0%</td>
<td>0</td>
</tr>
<tr>
<td>2001</td>
<td>1.6%</td>
<td>1</td>
</tr>
<tr>
<td>2002</td>
<td>1.6%</td>
<td>1</td>
</tr>
<tr>
<td>2003</td>
<td>1.6%</td>
<td>1</td>
</tr>
<tr>
<td>2004</td>
<td>6.3%</td>
<td>4</td>
</tr>
<tr>
<td>2005</td>
<td>7.9%</td>
<td>5</td>
</tr>
<tr>
<td>2006</td>
<td>20.6%</td>
<td>13</td>
</tr>
<tr>
<td>2007</td>
<td>42.9%</td>
<td>27</td>
</tr>
<tr>
<td>2008</td>
<td>50.8%</td>
<td>32</td>
</tr>
<tr>
<td>2009</td>
<td>12.7%</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 6 and Graph 3, which show the number of years of participation of students in the awards scheme, and nominated for the BHP Billiton awards, demonstrates clearly that many students are ‘repeat offenders’ in the scheme, either resulting from their own enthusiasm or as a consequence of the motivation provided by teachers and schools. The basis for this pattern is explored in the interviews.
### Table 6 Number of years of participation in the STA/CREST awards and nominated for the BHP Billiton Award of the surveyed student

<table>
<thead>
<tr>
<th>Years of participation</th>
<th>STA/CREST Award Participation Response Percent</th>
<th>BHP Billiton Award Nominee Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52.31%</td>
<td>78.46%</td>
</tr>
<tr>
<td>2</td>
<td>21.54%</td>
<td>12.31%</td>
</tr>
<tr>
<td>3</td>
<td>7.69%</td>
<td>1.54%</td>
</tr>
<tr>
<td>4</td>
<td>12.31%</td>
<td>1.54%</td>
</tr>
<tr>
<td>5</td>
<td>1.54%</td>
<td>6.15%</td>
</tr>
<tr>
<td>6</td>
<td>4.62%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

### Graph 3 Surveyed student participation in awards by number of years

- STA/CREST
- BHP Billiton Nominee
Table 7 The school Year Level when surveyed students participated in the STA/CREST awards

<table>
<thead>
<tr>
<th>Year Level</th>
<th>Response Percent</th>
<th>Response Count</th>
<th>Participant numbers of Nominees in the Years 2007-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>Note: the survey did not ask students their participation in these Year Levels</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>24.6%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>18.0%</td>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>27.9%</td>
<td>17</td>
<td>43</td>
</tr>
<tr>
<td>6</td>
<td>24.6%</td>
<td>15</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>14.8%</td>
<td>9</td>
<td>46</td>
</tr>
<tr>
<td>8</td>
<td>21.3%</td>
<td>13</td>
<td>94</td>
</tr>
<tr>
<td>9</td>
<td>31.1%</td>
<td>19</td>
<td>168</td>
</tr>
<tr>
<td>10</td>
<td>19.7%</td>
<td>12</td>
<td>157</td>
</tr>
<tr>
<td>11</td>
<td>13.1%</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>12</td>
<td>14.8%</td>
<td>9</td>
<td>82</td>
</tr>
</tbody>
</table>

Table 7 (Graphs 4 and 5) shows that participation in the STA/CREST awards occurred across all Year Levels from P to 12. The data show higher levels of participation in the later years of primary school (Years 5/6) and later years of compulsory schooling (Years 9/10). This may partly reflect teacher and school judgments about the appropriate years to run open investigations but it may also reflect the higher quality of entrants in these years, that lead to greater BHP nomination rates, particularly for the higher secondary school years.
Graph 4: Participation in the STA/CREST awards of the surveyed students, by year level

Graph 5: Participant numbers of BHP Nominees in the Years 2007-09, by year level
The student experience

This section is based on data from both teachers and students concerning various aspects of the way students relate to the awards and to investigation in science.

The ways in which students experience the award scheme

Students’ experience of the awards compared to their normal work in science

In the online survey students were asked to respond to a series of statements about their participation in the STA/CREST awards and involvement with the BHP Billiton Awards. Table 8 and Graphs 6-9 provide the data from the students’ response to the statements.

It will be noted that:

1. Around 50% believe that participation in STA/CREST awards was beneficial in getting better grades in science class.
2. Most students increased their interest in science through participation in STA/CREST awards.
3. 46% of students have undertaken similar science investigations in class whereas 41% of students have not.
4. 51% of the students learned in their normal class work all the skills they needed for the award investigation whereas 39% did not.

Table 8 Students’ perceptions about their participation in the STA/CREST awards and involvement with the BHP Billiton Awards

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree or Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Participating in the STA/CREST science awards helped me obtain better marks for my science subjects at school.</td>
<td>13.1%</td>
<td>39.3%</td>
<td>36.1%</td>
<td>8.2%</td>
<td>3.3%</td>
</tr>
<tr>
<td>2  Participating in the STA/CREST science awards increased my interest in science.</td>
<td>24.6%</td>
<td>50.8%</td>
<td>18.0%</td>
<td>6.6%</td>
<td>0.0%</td>
</tr>
<tr>
<td>3  In my normal science class I complete activities similar to my STA/CREST science awards where I get to design and carry out my own investigation.</td>
<td>19.7%</td>
<td>26.2%</td>
<td>13.1%</td>
<td>31.1%</td>
<td>9.8%</td>
</tr>
<tr>
<td>4  All the skills I needed to complete the STA/CREST award investigation were learned in my normal science classes at school.</td>
<td>11.5%</td>
<td>39.3%</td>
<td>9.8%</td>
<td>31.1%</td>
<td>8.2%</td>
</tr>
</tbody>
</table>
Students as scientists: The impact of the BHP Billiton science awards

Graph 6: Participating in the STA/CREST science awards helped me obtain better marks for my science subjects at school.

Graph 7: Participating in the STA/CREST science awards increased my interest in science.
Graph 8: In my normal science class I complete activities similar to my STA/CREST science awards where I get to design and carry out my own investigation.

- Strongly Agree: 25.0%
- Agree: 35.0%
- Neither Agree or Disagree: 15.0%
- Disagree: 10.0%
- Strongly Disagree: 5.0%

Graph 9: All the skills I needed to complete the STA/CREST award investigation were learned in my normal science classes at school.

- Strongly Agree: 45.0%
- Agree: 40.0%
- Neither Agree or Disagree: 30.0%
- Disagree: 25.0%
- Strongly Disagree: 10.0%
Aspects of involvement in STA/CREST awards

Table 9 indicated that participation in the STA/CREST awards was part of the normal science class activities for the majority of surveyed students, with involvement for about a third arising in other ways such as through a school science club.

<table>
<thead>
<tr>
<th>Avenue of involvement</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Because it was part of my normal science class activities.</td>
<td>64.4%</td>
<td>38</td>
</tr>
<tr>
<td>As an out of class-time activity that was organised by a school group (for example, science club).</td>
<td>16.9%</td>
<td>10</td>
</tr>
<tr>
<td>As an out of class-time activity that wasn't organised by the school.</td>
<td>15.2%</td>
<td>9</td>
</tr>
<tr>
<td>Other</td>
<td>8.5%</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 10 indicates the size of the group in which the responding students worked, with more than half working individually.

<table>
<thead>
<tr>
<th>Group size</th>
<th>Response Percent</th>
<th>Response Count</th>
<th>Percent of all nominees (Years 2008-09)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On my own</td>
<td>59.7%</td>
<td>37</td>
<td>64.9%</td>
</tr>
<tr>
<td>As part of a group of 2</td>
<td>35.5%</td>
<td>22</td>
<td>27.9%</td>
</tr>
<tr>
<td>As part of a group of 3</td>
<td>1.6%</td>
<td>1</td>
<td>6.9%</td>
</tr>
<tr>
<td>As part of a group of 4</td>
<td>3.2%</td>
<td>2</td>
<td>3.8%</td>
</tr>
</tbody>
</table>

Patterns of entry from schools

In addition to the survey data the discussion of the experiences of students and teachers is based on interviews with students and teachers. The sampling of teachers for interview was made from all schools which had a participant in the Awards during 2007, 2008, or 2009. An analysis of the data as shown in Tables 11 & 12 show that, while there are some schools which regularly have a large number of students selected for the BHP Billiton Award program, the majority of schools do not. However, in many of the latter schools the teachers have extensive involvement in managing science research project work.

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4 Group sizes for the year 2007 were not available at the time of completion of this report.
Hence the number of students nominated for the BHP Billiton Award does not necessarily reflect the full experience of the teacher with respect to science research projects. To illustrate, one of the teachers interviewed is the head of the science department in a large metropolitan school which requires all year 10 students to complete a science research project, based on the requirements of the state’s science teachers’ sponsored competition, as a significant component of their science studies for the year. However, students from the school were selected to participate in the BHP Billiton awards in only one of the three years studied. In the interviews, naturally, the teachers talked about the total experience, not just that of those few students who were nominated for the BHP Billiton Awards.

### Table 11: Number of schools across Australia with students selected for the BHP Billiton Award Scheme in one or more years

<table>
<thead>
<tr>
<th>Student(s) selected for BHP Billiton in one year only</th>
<th>Student(s) selected for BHP Billiton in two years</th>
<th>Student(s) selected for BHP Billiton in all three years</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of schools</td>
<td>106</td>
<td>35</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>(61%)</td>
<td>(20%)</td>
<td>(19%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>174</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(100%)</td>
</tr>
</tbody>
</table>

### Table 12: Number of students selected for the BHP Billiton Award Scheme in the 33 schools represented in all three years

<table>
<thead>
<tr>
<th>Students selected for BHP Billiton in all three years</th>
<th>Schools with an average of five or more students over the three years</th>
<th>Schools with an average of less than five students over the three years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of schools</td>
<td>9</td>
<td>24</td>
</tr>
</tbody>
</table>

The survey data provided insight into the same issue. Table 13 (Graph 10) shows that some schools had multiple nominees for the BHP Billiton awards that range in any one year (2007-2009) from a single nominee up to 20 nominees.

### Table 13 Number of projects from individual schools nominated for the BHP Billiton Award in any one year

<table>
<thead>
<tr>
<th>Number of nominees from a school in a single year</th>
<th>Participant numbers of Nominated projects in the Years 2007-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 3</td>
<td>41.7%</td>
</tr>
<tr>
<td>4 to 6</td>
<td>20.4%</td>
</tr>
<tr>
<td>7 to 9</td>
<td>9.2%</td>
</tr>
<tr>
<td>10+</td>
<td>23.0%</td>
</tr>
</tbody>
</table>
Thus, in discussing the experience of students and schools involved in open ended science investigations and the role of the BHP Billiton Awards in this, it needs to be kept in mind that the awards represent an important part, but in fact only the tip of the iceberg, of science investigative activity in Australian schools. The total of the impact of the award schemes is to be found, not only in the experience of the national teacher and student winners, but also in the stories of schools and students with intermittent or perhaps once-only involvement in the BHP Awards. The research reported in this report aims to capture and interpret the stories of not only the highly active and obviously successful schools, but also schools who have less of a profile but who represent different contexts or stages of involvement in student investigative work. We can learn from all these schools.

**The context of the awards within schools**

Part of the variability in the context in which students develop their projects arises from differences in state curricula. In Tasmania, students doing investigative work in science built around their own questions is now part of the mandated curriculum. Teacher interviewees reported that this has given a substantial impetus to serious consideration of students' investigative skills and renewed interest in the Tasmanian Science Talent Search (STS). Conversely, the experience of teachers who had been involved in this type of work with students through the awards scheme was invaluable in supporting this curriculum innovation. The environmental science senior course in Tasmania also involves research investigations and this has given rise to quality entries at the senior level and has encouraged investigative work at lower levels. A similar circumstance exists in Queensland:

Queensland tends to be over represented in the BHPB awards because they have Extended Experimental Investigations for students in the Year 12 sciences. Many of the teachers have taken on the CREST model to help provide structure to their students in completing these investigations. Queensland does not have formal exams at the end of Year 12 and the students are "school assessed". Many of these Year 12 CREST projects end up in the BHPB awards. The teacher will often also enter the same project in the STAQ awards.
For comparison, in Victoria STAV rarely gets any students in Year 11 and 12 competing in the STS because the teachers are so focussed on preparing students for the VCE exams. (Official involved with the award scheme)

Across the states from which the teacher interviewees were drawn, New South Wales and Tasmania, there is significant variability in the context in which the individual projects were developed. In some schools the project was done as part of a mainstream curriculum unit, in which case the project itself was often preceded by class work which ensured that the students understood the essential features of a scientific way of working. In one school in NSW this introduction was provided at the conclusion of Year 9 with the project itself being done in the first term of Year 10. At Redeemer, younger students were taken through the scientific method prior to their involvement in project work. In other schools the project is part of the activity of a small group or club under teacher supervision. In Tasmanian schools the projects had often been the province of an ‘extended science’ class, although this seemed to be less common in recent years and the practice extended to core units. A number of teachers made the observation that talented students tended to be more positive about this sort of work. One NSW school had explicitly provided a different experience for students depending on their ability:

There are three categories – the least able students have a booklet which gives them scaffolding, the boys of intermediate ability have some help and the most able boys are expected to work at greater depth and in more detail. (N, NSW teacher)

Across all states, the online survey showed students divided in their agreement as to whether they complete similar investigative activities in their normal science class (Graph 8). There was further variability across schools in the next step toward the BHP Billiton Awards. In some rural areas the projects were entered in a locally organised science fair and as a result some were selected for entry in the state science competition. There was at least one notable example of this in each of Tasmania (The Cradle Coast fair) and New South Wales (The Illawarra fair). In some metropolitan schools there was selection at the school level of those suitable for state run competition. In some cases there is a science fair or competition held at the school prior to submitting projects.

We have run a science contest in the school that is like a science expo context since 2000 and students who do well in that are nominated to go onto the Queensland science teachers contest. (Teacher award winner 5)

There are also a number of instances where the school pays special attention to supporting and refining selected high quality projects. This might amount to extra help with completing the project, or support in preparing the report and presentation once the project is nominated. One student explained that all students in her Year 7 science class were required to complete a project that was partly supported by the teacher in school time, but was largely conducted outside of school. The best experiments were selected to enter the “Young Scientist” award and “BHP science award”.

One interviewee referred, rather critically, to a not uncommon attitude of teachers that since these were open investigations the students should be doing the work unaided, and that teachers should refuse help. This attitude is not unknown to the authors of this report, and represents a misunderstanding of the nature of scientific research. Perhaps it relates to an image of the scientist as lonely hero! It is important to send a clear message to teachers that the capability to do quality scientific research is not innate and requires considerable support through knowledge development, and scaffolding and modelling. That being said, there were
Students as scientists: The impact of the BHP Billiton science awards

a number of teachers who emphasised allowing students space to make their own decisions, and this was emphasised in Daniel’s case study:

In normal science the teacher would be on our backs telling us “No, you’re doing that wrong” or “That is incorrect”, but now we can learn for ourselves of what we are actually doing, able to decide what we are doing, how we are going to do it, and how we are going to present it, and how we’re going to sum it up. It gives us more control over what we are doing. (Daniel, student award winner)

One secondary school has their Year 11 and 12 students working closely with primary school students, as mentors.

I teach in a Year 11 and 12 college – in a regional area of Tasmania. During the Science week project - we have 19 primary schools and 5 high schools that attend working on hands-on activities - over 60 activities last year. This year we had 50 activities and over 1800 to 2000 primary school students attend. There are competitions- for instance students had to build a time machine … something that was non-electrical, capable of estimating time, and another based on the national theme of astronomy. 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, prior to that, but our students actually lead the activities (Teacher award winner 1)

At a Sydney primary school, Grade 5 students are mentored by Grade 6 students who completed projects in the previous year. One successful student shared his experience of participating in the science award scheme in Grade 5, and then as a Grade 6 student mentoring a pair of Grade 5 students. He has found it “fun to brainstorm project ideas”, but has been amazed at how “unrealistic the Grades 5s are about what resources are available…expectation of equipment”.

Students’ experience of doing the projects

One thing that becomes clear in talking with teachers and students is the diversity of students’ experience of doing open ended investigative projects. This applies to how the topics are chosen, the context in which the project is pursued, whether it is a group or individual project, how it relates to the school curriculum, and the level of commitment and response to the experience.

Where the ideas come from

Teachers indicated that identifying investigable questions is one of the most challenging parts of the project task. As one teacher pointed out:

The hardest thing is finding that question that is researchable and can be done locally. …We bring a lot of scientists into the school – they say that’s hard, to find a meaningful question that can be answered.

There is a great deal of variation in the way teachers assist students with this task. For example, in one rural school the teacher has articles she has collected from the local newspapers, agricultural magazines and New Scientist which she makes available to students as prompts to finding questions. In other schools, where there is a tradition in such work, students are pointed to the topics explored by previous students. In both the Redeemer and Marist schools a tradition has been built up over the years of exploring particular areas of inquiry. Stuart from Redeemer school for instance has students choose their topics and then tries to put them in touch with science professionals to help them refine the question, but has topics ‘up his sleeve’ for those students who can’t think what to do. Each year he gives out a booklet including examples of projects from previous years. In one case he came up with the
idea of exploring light pollution for astronomy, and his class voted on this as their project focus and then worked up their approach to it. Ann from MRC emphasised the importance of teacher knowledge and had built up banks of journals and also contacts with science professionals that she could call upon for ideas and support.

One secondary school which is very involved in the award scheme talked of introducing the idea of investigable questions and identifying projects by degrees, leading to a substantial Year 10 unit:

The program starts at the end of year 9 when they learn about the research processes through some mini projects. In Year 10 the boys are given information on possible topics they could research. They have a checklist to see that they are working through it appropriately. Each project must have an experimental basis. (N, NSW teacher)

Another experienced teacher recommended building research around topics they had knowledge of, associated with the curriculum:

Schools tend to embed this work in the curriculum and do a research project as part of a topic. We suggest students focus on a topic they’ve done in class, and to get a mentor. (A, Tas. teacher)

A teacher described the practice of his primary school colleagues:

Kids enjoy doing their own investigations. Each class has ‘wonder’ walls focusing on experimental investigations.

Location was also a factor - one teacher from rural Tasmania indicated that the location in which she worked provided an ideal source of problems to be investigated. She provides the students with articles which have relevance to the rural, coastal, agricultural setting of the school.

A number of teachers talked about the value of students attending the local science awards where they meet other students doing this sort of work and coming home with ideas about standards of research and about researchable topics. The website of the Tasmanian STS awards was mentioned by one teacher as very useful for ideas.

Part of the real power of being involved in this work over time is the way a culture is built up in which students themselves advance in this way of thinking, and are supported by what has gone before them. Ann described projects on crayfish that were extended over a number of years with groups of students supported by Department of Primary Industries scientists. Similarly Stuart had students extending work on luminescence over a number of years. It is not uncommon to find a student gaining expertise and interest in a topic and basing their research on questions that arose in previous work, or variations in exploration of this. An example can be found in the MRC case study regarding a girl who focused on carbon sequestration over three years.

In a senior environmental science program in another school, a story emerged of students building on previous work:

The last couple of years we have focussed on environmental science projects that were related to climate change and it has been quite interesting – there have been students who have seen what others have done in previous years and then what we have done is extended on that - expanded on it … and that is what real science research is like go out find out what someone else has done and then try and extend the scientific knowledge that is out there. So they have picked up … I guess they are tapping into your awareness of the scheme and the competitions out there as well. Some of the projects are quite sophisticated and use advanced equipment. We have purchased a lot of environmental probes – for
example CO2 probes – looking at CO2 sequestration – in different lighting, temperature. (Teacher award winner 1)

Inspiration and support for developing topics could also be found in teacher expertise and enthusiasm around subject areas, or particular technologies. Stuart’s (Redeemer case study) early work with students using video to analyse motion, based on his own expertise and enthusiasm, is a case in point. In the notable cases of Redeemer and MRC, there seemed to be a moral commitment to science that makes a difference as illustrated by a particular focus on sustainability issues, reflected in students’ work, and Stuart:

We emphasise the beneficial nature of projects … that are innovative and helps a need. We try to think of bigger projects than the dynamics of a falling ball (S, NSW secondary teacher)

Case study of Ian – Effect of a science research-rich learning environment

Ian participated in the state science competitions and BHP award scheme many times during his primary and secondary years. According to Ian, the P-12 school he attended in Sydney was well known as a “strong performer in science research and competitions”, encouraging its students to participate in “scientific research”. Specialist science teachers were used in primary school to promote interest in science and support inquiry based approaches to learning. In secondary school, independent research was taught and supported in the school syllabus. Involvement in the science awards was mainly extra-curricular, with teacher support provided as needed. Students were encouraged to participate in the science award schemes every second year as teachers understood the energy and time that students needed to commit. According to Ian, up to 100 students perform investigations each year, with the school producing some award winners most years. During his schooling career, he won four first places, and in Year 12, Ian and his partner won “Young Scientist of the Year”. A physics-based project in Year 11 took Ian and his partner to the US to present their research to scientists and students, an experience that improved his oral communication skills:

In the States, on the judging day we presented our projects to 15 PhD judges in 15 minute segments with only a 2 minute break, so you learned very quickly how to get through your presentation and go on to the next one. So I definitely learned a lot of communication skills.

Meeting other students and hearing about their research was also an important outcome of being an award winner. The BHP camp provided opportunities to meet people in industry, but he felt that “the best experience has been meeting students from others states, and discussing with them what they did and how they did it”.

Teachers played a major role in generating Ian’s interest in science by promoting science research and embedding it within the school curriculum. Specific maths, physics and chemistry teachers were enthusiastic and supported students to “have a go at the science awards and have a go at some proper research”. Teachers inspired students to persist with their investigations, but supported them by providing ample opportunities to develop “good research skills” in designing, implementing, and reporting on, science research:

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.

Ian had access to school facilities and equipment. In the school laboratory he was able to build the electronic circuit, as well as calibrate and test his prototype. Teachers also assisted him in making links with industry once he was up to the testing stage:

We had to go out and talk to people in industry... The school took a lot of responsibility for care of the students so you did not end up in a situation you did not want to be in... My science teacher took me out [a number of times]. When we built our prototype and we were looking to explore options for production my teacher took me out to a person he knew in design and he helped us with that interview to explore the avenues we could take to production. He also took us out when we were looking for an industrial device to compare our prototype with. So he would take us out when he could, to look after us.

The authenticity of the science experience made participation more significant. A major difference in his response to independent investigations compared to normal school science is the degree to which the unknown motivates student engagement. Ian’s experience of school science was largely of experiments where the result is already known. Independent research projects provide the opportunity to experience science in alternative ways to normal school science, resulting in increased motivation and greater links between theory and practice:

For the first time it was exploring. In class you do experiments and you come up with a result you know you’re going to get because the teacher has tested it himself and you know you’re going to get a result. But with an independent research investigation you never know if you’re going to get a result, or a good result. We were very surprised when everything that we learned in the theory was actually coming out in our research.

When you’re involved in science research you get more enjoyment with science than if you’re just in a classroom all day.

Ian has gone on to pursue physics at a tertiary level. He attributes this choice to the enjoyment he received through the school science research, and his success in science competitions, which helped him to secure a scholarship to university. Although a career in physics is attractive, he ultimately wants to become a science teacher.

I like working with kids and helping kids out. While I’ve been at university I’ve been coaching and tutoring. It’s something I enjoy and, as everybody knows, there’s a bit of a shortage at the moment. I want to be able to help kids and teach kids properly. I was given a good opportunity at my school through good teaching, and I’d like to give other kids a good opportunity... I’ve learned a lot more about how to do research at university and I’d like to see how much of that you can bring into the classroom and how much research you can teach the kids to do. And of course the main limitation is school resources, but I’d like to see how you can develop partnerships with universities to get kids using more high tech equipment to do some research.

When asked if he thought he would feel the same way about science if science research was not so promoted throughout his schooling, he replied:

Definitely not because every year you’d think "What science project can I do this year?” And the teacher was always keeping you inspired in science by these research projects that were more interactive and a lot more fun than just classroom book work.

During his university degree, Ian has mentored science research students at his old school, Redeemer Baptist School. He sees great power in allowing students to have authentic engagements with science.
The following quote suggests how learning in a science research-rich environment can help to make science attainable and enjoyable for all students:

*What you find is that when students get involved in research projects it actually changes their idea of science. So there’s no such thing as a science geek or a science student once you get involved in research projects because they get to see how much fun you can have. I’ve seen so many people who have been totally disinterested in science get involved in a research project and have it change the way they think about science.*

The diversity of topics

Appendix B shows the enormous range of projects students reported in the online survey, some of which are relatively bounded and others are design projects or interventions of some sort. The breakdown of topics shows the relative predominance of environmental and biological topics (Table 14).

<table>
<thead>
<tr>
<th>Science area</th>
<th>Number of projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth Science / fossils</td>
<td>3</td>
</tr>
<tr>
<td>Environmental science and renewable energies</td>
<td>13</td>
</tr>
<tr>
<td>Biology</td>
<td>22</td>
</tr>
<tr>
<td>Physics</td>
<td>12</td>
</tr>
<tr>
<td>Chemistry</td>
<td>7</td>
</tr>
</tbody>
</table>

Realising a standard of work

Some schools have developed their programs to the point there are substantial and longitudinal projects involving high level science ideas, whereas others, particularly in primary or lower secondary years, are relatively simple, variable control experiments. In schools which have been involved for some years, teachers talked about students becoming aware of what it was possible to do with science research and what the standards were in the state and national competitions. Gaining a sense of standards was mentioned by a number of teachers as an outcome of students attending the award ceremonies. Becoming inspired by the success of other students in the school was also a common theme.

We’re a small country school so winning awards is great for us. Standards have risen over the years as students are keen and want to get on the photo board (at the school). The school comes together to support entries. Now, with BHP, students are more aware and really keen. Success shows that this is achievable and we have now had a number of successes. It’s one of those things that builds on itself. It’s a really nice culture that comes out of it. One girl came back from the presentations saying she wanted to work for an award and the next year won first prize. They can see other work and know the standard and see what needs to be done. The standard of work that (Ann’s) students have achieved has helped my kids. (J, Tas. teacher)

They have seen what other children have done and the rewards they have – personal rewards, overcoming something that is challenging work through it and solve the problems along the way. Fortunately we always have the same ones coming back for more, but we
have new ones joining them. It takes the ones who haven’t done it before about a year, with mentoring, to know how to set their goals, pace their work, and really get it to the standard for the external contests (Teacher award winner 5)

Stuart (see Redeemer case study) was particularly articulate about standards, with his 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 Stuart credits that project with providing inspiration for the path the school subsequently took:

We’ve never really looked back since then. … Once you’ve got the idea that doing a good project requires time. … we can do something that will actually help society … .It provided a model for research projects – what is possible, what is inspiring. (S, NSW secondary teacher)

Schools involved in this work in some cases structure their curriculum in science investigations in a way that builds over years. Some schools such as MRC start with simple variable control designs in year 7 and work to introduce more sophisticated designs in subsequent years. Another Tasmanian school has embedded inquiry into their scope and sequence planning.

Teachers touch on the inquiry process each year. Longer case studies is a problem – you need something to support smaller studies. In year 7 they do teacher guided tasks and by Year 10 students are choosing their own investigations. We allowed 10 lessons in ‘extended science’ for open ended work. (H, Tas. teacher)

A large part of the task for any teacher, and any student, in developing investigative projects and capabilities, is therefore to build a sense of the nature of quality extended science investigations - what it is possible to do, and how to go about doing it.

Where support is found.

In the online survey, students were asked to respond to the extent to which they had support from a number of sources. Table 15 (Graph 11) gives a breakdown of their responses.

<table>
<thead>
<tr>
<th>Resource</th>
<th>A lot of help</th>
<th>Some help</th>
<th>No help</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher</td>
<td>12</td>
<td>33</td>
<td>16</td>
<td>61</td>
</tr>
<tr>
<td>Parent or other relative</td>
<td>18</td>
<td>27</td>
<td>15</td>
<td>59</td>
</tr>
<tr>
<td>Other student(s)</td>
<td>8</td>
<td>14</td>
<td>34</td>
<td>55</td>
</tr>
<tr>
<td>Internet</td>
<td>17</td>
<td>35</td>
<td>8</td>
<td>59</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
<td>15</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>Books and other text-based resources</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Experts and specialist organisations</td>
<td></td>
<td></td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>
Students derived a lot of help from parents or relatives, from the internet, and teachers, in that order. Although they were not asked to explicitly identify help from science experts and organisations, nine students identified these as being of help. This is in line with information gained from the teacher interviews.

The interviews identified great variability in where students find support, due to a number of factors. There are significant differences between schools in the availability of people who can act as mentors. For instance, in a school in rural Tasmania the teacher organising the program within the school indicated that the parents were “willing but not able” to contribute a great deal of guidance to the participating students. In such cases most of the mentoring falls on the teachers. Others where the school draws on a more educated parent body reported the parents playing a significant role in providing guidance.

Each project must have an experimental basis. They can take equipment home to complete their research…. There is lots of parental involvement and it is a problem to ensure that it is the student’s work being assessed (N, NSW secondary teacher)

The interviews revealed that overall while teachers and parents were the most likely source of assistance to the students the students drew upon many people with expertise in the area under investigation, for example scientists from CSIRO, staff of the Bureau of Meteorology, agricultural scientists, etc. In Redeemer and Moriah, students were explicitly put in touch with science professionals as part of the support structure for investigations. We shall discuss in a section below the fact that almost every teacher interviewed linked their running of investigative projects with the visits of scientists in schools. These two initiatives should be seen as mutually supportive.
Case study of Christina – the scientist-in-nature and her support crew

Christina participated in her first science award in Year 7 at a NSW girls secondary school. All Year 7 and 10 students complete an open-ended investigation, with the best ones selected to enter the “Young Scientist” awards and BHP science awards. The investigation did not contribute to her science grade. Christina received a first prize in NSW in the Biology section for Years 7-9 in the Young Scientist competition, but was not a finalist in the BHP awards. Her project investigated the reaction of birds to insects of different colours. She dyed seeds different colours, red, black and white, then feed them to birds at a local wharf. Overwhelmingly, the birds selected the white seeds. Christina was delighted with how clear her results were.

Support from family, and teachers at her school, was important at all stages of the investigation. Christina found that the most support came from her family, who assisted in selecting a suitable investigable question, designing the experiment, selecting edible food dyes for the seeds (she used dyes found in Vegemite), and laying out and interpreting the results in the report. Her science teacher gave guidance in terms of providing some class time to generate ideas, setting guidelines and timelines, presenting examples of previous experiments, providing instruction on how to carry out scientific experiments, and offering suggestions as needed.

Prior to doing this investigation, Christina had not written a detailed science report, although they had been learning about it at school. While the experience did not change the way she thought about science, as she was always interested in biology and nature, she felt that it gave a strong grounding in the scientific method, what is involved in the process of investigating, the need for fair testing, and the importance of time management. When reflecting on her school science, she felt that what she does in school science is similar, but that “you don’t go places in science except for the occasional excursion”. Being out in nature was an important part of her experience. Completing the investigation outside of school meant that she could generate an image of a scientist that was attractive to her.

Student response to open investigations

A number of teachers pointed out that not all students are naturally drawn to this sort of investigative work. It seemed as though, while it was strong students who got the most out of the awards and doing this type of science, it was not uncommon for strong students to dislike the work. That has also been the experience of the authors, where sometimes very successful students dislike open investigation work because it represents a change in the assessment rules under which they have always prospered. There is also the question of the commitment involved in longer term projects.

In grade 5/6 when you mention the competition and they think ‘let’s have fun’. They don’t like the process of writing an abstract... the teacher needs to be there motivating, showing enthusiasm. (D, Tas. primary teacher)

Student attitudes – it switches them on – prepares them for university. Although it’s not for everybody. (S, NSW secondary teacher)

For most it is useful exercise. There is ownership. For some it is invaluable. For the majority it is not important but for those whose projects are selected for entry it is. (N, NSW secondary teacher)

When it is purely open-ended some students are just lost- so that’s why we have given those students going into the BHP or science fair to the top class because there is a lot of work needed helping students if it is a completely open ended task. (Teacher award winner 3)
Students can find the open-endedness of this science investigative work challenging, and many of the strategies teachers talked about for running successful projects were to do with scaffolding and enthusing students such that they remain positive and committed. On the other hand, it seemed clear that this open-endedness, and the capacity of students to deal with problems that arise by drawing on their own resources, is the reason why some students find the experience so rewarding, and also the source of the capabilities they develop.

In normal science the teacher would be on our backs telling us ‘No, you’re doing that wrong” or “That is incorrect”, but now we can learn for ourselves of what we are actually doing, able to decide what we are doing, how we are going to do it, and how we are going to present it, and how we’re going to sum it up. It gives us more control over what we are doing. (Daniel, award winning student)

If a teacher feeds them … like I want you to do this .. and this is the next step , it’s not much use. (S, NSW secondary teacher)

For the first time it was exploring. In class you do experiments and you come up with a result you know you’re going to get because the teacher has tested it himself and you know you’re going to get a result. But with an independent research investigation you never know if you’re going to get a result, or a good result. We were very surprised when everything that we learned in the theory was actually coming out. (Ian, award winning student)

Clearly, there is a balance to be made, as for supporting quality learning generally, between providing too much direction, and too little. Students need to be provided with the level of support that will represent a challenge that is both substantial and achievable.

For many students who become seriously involved in the awards, they are also actively involved in other aspects of school life, awards, and projects. Like adults, they need to balance their lives, and it is unrealistic to expect they will see science investigations as central to their identities, or necessarily representative of their career intentions. This latter point will be further discussed below. However, it was clear from some of the teacher interviews that students need to make decisions about their time commitments, and this has led some schools to limit their involvement in the science awards to every second year only, for a given student cohort.

The attraction of open investigative work

From the interviews with teachers and teacher award winners there seemed to be a number of features of open investigation work in science, and the award schemes, that make the experience powerfully educative for students. These are the:

- Importance of students owning the work
- Importance of doing science investigations they see as authentic
- Power of making links with science professionals or others with expertise
- Importance of students showcasing their work
- Importance of there being a competitive environment – especially at the national level
- Importance of recognition for the quality of their work.

Students like the prizes. They have seen what other children have done and the rewards they have – personal rewards, overcoming something that is challenging work through it and solve the problems along the way ..Take on a challenge and solve the problems and feel the satisfaction. The kids are enthused –you don’t take on a 2-3 month project unless you’re enthusiastic. (C, award winning teacher)
Students as scientists: The impact of the BHP Billiton science awards

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. (S, NSW secondary teacher)

Students getting letters from BHP is really good, and cash. (J, Tas. secondary teacher)

Again, these views are borne out by the student interviews (see Case Studies) and their open comments on the survey.

Other science award categories

A number of interviewees argued for the benefits, at the state level, of having a range of categories under which students could compete. Their argument was basically that science experimental investigations were not appropriate for everyone and that teachers also found it difficult to run this type of work. Having categories such as video and photography, drama and creative writing allowed teachers to run project work less problematically but also allowed students with particular talents and interests to express an interest in science. It can also be a way in to investigative work. Stuart (Redeemer case study) started his trajectory promoting the STS in a variety of categories:

I pushed STS by visiting classes and promoting creative writing, photography, science research. These other categories are easier than investigative work – the beauty is you can have a lot of people go through. It also caters for creative kids (S, NSW secondary teacher)

Case study of Daniel – Discovering real science for the first time

Daniel completed his first open-ended science investigation in Grade 5 at a Sydney government primary school. Grade 5 and 6 have an accelerated program, where they do CREST investigations, some of which are selected to enter into the BHP awards and the “Young Scientist” award. The standard science class in the past had mainly entered the CREST awards. Students in the accelerated program received mentoring from Grade 6 students who act as CREST partners, meeting once with a pair of Grade 5 students to share their experiences, to brainstorm ideas, and assist with designing the investigation. Students in the standard science class received mentoring from scientists from local industry, who assist students in generating ideas, and meet on a semi-regular basis in Term 2.

Daniel’s focus for his investigation arose out of conversations at home relating to food storage. His investigation, entitled “Yuck, I’m eating sour biscuits”, tested storage options for different types and combinations of food. Testing was completed at school, where the teacher could support students’ progress, and the report was completed in the students’ own time.

Daniel enjoyed the experience immensely for a number of reasons.

The first reason was because he found the investigative process and his results very interesting. He enjoyed the challenge of devising different ways of testing and selecting what food to test, devising a method for testing the moisture of foods before and after the test, also the results were most unexpected for him. He also enjoyed the research required to explain his results, and deciding how he would present his findings; his Year 6 CREST partners assisted in this process.

The second reason he enjoyed the experience was because it presented school science, and science generally, in a new and exciting way. Prior to doing the investigation in Grade 5, Daniel explained that science had been restricted to worksheets and lots of class experiments that did not involve open-ended investigations: “having the awards has changed science. We are more on our own now, we can do our own investigation, and we get a feel of what it’s like to do proper science”. Student and teacher roles change in this space as learning becomes student directed, and the teacher steps into the background: “In normal science the teacher would be on our backs telling us ‘No, you’re doing that wrong’ or ‘That is incorrect’, but now we can learn for ourselves what we are actually doing, able
Students as scientists: The impact of the BHP Billiton science awards

to decide what we are doing, how we are going to do it, how we are going to present it, and how we're going to sum it up. It gives us more control over what we are doing."

Through this experience he now sees that "Science is so much fun... There are more aspects of science to enjoy".

A third reason for his enjoyment related to the competitive nature of the experience. Daniel felt that the competition element prompted him to "perform better", "try harder", and "produce better results". By this he meant that without the competition element he would not have as thoroughly researched to explain the results, nor investigated as many variables. He felt that he made his investigation a more challenging investigation than if he was not in the competition.

A fourth reason for enjoyment, and an added benefit for Daniel, was that he believed that he was encountering science in a way that prepares him for secondary school science. Daniel's view is consistent with research reporting that students have great expectations for science as they embark on the transition into high school (Speering, 1995). Daniel projected that his future engagements with science at school would involve more opportunities for open investigations, autonomy over project choice and design, and would delve more deeply into the different sciences: "Year 5 and 6 students enjoy it because it sets them up for high school, to enjoy science in high school." He approached this with excitement, anticipation, and a desire to pursue post-compulsory science and beyond school. "I now know science is so much fun. And in high school there will be so many more aspects there to enjoy. It's just an enjoyable subject. So I think I will definitely be doing it in Year 12." After school he says he is "keeping his options open, but I am thinking of being a doctor, a lawyer, engineer, or doing scientific studies. Even a scientist; that would be lots of fun."

Overall, he sums up his experience thus: "Science before BHP was always reasonably boring, but now with BHP I know just how fun science can be".

Student engagement with science

It was quite clear, in the interviews with teachers, that what drove them in running and promoting science investigation work was a desire to engage students more fully in an approach to science that would capture their serious interest and commitment. Student engagement in learning science in authentic contexts was a key driver for them. Teachers recognised the importance to students of having ownership of the investigation and to showcase their work in a competitive environment.

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### Attitudes to Science in School and to Science in general

#### Table 16 Surveyed students’ attitudes to school science and science in general

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree or Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 I look forward to science lessons.</td>
<td>41.9%</td>
<td>33.9%</td>
<td>16.1%</td>
<td>6.5%</td>
<td>1.6%</td>
</tr>
<tr>
<td>2 I enjoy the activities we do in science.</td>
<td>33.9%</td>
<td>54.8%</td>
<td>9.7%</td>
<td>0.0%</td>
<td>1.6%</td>
</tr>
<tr>
<td>3 What we do in science are among the most interesting things we do in school.</td>
<td>32.3%</td>
<td>30.6%</td>
<td>22.6%</td>
<td>12.9%</td>
<td>1.6%</td>
</tr>
<tr>
<td>4 We should spend more time on science each week.</td>
<td>9.7%</td>
<td>32.3%</td>
<td>45.2%</td>
<td>11.3%</td>
<td>1.6%</td>
</tr>
<tr>
<td>5 Science is useful in everyday life.</td>
<td>45.2%</td>
<td>45.2%</td>
<td>6.5%</td>
<td>3.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td>6 I am good at science.</td>
<td>44.3%</td>
<td>39.3%</td>
<td>9.8%</td>
<td>6.6%</td>
<td>0.0%</td>
</tr>
<tr>
<td>7 Knowing science helps get a job.</td>
<td>32.3%</td>
<td>41.9%</td>
<td>19.4%</td>
<td>4.8%</td>
<td>1.6%</td>
</tr>
<tr>
<td>8 Studying hard in science is not cool to do.</td>
<td>1.6%</td>
<td>6.5%</td>
<td>29.0%</td>
<td>29.0%</td>
<td>33.9%</td>
</tr>
<tr>
<td>9 I have always been interested in science.</td>
<td>38.7%</td>
<td>37.1%</td>
<td>11.3%</td>
<td>12.9%</td>
<td>0.0%</td>
</tr>
<tr>
<td>10 I would be interested in working in a science related field.</td>
<td>50.0%</td>
<td>19.4%</td>
<td>16.1%</td>
<td>12.9%</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

The survey explored students’ attitudes to science in school and science in general. Table 16 and Graphs 12-21 show students’ level of response to a list of statements. The students were very positive in respect of their school science and science in general; this contrasts significantly with research which reports student disengagement with school science (for example, Lyons, 2005\(^6\)).

In summary the survey suggests that generally the participating students:

- look forward to participating school science very strongly,
- enjoy the activities in science,
- find school science interesting,
- don’t necessarily think there should be more science at school,
- think that science is useful in everyday life,

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Students as scientists: The impact of the BHP Billiton science awards

- have a strong sense of being able to do science well in class,
- believe that studying science will assist in getting a job,
- disagree with the stereotypical view that doing science is not cool,
- have always been interested in science,
- would be interested in pursuing a science related career.

Graph 12: I look forward to science lessons.

Graph 13: I enjoy the activities we do in science.
Students as scientists: The impact of the BHP Billiton science awards

Graph 14: What we do in science are among the most interesting things we do in school.

Graph 15: We should spend more time on science each week.
Graph 16: Science is useful in everyday life.

Graph 17: I am good at science.
Graph 18: Knowing science helps get a job.

Graph 19: Studying hard in science is not cool to do.
Graph 20: I have always been interested in science.

Graph 21: I would be interested in working in a science related field.
Subject related intentions of nominees

Table 17 (Graph 22) indicates that apart from 1 student on a gap year all surveyed students are currently at either secondary school or university. Table 18 indicates that most of the secondary school students are in Year 11 and 12.

<table>
<thead>
<tr>
<th>Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>School</td>
<td>77.3%</td>
<td>34</td>
</tr>
<tr>
<td>University</td>
<td>20.5%</td>
<td>9</td>
</tr>
<tr>
<td>TAFE</td>
<td>0.0%</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>2.3%</td>
<td>1</td>
</tr>
<tr>
<td>Other (please specify) (Gap Year)</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Table 18: Secondary school current status of surveyed students

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years 7-10</td>
<td>36.4%</td>
<td>12</td>
</tr>
<tr>
<td>Years 11 or 12</td>
<td>63.6%</td>
<td>21</td>
</tr>
</tbody>
</table>
Tables 19 and 20 indicate a significant percentage of students (85.7%) in Year 11/12 are undertaking courses of study that contain mostly mathematics/science and that the majority of Year 7-10 students (66.7%) are planning future courses that contain mostly mathematics/science subjects.

**Table 19: In planning for my Year 11/12 course I plan to have**

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>mostly mathematics/science subjects</td>
<td>66.7%</td>
<td>8</td>
</tr>
<tr>
<td>some science subjects</td>
<td>33.3%</td>
<td>4</td>
</tr>
<tr>
<td>no science subjects</td>
<td>0.0%</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 20: In my Year 11/12 course I have**

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>mostly mathematics/science subjects</td>
<td>85.7%</td>
<td>18</td>
</tr>
<tr>
<td>some science subjects</td>
<td>9.5%</td>
<td>2</td>
</tr>
<tr>
<td>no science subjects</td>
<td>4.8%</td>
<td>1</td>
</tr>
</tbody>
</table>

Tables 21 and 22 show variation in university courses currently undertaken by the surveyed students. However, the majority of the courses have at least some science subjects (67.7%).

**Table 21: The title of the my University course is**

<table>
<thead>
<tr>
<th>Response</th>
<th>Response Count (9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor of Medicine and Surgery</td>
<td>2</td>
</tr>
<tr>
<td>Bachelor of Exercise and Sport Science (Trying to transfer to the double degree with Physiotherapy)</td>
<td>1</td>
</tr>
<tr>
<td>Bachelor of Journalism / Bachelor of Arts (International Studies)</td>
<td>1</td>
</tr>
<tr>
<td>Bachelor of Law/Arts</td>
<td>1</td>
</tr>
<tr>
<td>Bachelor Animal and Veterinary Bioscience</td>
<td>1</td>
</tr>
<tr>
<td>Bachelor of Science (Resource &amp; Environmental Management)/Bachelor of Laws</td>
<td>1</td>
</tr>
<tr>
<td>Bachelor of Pharmacy</td>
<td>1</td>
</tr>
<tr>
<td>Bachelor of Science (Macquarie University) and Master of Teaching (University of Western Sydney)</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 22: In my university course I have

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>mostly mathematics/science subjects</td>
<td>33.3%</td>
<td>3</td>
</tr>
<tr>
<td>some science subjects</td>
<td>44.4%</td>
<td>4</td>
</tr>
<tr>
<td>no science subjects</td>
<td>22.2%</td>
<td>2</td>
</tr>
</tbody>
</table>

Evidence of the awards swinging students towards science.

It is not a simple matter to identify factors which influence students’ choice of studies beyond the compulsory years, even for the students themselves. However, The Moriah and Redeemer case studies provide anecdotal evidence of many students going on to study science and in the case of Redeemer there was some quantitative evidence. There were other teachers who were able to say with confidence that the research program did have an effect:

I have picked up 6 kids for senior chemistry next year directly as a result of the projects this year. They like the way of learning. In fact over the last four years there have been a lot of kids choosing sciences who we wouldn’t have expected to do so (L, NSW Secondary teacher)

This year our school won a Queensland showcase award for academic excellence in science and for that part of our submission, I did an interview with past students. Quite a few of them have done science. They remember the competitions and are enthused by the investigative parts. The high school tells us that 20% more of our students go through to the year 12 in science compared to other intakes. That would indicate that all of these contests are a contributor to that. (Teacher award winner 5)

Yes. I’ve kept in touch with students at high school. They ring me and tell me how much they love science at high school. The high school teacher tells me they’re that little bit of a step ahead in science. The boy who won a prize for the Billiton said he wanted to become a scientist. That would be the right sort of feedback for him to confirm him, to get an award like that. (D, Tas. primary teacher)

I’ve had a lot of comments from kids who’ve finished a research investigation that ‘I want to work in physics’, ‘I want to do chemistry’. We’ve had a lot of kids go into the high school and we’ve set their interests up in science in primary school and they’ve continued that into high school. We’ve had pretty motivated kids. We’ve had an after-school science club and it’s gone from 8 to 32 over the last few years. We use the high school lab. The kids are keen. We’ve noticed those kids who’ve done a bit of science at school, they’ve gone over there and continued their science work. It will be interesting to see where they end up. (M, Tas. primary teacher)

Probably while every other state school is losing numbers in science we are increasing them. We are having to cap class levels. We have 100 students doing chemistry in year 11, 5 classes of physics in Year 11…..We are sustaining numbers in sciences and bucking the trend. (Teacher award winner 6)
Students as scientists: The impact of the BHP Billiton science awards

One particular girl who just won the physical science prize had spent all last year telling me how she hated science.. she’s continuing on with science (after doing a quality investigation). (J, Tas secondary teacher)

We’ve had some this year who’ve become very, very keen on it. Whether it’s that or just the way things are taught and they’ve suddenly developed a real interest in science and we’ve had some who were a bit iffy and now they really do want to go ahead with it (science) into college and into uni. (I: You think there are students who are inspired to go on with science who wouldn’t have otherwise?) Yes, absolutely! (H, Tas. secondary teacher).

I have for example one girl who left school two years ago – she did STS in year 10 and she won her category and got a second in BHP Billiton. Then the following year to be involved in the extension program- I talked her into it and she did extremely well in a few other state based competitions and then decided to change her whole career goal-she changed it to medicine and she focused on research and is now at ANU doing a medical research degree. (Teacher award winner 7)

We had a lot going on to UTas in science who have had success in the science fair. They seem to develop a capacity to see science as more than just knowledge. I’ve had feedback from UTas to this effect (A, Tas. secondary teacher)

All of the judges interviewed supported the claim that the competition did impact on students’ decision as to whether to continue to study science beyond the compulsory years. In their discussions with students and teachers, it was evident that the uptake of science in later years was increased. Teachers made comments about higher enrolments in later science and that it was quite common for there to be an increase in science enrolments after students had experienced the science competitions. There was a general belief that the science competitions led to improvement in numbers undertaking science at the tertiary level, but the evidence was anecdotal only.

The case studies (Daniel and Ian) demonstrate that students are also of this belief, both through their own experience and observation of their peers. Daniel talked about seeing, through the experience of doing research, that:

Science is so much fun… There are more aspects of science to enjoy… (I am) keeping my options open, but I am thinking of being a doctor, a lawyer, engineer, or doing scientific studies. Even a scientist, that would be lots of fun…. Science before BHP was always reasonably boring, but now with BHP I know just how fun science can be. (Daniel, student award winner)

Ian, now a university student, talked of the benefits of the BHP award scheme:

What you find that when students get involved in research projects it actually changes their idea of science. So there’s no such thing as a science geek or a science student once you get involved in research projects because they get to see how much fun you can have. I’ve seen so many people who have been totally disinterested in science get involved in a research project and have it change the way they think about science. (Ian, student award winner).

Engagement with science and with schooling

The data indicate that most of the students who win their way to the BHP Billiton award nomination are committed and able science students (see Graphs 12-21), others are committed to project work but not exclusively science, while for other students the project becomes a major impetus for improving their commitment to schooling and proves unexpected for teachers. There are examples of the research projects being a means of engaging students with science, which matches the findings reported in the section on student responses.
Students as scientists: The impact of the BHP Billiton science awards

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 … Science Fair to get the kids involved. I found I got them engaged with success. (M, Tas. secondary teacher)

Teachers reported that they were sometimes surprised by the positive response of students to the requirements of research projects. Each teacher who had been involved for some time with award work seemed to have stories of students for whom the project was unexpectedly rewarding and in some cases a key to their wider engagement with schooling. Stuart’s (Redeemer case study) story of the student who took out a national prize with developing luminosity standards is a case in point. There were other stories.

You can get the kids engaged and it provides success for the less academic as they can choose what to do. I had two boys who were in trouble and had been suspended but they won a prize for their project on corrosion to do with craypots. The other teachers commented on how they had improved and their parents were delighted (H, Tas. Secondary teacher)

I have a gallery of photos. It started with a parent who was really thrilled that her daughter got a prize because she wasn’t a high achiever in any other areas but she did a really nice investigation on different campfire fuels, working out the kilojoules that were being produced in each burning. So mum came along and made a scrapbook of photos of all the kids who had won awards and it went up on the wall. (J, Secondary Tas. teacher)

In year 10 it is not always the strongest science students who do well, because they need good organisational skills and good literacy skills. Some students who do well are not necessarily from the science background - so students with traditional strengths in humanities can get a lot out of it. I do find that kids that are good at science love it immensely, but it’s the kids on the fringes of the science classroom - they actually do get engaged- because it is their work and they take that ownership. (Teacher award winner 7)

The prize winner in Year 6 was not in the top class (The classes are streamed) so that was a pleasant surprise. (A, NSW primary teacher)

I have very vivid memories of the first grade 8 class who I undertook this with and a very naughty year 8 boy … and you do lose a certain amount of control when you let students choose their own topics and it’s risky and I get frightened every year but I remind myself every year of (his) beautiful behaviour. I’ve never seen him on task like he was when he’d chosen what to do and he was recording his own results…. Some waste time but most are very motivated when they’re finding their own answers. (J, secondary Tas. teacher)

**Student outcomes**

From the interviews and also from the responses of students in the online survey (Table 23), it is clear that these open investigations are in stark contrast to traditional approaches to and purposes of practical work, involving knowledge and skills that are not normally developed in science curricula. On this basis one could argue that simply by being involved in investigations students are learning new and valuable skills. The traditional set of ‘skills’ associated with working scientifically include question posing, measurement, experimental design (often conceptualised as control of variables), analysis and drawing conclusions. Other process skills include observation, classification, hypothesising, inferring and concluding. These skills are all represented in the stories teachers told of student work, and in students’ stories. They were often mentioned by teachers as part of their description of student outcomes.
Recent thinking around the purposes and outcomes have shifted the emphasis and ways of thinking about thinking and working scientifically. Richard Gott (Gott et al. n.d. 7) has argued that understanding how evidence is collected and used in science should be a core purpose of school science, and this should be described as ‘concepts of evidence’ rather than as ‘skills’. Arguments for inquiry approaches to science have also moved beyond a notion of process vs. content, to a concern that students are exposed to ways of reasoning with evidence: scientific argumentation and the nature of science. Alongside this is recognition that scientific methods are more complex and context dependent than can be characterised by a simple ‘scientific method’ rubric, and that students should be engaged in reasoning with evidence in flexible ways that reflect the purposes of particular investigations 8. 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. Ann’s (Moriah case study) 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 9 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 from investigative projects.

The capabilities particularly mentioned by teachers in describing student outcomes included learning to ask questions, information processing, measurement and analysis (including the use of excel), critical thinking, independence and persistence, imagination, becoming aware of science professionals and how they work, and science conceptual learning.

Teachers were able to indicate significant ways in which the science research programs in their schools provided students with important competencies which are not necessarily learned by other means. They pointed to the fact that students had to seek out information

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from a variety of sources as part of their projects and this is an essential life skill. Illustrative of this was the story of student doing a project on the conditions for fog formation on rivers and the student needing to gather information from sources such as the Bureau of Meteorology. The Moriah example of the student becoming expert in carbon sequestration is another instance.

The projects were reported by some teachers as the most demanding piece of work that students had to do during the compulsory years of schooling and that students learnt about perseverance and meeting timelines. While not all students appreciated the challenge it was suggested that “for some students the project was the sort of thing that they will look back on and say, ‘Remember when we did...’”

A common theme for teachers was the development of critical thinking skills

Past students have related that .... (a study with about 20 past students revealed the importance of critical thinking). The ability to pace yourself and to know how to plan for what you want to get done, when you come up against a problem to be able to look at all the possibilities and the determine the most logical, or best fitting, to what you are wanting to find out, recognising data – when they find the data isn’t very useful to support their hypotheses – they reassess and start another project- starting to think scientifically. (Teacher award winner 5)

They gain a sense of working like a scientist. Their results are very important to them. They learn a great deal about experimental method and communication. (L, NSW secondary school)

The thinking and the problem solving. The thing I like best is watching them have to develop their method and deal with their problems they encounter along the way. I just loved having … a kid doing an investigation on waves and he was trying to generate regular waves with paddles all sorts of things, and he decided he’d use a vacuum cleaner and blow and produce waves… like the wind, and he was producing curved waves… so he went home and thought about it and he came in with his mum’s venetian blinds cleaner attachment … that had a straight sort of paddle, and blew through that .. and just watching him go away and think about how to solve problems… like real scientists … the creativity you need to solve problems. I love seeing that happen with the kids (J, Tas. secondary teacher)

Using graphs and spreadsheets and the literacies of science were mentioned as outcomes of participation in this form of activity.

Every time they do an investigation they gain knowledge about science in that area. A lot of them are working with excel spreadsheets and data stuff, things like averages, how to record data. The hardest things they find are finding researchable questions. Also procedural writing and instructional writing. (M, Tas. primary teacher)

I showed them (primary school students) how to do a graph and the teacher watched and when I came back three weeks later there were 10-20 graphs done. It was really good. So now they have an example of a good project and this year they have the whole school doing projects. One group was a winner this year. (S, NSW secondary teacher)

The National Organisers interviewed indicated that some of the skills developed are not normally part of the science curriculum as they relate to time management and more generic skills. They commented on students’ levels of deeper thinking.

Deakin University, February 2010
Communication skills.

There is an emphasis on communication at each stage of the competition process from school level, local science fairs, through to the state competitions and finally to the BHP competition and science camp. The camp also provides the opportunity for students to be coached about how to present. They use the camp time to prepare a poster about their project and then they are further interviewed. The role of the interview is to drill down to levels not apparent through the report. The interview gives students opportunity to talk about their project and highlights the quality of the science project, both theoretically and in the thinking processes.

The opportunities to communicate - in written, verbal and visual means - was valued by teachers. Some teachers talked about the need to educate students on the expectations of a scientific report:

We have a template for them with suggested ways of writing and sentence structure and the tense and the verbs they should be using, so that it gives them a chance to work through the templates so by the time they are finished they will be writing in a proper scientific manner.

There was a girl (who is at college now) who comes back and tells me the handout I gave her on writing reports back in grade 8 are really helping her now in her work in Grade 11/12. She did reports in grades 8, 9 and 10 and I think that probably helped her get a scholarship and they’re really helping her now. (J, Tas. secondary teacher)

Similarly with visual displays such as posters, students needed instruction in how to best present the information. It was also pointed out that a large part of the value of attending the awards was related to communication:

I could see the very capable young people it was a fantastic experience for them. Just the experience of justifying their studies, thinking, talking to scientists who can suggest modifications. The process of them thinking … communicating, and crystallizing what they’ve done. It’s a fantastic skill to have. (H, Tas. secondary teacher)

There is evidence that a very significant outcome for many students is a greater competence in communication skills. The teachers talked about the requirement for designing a display which communicated their work, making verbal presentations, and also talking with others about their project during the science fair days. This was particularly significant for students from remote areas who “don’t get much opportunity for such interaction”.

Science has its own sort of literacy. They want to write a story but they learn to write in a scientific genre, and how to refine this sort of writing. (D, Tas. primary teacher)

A teacher from a rural school identified:

Communication skills – these kids aren’t used to talking in public so it’s important. (H, Tas. secondary teacher)

A number of teachers in schools with multiple awardees talked about the support they give students with framing their reports and particularly with communicating in preparation for the award competition. The Redeemer case study is a good example of this, but a number of teachers referred to workshopping presentations and the involvement of English staff.

If you look at the project before and after BHP you will find a big difference. Students need to learn to prepare a poster and speak to it. The fact of asking for a presentation is excellent because it encourages the learning necessary for scientists to get ideas across. There is support at school – students prepare a poster and stand and present it. They are given advice on eye contact, how to emphasise key points, be sensitive to the audience. This has cross curriculum implications for instance these students are said by English teachers to be good at English (A, Tas. secondary teacher)
The camp personnel interviewed indicated that initially some students can be a little nervous and challenged by the status of winning and presenting their work. The camp for the finalist students allowed them to talk with like-minded students. This validates their interest and passion for science and increases their confidence to talk about their projects.

**Appreciation of the nature of science and the work scientists do – contact with scientists**

It was clear, as has been discussed, that student investigative work in schools was almost universally linked, at least in the teachers and students interviewed, with direct contact of students and teachers with the scientific community. This was often through the Scientists in Schools program but also through schools setting up contacts with local scientists or university departments (Moriah, and Redeemer) or through students themselves making such contacts (as evidenced by the online survey responses). The student case studies of Daniel and Ian demonstrate the extent to which they saw their projects as providing greater insight into the work of scientists and what it was like to do ‘real science’, and involving more complex skills than they normally encounter in school science. For Bella, learning the efficacy of variable control designs and becoming immersed in field research were significant experiences. As an example of the links made with science professionals:

I have introduced working with a scientist to mentor and assist students with their scientific investigations. One such example has been the use of “Biomimicry” in the classroom and allowing the students to imitate nature by designing models that perform a specific task. My Year 8 students undertook this open-ended task. (S, teacher award winner talking of changes flowing out of winning the award)

Appreciating the way science works in relation to its social relevance was often described:

They are exposed to how scientists work .. all sorts of benefits .. ethics, who benefits – it broadens their horizons. Students are naturally interested in science. (D, Tas. primary teacher)

Teachers valued the way the awards scheme encouraged students to working as scientists:

They get to be a real scientist. To see how science works, be creative, use their own thinking processes and they get immediate feedback - if something doesn’t work. (Teacher award winner 6)

We did some cool ant investigations and I have had a look at cane toads – their experience of the first wave of cane toads, quolls in the area. (NT). We’ve done different investigations with bio control beetles, insect trapping, weeds. (Primary teacher award winner 4)

**Teaching investigative knowledge and skills**

Schools varied in the extent to which they explicitly developed students’ understandings and skills in preparation for the research investigations. For schools who had been involved for some years and particularly in states for which investigative outcomes is written into the curriculum, student investigative capabilities are developed as part of the scope and sequence planning over a number of years. A teacher in Western Australia looked for quantitative evidence to support a claim that investigative skills had improved with their program:

The transition in data from Year 8- 10 shows there has definitely been an improvement in the outcome levels for investigating that the students have achieved in last five years. Previously, the students were achieving level 2 and 3 even at Year 10. We now have students functioning at level 6 in Year 10 so it’s definitely looking better. (Teacher award winner 6)
There are, however, specific skills and understandings such as organisation and time management, persistence, and understanding of how scientists work, which are uniquely developed within the project.

In the online survey, students were asked firstly whether they complete activities in their normal class similar to their STA/CREST science award work, and whether the skills needed are learned in their normal science classes (Graphs 8 and 9). Opinion was divided in each case but a slight majority of students agreed that they learnt the necessary skills for the investigation in their normal class. Table 23 below shows students’ explanation of their response, separated into descriptions of skills learnt at school, extra skills learnt, and other comments. It is clear from the table that there are many scientific capabilities developed as part of the awards that are not covered in most school science programs, but that many schools are teaching these skills as part of teaching open investigations. This is consistent with the stories from the teachers.

<table>
<thead>
<tr>
<th>Skills learnt at school</th>
<th>Table 23: Skills learnt in normal science classes and out of class</th>
</tr>
</thead>
<tbody>
<tr>
<td>the CREST award was part of class</td>
<td>We were given the option of completing an Extended Experimental Investigation (EEI) in my Yr. 10 Science Extension class, and those you chose to complete one were high-achieving students who were confident with researching and experimental design skills gained through other activities.</td>
</tr>
<tr>
<td>I learnt the basic principles of conducting a scientific experiment and then writing out a report</td>
<td>In normal science classes at school, we are taught scientific investigation methodology and procedure, which in turn allows us to plan and investigate our own individual projects. Furthermore, we were able to seek advice from school teachers in all aspects of our projects. However, in terms of research and data presentation, these skills were inadequately supported in the school's science curriculum.</td>
</tr>
<tr>
<td>I gained report writing skills</td>
<td>I have done outside research with my partner, but we have generally obtained all the information and experiment skills in school.</td>
</tr>
<tr>
<td>Aspect on how to run an experiment with controls and achieve reliability and accuracy etc</td>
<td>Because all of the investigation was carried out at school.</td>
</tr>
<tr>
<td>The ability to carry out experiments properly, and document the processes clearly was taught in science classes at school.</td>
<td></td>
</tr>
<tr>
<td>The International baccalaureate requires students to undertake in investigations of this standard as regular internal assessment... very challenging!</td>
<td></td>
</tr>
<tr>
<td>because my entry into the STA/CREST was just a slightly altered version of one of my school practical assessment pieces</td>
<td></td>
</tr>
<tr>
<td>Basic outlines of how to write up the investigation and the level of detail needed.</td>
<td></td>
</tr>
<tr>
<td>As a compulsory part of high level science in high school we had to carry out a individual major prac and we were taught how to formally conduct an experiment and how to write a report.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers instructed us in how to set out the investigation. They gave us a list of outcomes that we needed to achieve. The teachers gave us example of what investigations could be done and we were studying physics at the time of the investigation which I could apply to the investigation.</td>
<td></td>
</tr>
</tbody>
</table>

| strong science program at my school with teachers who help enormously with this sort of thing. |

| entering the awards was part of our assessment, so my teacher made sure we knew what to do. |

| In science class, we learn how to do good experiments. In English we write lots of reports. In Maths we learn to draw graphs. In computers we learn to type and make slideshows. |

| My teachers basic scientific thinking such as:  
* hypothesis  
* aim  
* conclusion.. etc. |

| I have learnt how to display my information from school / but the rest I learnt from books and my mum. |

| All of my school subjects help towards what I do in the STA awards, especially computers and science. |

| We learn scientific method and research skills in classes and this helped aid investigation. |

| As part of our final year of high school all members of our Biology class participated in a research investigation, and many entered the CREST Science awards as a result. The skills of setting up, carrying out and reporting on our projects were all taught in class. |

| Our school has a strong science program, and as a part of some of our classes, we must perform stringent investigations, such as in Physics. I can't fully agree with this, because the maths for our project (rates of change) is learnt towards the end of year 12, and we worked out the equation while still in year 11. We were still able to get assistance from our school for constructing our equation. |

| I don't learn much about science outside of the classroom. |

| We got taught in class how to set out and perform a research project and how to present it. |

| I have a wonderful teacher who makes herself available in breaks and before school and by email if I require advice but my projects are an extra thing I do and have taught me many extra things, a successful primary project is a collaboration between student and teacher with strong parental support |

| Whilst conducting and designing our experiment we had help and advice from our Teacher. |

| We learned to write up practical reports and conduct experiments in class |

| There is a strong science research focus in the school. The method and structure of scientific research and reporting is well taught at all age levels. |

| Some skills were taught at school / others were gained at home |

<p>| Skills learnt that were needed my science teacher's help with some advanced Excel skills that I hadn't learnt at school in order to make the calculations I needed with my data. |</p>
<table>
<thead>
<tr>
<th>extra to the normal school program</th>
<th>My research was original and unrelated to anything I learned in my school science lessons as I study Physics and Chemistry and my experiment was in the field of Biology.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I had to learn how to take blood pressures with a sphygmomanometer. We did not learn this at school, therefore a nurse taught me.</td>
</tr>
<tr>
<td></td>
<td>We needed to learn some extra skills such as drawing and interacting classes. We needed to interact with other students younger than us to get our results, sort of like a teacher.</td>
</tr>
<tr>
<td></td>
<td>This was a different experience and I needed to talk to a relative to get a scientific approach to the research I wanted to do.</td>
</tr>
<tr>
<td></td>
<td>At the time I was doing the investigation, I was in Primary School and in those science classes, the skills and information we learnt we very generalised and only is it in High School that we actually start to really learn more and develop important skills to help us in future science lessons.</td>
</tr>
<tr>
<td></td>
<td>Working with spreadsheets and writing scientific reports is something I haven't done at school.</td>
</tr>
<tr>
<td></td>
<td>I had support from my parents and I didn't know how to carry out the experiment properly, until they advised me.</td>
</tr>
<tr>
<td></td>
<td>School science classes didn't help me at all with my investigation, my partner and i were just lucky we knew enough about science and were good at researching!</td>
</tr>
<tr>
<td></td>
<td>At school we don't learn the skills of designing an experiment, such as deciding controlled variables, writing a hypothesis etc. Learning at school is more focused on theory and carrying out a few practicals.</td>
</tr>
<tr>
<td></td>
<td>A lot of the research projects I completed were done outside of my science class in my own time, and above what the rest of my class were doing.</td>
</tr>
<tr>
<td>Other comments</td>
<td>Normal science classes did not have the time to spend, also not all the students were completing investigations for them to be interested - interest played a part in what was studied</td>
</tr>
<tr>
<td></td>
<td>This is the first year that my school has had a Science teacher and we only have her for a semester. It is more a teaching time, rather than following what I am interested in.</td>
</tr>
<tr>
<td></td>
<td>Though my teacher (at the time) was a geologist, the curriculum didn't cover fossils.</td>
</tr>
<tr>
<td></td>
<td>At the time, which was in year 9, this investigation was much larger than anything else beforehand. However, the skills from it have helped significantly in year 11 and 12</td>
</tr>
<tr>
<td></td>
<td>I felt that a single project would, quite honestly, have very little impact on overall marks. also the level of work required to produce a decent project was barely comparable to the sort of assignments schools hand out at my year level at the time. My school work was virtually irrelevant to my project and vice versa, while I would like to say such a project helps people advance in science I believe that a one off high detail project really doesn't make much difference in the whole scheme of things.</td>
</tr>
<tr>
<td></td>
<td>In order to present a detailed idea, concept or experiment towards the STA you need to explore information comprehensively, at school we no doubt get a thorough knowledge of the issue, but using this program I was stretched far beyond the average school task. I believe STA gave me an opportunity to extend myself further as a science student and offered some variety as to the usual day to day school science activities which ... College offer.</td>
</tr>
</tbody>
</table>
Students as scientists: The impact of the BHP Billiton science awards

Students’ experience of the award scheme

Students were asked in the online survey to provide a final comment on the award scheme. Their responses (Table 24) show considerable enthusiasm for the award scheme generally, and also for the BHP camp. What they write is consistent with the views from the interviewees. There is reference to challenge, to discovering a passion for research, to identifying themselves as science enthusiasts and increasing their confidence, to learning more science, to appreciation of the prizes, and to meeting others.

<table>
<thead>
<tr>
<th>Table 24: Final comments from the surveyed students</th>
</tr>
</thead>
<tbody>
<tr>
<td>It's a great program which encourages students to think outside the boundaries and develop a greater understanding of why things are the way they are.</td>
</tr>
<tr>
<td>I like hands-on science rather than sitting at our desks writing.</td>
</tr>
<tr>
<td>I enjoy the challenge and it is totally awesome!!!!!</td>
</tr>
<tr>
<td>Participating in these science competitions had given me skills that have been helpful in all science subjects.</td>
</tr>
<tr>
<td>It really helped me as the student to take the initiative and pursue science in a way that I wanted.</td>
</tr>
<tr>
<td>I was very honored to be considered as a semifinalist, this in conjunction with crest awards has made my resume and applications to uni much more eligible.</td>
</tr>
<tr>
<td>This program had helped me boost my confidence in the area of science and it has helped me progress through my schooling career.</td>
</tr>
<tr>
<td>this was a great experience</td>
</tr>
<tr>
<td>I enjoyed conducting my own investigation.</td>
</tr>
<tr>
<td>I enjoyed the independence from the teacher in that we had to plan and carry out our own experiment our own. I also enjoyed the hands on aspect of the work, and writing a report on it.</td>
</tr>
<tr>
<td>Thanks for the great opportunity! These awards are a great encouragement to students, and STS awards have really helped foster my interest in the sciences.</td>
</tr>
<tr>
<td>I quite liked the science competition because it gave my classmates and I, an opportunity to extend our science skills and investigate and learn more about what we wanted to. It was especially fun for us, because it was a first for our relatively small school, and we were all really excited about what the results would be. The BHP Billiton science awards also encouraged, us to be more interested in science for the future, which, I, personally, think is important because in this day and age, the young generation of this century are taking absolutely no interest in science and many people I know, loathe the subject in school. So to have this competition is just great!</td>
</tr>
<tr>
<td>Greatly appreciate the STA science awards - they were part of what helped me find my passion for research. Thank you very much.</td>
</tr>
<tr>
<td>These projects were fun and interesting.</td>
</tr>
<tr>
<td>I have enjoyed participating in these awards and found that participation extended my knowledge of science.</td>
</tr>
<tr>
<td>The awards I received both from STA and BHP were helpful in my application to participate in the National Science Youth Forum which I am looking forward to attending in January.</td>
</tr>
</tbody>
</table>
3 and 5 years later I am still in contact with some of the people I met at the science camp in Melbourne.

The BHP Billiton Science Awards camp was great! And I recommend that younger students complete a similar type of scientific investigation as it is a truly enriching experience. And there is also money to be won in these competitions!!!

Participating in the BHP Billiton Science Awards was beneficial as it urged me to work harder on my projects.

This is the best thing that I have become involved in. More schools should be involved - when I move to Middle School next year, this is not offered, but we can still do it privately through our Science teacher from primary school which I will do.

I enjoy doing the STA science awards but unfortunately I can't do any experiments on vertebrates without special permission.

I am hoping to carry on with the project that we began in earlier years, and increase the accuracy of the equation, as well as completing the web page that we began as a part of the project. I have thoroughly enjoyed the experience of such competition, and am sorry to leave these awards behind as I leave school.

The number of scientific investigations undertaken by students in 2009 has greatly increased due to me winning Billiton and STA because they have seen me achieve and believe they can do it as well. This year we had a record number of investigations and have 10 students through to Billiton 2010.

Oliphant science awards and BHP Billiton awards is really fun and a great way to learn about science. It is also a nice treat to be able to be rewarded for your efforts!

I think its wonderful that you recognise and encourage the work and learning of students in the area of science.

The awards increased my confidence and fuelled my interest in scientific investigations. I think they are a fantastic initiative and if more people could be involved in some way or another then perhaps more could have experiences as I did.

I love the prizes - money was a great incentive.

On a whole the awards system is great and provides great opportunities for young scientists to get involved in research.

Students also offered commentary on how they felt the awards could be improved. These are shown in Table 25.

<table>
<thead>
<tr>
<th>Table 25: Student suggestions on areas for improvement in the awards scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>While I don't think a compulsory project would go down well, I believe these science awards need a lot more support and promotion by schools. I wouldn't have known about these awards had I not been subscribed to the &quot;double Helix&quot; at the time. After I entered the school did put up several poster regarding the competition but a couple of posters is hardly promotion.</td>
</tr>
<tr>
<td>a good website with plenty of info on how to make a scientific report would help, as well as background on scientific theory</td>
</tr>
<tr>
<td>The 2009 STAQ Queensland Science Contest Awards Presentation was poorly run, and I would have appreciated more information from CREST with regards to my investigation proposal and whether or not I have achieved a Gold CREST.</td>
</tr>
</tbody>
</table>
Students as scientists: The impact of the BHP Billiton science awards

<table>
<thead>
<tr>
<th>Suggestion</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>there wasn't much contact made apart from receiving a badge with a letter,</td>
<td>how would this have changed anything about in-class science for me?</td>
</tr>
<tr>
<td>and then a rejection letter</td>
<td></td>
</tr>
<tr>
<td>More prize money in the award will motivate me more and likely to do another investigation</td>
<td></td>
</tr>
<tr>
<td>I would like to hear of my STA results sooner.</td>
<td></td>
</tr>
<tr>
<td>I have been a BHP Primary winner twice and it would have been good if there</td>
<td>completing these research projects.</td>
</tr>
<tr>
<td>was some sort of presentation ceremony for the major primary awards instead</td>
<td></td>
</tr>
<tr>
<td>of just getting a cheque in the mail. It would be more special if there was</td>
<td></td>
</tr>
<tr>
<td>a special presentation.</td>
<td></td>
</tr>
<tr>
<td>Completing a research task is very time consuming for students and it is</td>
<td></td>
</tr>
<tr>
<td>becoming increasingly hard for students to balance time for research against</td>
<td></td>
</tr>
<tr>
<td>time to complete the mountain of school assessment work that they have.</td>
<td></td>
</tr>
<tr>
<td>This pressure increases as students get further into high school. There</td>
<td></td>
</tr>
<tr>
<td>needs to be more support to students and their teachers to allow for</td>
<td></td>
</tr>
<tr>
<td>students to have a better chance at completing these research projects.</td>
<td></td>
</tr>
</tbody>
</table>

These suggestions are quite varied but pick up on some commentary in the interviews. There was some comment on the fact that the BHP Billiton awards are expressly aimed at the best projects and students, and this involves many students missing out. Some of the student comments relate to a feeling of lack of recognition. The standards in the BHP Billiton awards are very high, and there is disappointment from students when they are not successful. There are one or two comments about timing of results which was also mentioned as problematic by at least one teacher. On the question of profile, it seemed as if some schools were much more strongly focused on the process of science investigations and secondarily on the STA awards with little consciousness of the BHP Billiton awards.

There’s not much awareness of BHP. We don’t put an emphasis on the actual awards – it’s the process. We’ve won many awards but .. It is an incentive to see kids winning awards or trips. It’s an encouragement for other kids to have a go. It provides emphasis and recognition of their work. STS has a good website that provides models. We don’t go out of our way. We focus on the STS and the BHP but it’s a bonus if it happens. (M, Tas. primary teacher)

Students aren’t so aware of the BHP we’ve had a few students as semi finalists. (H, Tas. secondary teacher).

However, as has been described elsewhere in this report, this lack of focus tends to change quickly if students in the school were nominated, and especially if they were successful and attended award ceremonies. For schools in which students had won awards over a period of time, the BHP award scheme was well recognised, and targeted, by both teachers and students.

**Experience of the award schemes**

Comments from teachers about the award ceremonies tended to include both the state awards and the BHP awards. The teachers were very positive about the experience of the award ceremony for a variety of reasons. A number talked about students having the chance to mix with like minded science enthusiasts. Others mentioned the value in sharing their work.

It gives them a sense of achievement and an opportunity to share and celebrate their investigation with others. (S, teacher award winner)

There was an understanding that students came back from these award ceremonies with renewed enthusiasm and with ideas for projects. The ceremonies also have the effect of exposing students to work of high quality, and making them aware of the standards that are
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possible in student science investigations, and what can be achieved with effort. In this way, the award events help build standards over time. This was held to be particularly important for students in rural schools:

The local competition is very important. We are isolated and it is important that they see what other kids are doing and succeed. (H, Tas. secondary teacher)

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, NSW secondary teacher)

One teacher emphasised the value of the award events as an expression of support from the scientific community for schools and students.

I’d just like to say - when I go to the state presentations of the awards with all the sponsors, as a teacher and the fact you’ve got all those parents there .. It’s overwhelming that you’ve got businesses and BHP there prepared to back kids and to back science. Some of them got up and gave a few sentences about themselves – it’s really helpful and I think wow, I’m getting some support. I can say I value science in the classroom but if you’ve got something as big as BHP saying we are backing science, we really need that. It’s also a good community thing. They’re really saying ‘we value science’ and I really appreciate that. (D, primary science teacher)

Experience of the BHP awards and ceremony

The seven teacher award winners who were interviewed had quite a bit to say about the BHP awards both for students, pointing out the fairness but high standards of the awards, and the prestige.

• There was a general acknowledgment of the prestige and importance of the BHP Billiton Award scheme, both internationally (with the overseas trip), national recognition, and locally in terms of community recognition. (Teacher award winners 2, 3, 5)

• They were all capitalising on the available schemes that recognise and reward student and teacher effort, for example the state awards schemes that serve as a gate to BHP award scheme as well as other national award schemes. For example their students enter CREST and the state award scheme. (Teacher award winners 3, 5).

• There was a general view that the standards of the award scheme are strong but fair - requiring students to work very hard to achieve an award.

• It was pointed out that there is a big difference between junior/senior (9-12) levels, similar to the difference bronze to silver in CREST. (Teacher award winner 3)

• One interviewee made the point generally that the BHP awards are directed at elite science students; that the BHP award targets very, very high performers “the BHP competition is about the students who are really serious about science…” . Given that the standard for winners is very high- there are very few winners – students need a lot of encouragement. (Teacher award winner 3)

Over the years from 2000 to probably three years ago I think BHP Billiton was accessed through the STA competitions We had a good deal more interest in the school amongst students who hadn’t before taken on a scientific investigation. They had done collections and done building models and working models and some always did a scientific investigation, but not that many. Since the connection with BHP Billiton competition
through the STA competition we have had an enormous increase in the number undertaking long term scientific investigations which I think is a absolutely wonderful outcome of that association. (Teacher award winner 5)

Having a team of students being sponsored to go to US - that changed projects a lot. It created incentive and resulted in a shift in emphasis towards research and the quality improved. We had more secondary projects (S, NSW secondary teacher and award winner)

We have our own means of publishing about (students winning BHP awards) – it raises awareness among other students who become really keen, along with staff, to be involved (A, Tas. secondary teacher and award winner)

(Awareness of the award is) quite high among the staff. (There is some) resistance to do competitions because they are lot of work among the staff, but those staff that do engage their kids find it really wonderful. Our kids in particular really like the fact that it’s a national competition … like that they are competing against kids that are like them (gifted) because we have gifted kids that don’t always see the challenge unless they are competing against other kids that are like them, and they really enjoy that … and the prizes and the travel (Teacher award winner 7)

The BHP Camp

There were only 8 respondents (secondary school finalists) to the survey who indicated they attended the science awards camp. This group of students was asked about their experiences in participating in the camp. Table 26 and Graphs 23-27 indicate that the students had a positive camp experience in terms of enjoyment, challenge, increased enthusiasm for science, greater insight into the work of scientists, and improved communication skills.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree or Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  I found the BHP Billiton science awards camp an enjoyable experience</td>
<td>75.0%</td>
<td>25.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2  I found some aspects of the BHP Billiton science awards camp quite challenging</td>
<td>0.0%</td>
<td>75.0%</td>
<td>12.5%</td>
<td>12.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>3  By participating in the BHP Billiton science awards camp I increased my enthusiasm for science</td>
<td>37.5%</td>
<td>37.5%</td>
<td>25.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>4  The BHP Billiton science awards camp gave me a greater insight into the work of scientists</td>
<td>50.0%</td>
<td>50.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>5  The experiences I had in participating in the BHP Billiton science awards camp improved my communication skills</td>
<td>0.0%</td>
<td>87.5%</td>
<td>12.5%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
Students as scientists: The impact of the BHP Billiton science awards

Graph 23: I found the BHP Billiton science awards camp an enjoyable experience

Graph 24: I found some aspects of the BHP Billiton science awards camp quite challenging
Graph 25: By participating in the BHP Billiton science awards camp I increased my enthusiasm for science

Graph 26: The BHP Billiton science awards camp gave me a greater insight into the work of scientists.
The students had the opportunity to provide some qualitative comments about the camp. The following comments were made:

<table>
<thead>
<tr>
<th>General comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>The camp was great. The coordinators were genuinely nice people and arranged many enjoyable activities.</td>
</tr>
<tr>
<td>I had a great time, but there could have been more non-science-related activities just to mix it up!</td>
</tr>
<tr>
<td>It was fantastic! Thank you :)</td>
</tr>
<tr>
<td>I missed firing rockets in 2008. That was the highlight of the 2004 camp!!</td>
</tr>
<tr>
<td>It would be great to have a prominent scientist meet the students and talk to them about their work. This is probably very hard as most of them end up working overseas.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Challenging aspects of camp</th>
</tr>
</thead>
<tbody>
<tr>
<td>I found my first camp experience in 2004 had more hands on projects, which I loved to do (especially the fake wounds using dough and chocolate sauce). In 2008, the camp had more of a sightseeing feel to it, though there were still the fun activities. I never felt out of my depth with the science that was being presented, so it could have been slightly more challenging.</td>
</tr>
<tr>
<td>Being away from home and rock-climbing were challenging!</td>
</tr>
<tr>
<td>I found out I am not the artistic type when it comes to making rockets...</td>
</tr>
<tr>
<td>Mainly judging</td>
</tr>
<tr>
<td>I was involved in the first year of the presentations and this meant that some of the rules were not clear. As a student we were not given a printed itinerary which meant that it was hard to plan for what was coming next. It was also a very fast paced camp and did not leave a lot of time to take a breath.</td>
</tr>
</tbody>
</table>
A teacher who had students win a BHP award was very positive about the effect:

Fantastic. They had four days and just loved it. We’ve had a number of students go and they all had a really fantastic time. They were able to engage with students who were like-minded. There was a bit of competition. We’ve had some high winners. We had a girl who went to Georgia and it’s an experience she’ll never forget (A, Tas. secondary teacher)

The teacher experience

School and teacher practice

The awards have a very significant impact on some schools. They build curriculum programs which have the competitions as the end point for the activity. This influence even extends to changes to the competition rules being reflected in how the school organises its program. This is not seen as an imposition but as reflecting the benefits the schools feel come both from the internal activity and from the competition. In the interviews, there are many stories of teachers responding to the awards in a variety of ways and building investigative work into their practice in different ways. The awards play an important role in promoting science – through subjects and careers – at schools with embedded and significant programs. There are numerous anecdotal comments by teachers relaying students’ enthusiasm for science and the development of investigative and research skills that can influence subject and career choices. There are some schools that over time have specialised in and become very successful at building a culture of open investigation work, which involves:

• Building a history of projects that can be drawn on as examples, and particular techniques / instruments.
• Building standards over time as both teachers and students get to understand how to approach this sort of work.
• Supporting both teachers and students through a mentoring process.
• Enlisting the support of science professionals in the local community or through science organisations – teachers can play a major role in this, as can students’ relatives who have some science related training.
• Building a group focus around themes, similar to what happens with science organisations.

The trajectories of these schools seem to be built around enthusiastic and talented teachers who gradually build commitment from their colleagues.

The following case study of Ann Burke from Marist Regional College in Burnie, Tasmania provides an example of a committed and talented teacher building a research culture that extends within her school but more recently to a successful regional science fair. At Marist College, science investigation capability is built into the curriculum and teachers are supported to become involved.
Case study of Ann from Marist Regional College: Building a local research culture

Ann Burke came to Australia with a history of involvement in investigations and competitions. She had developed a real love of doing research even though “it is full on, frenetic work ... A lot of my projects are around sustainability issues”.

When she started in the mid 1990s the research section in the state Awards was small and “most projects were from students who had a home based mentor- standards were generally lower that at present and numbers were smaller”.

*From 2000-2003/4 I started mentoring students in small groups and individuals and they did well in the awards. Occasionally we had a BHP nominee. 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 40 entrants in 2003 to 80 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 18 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.*

At Marist College they embed research work in the curriculum and build expertise over time in a deliberate way. Students are encouraged to focus on a topic related to what they have done in class, and to find a mentor.

*Very often traditional experiments are short term and the outcomes are already known. Independent research is more exciting being a great ‘unknown’, but they have to spend longer in the laboratory which can pose difficulties. It creates interest for students because they don’t know the answer. Students need to start looking at science this way as early as possible.*

*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.*

Ann talked about the way that particular investigative topics could build over successive projects:

*Some students can go further. We see the results of that sometimes with BHP awards where a student may have had a project one year that may have looked at water quality and invertebrate distribution in a particular waterway and then the following year they might come along and look at the impact on the food chain or webs in that habitat as a consequence of the dissolved oxygen that drives the macro invertebrates ..*  

*We’ve had one on freshwater crayfish that was like that. It started off very simply just looking at the factors in the waterway to sustain life and continued into a study of why crayfish numbers were diminishing and came up with recommendations of what needed to be done .. recommendations which were taken up by the local city council. The project, in its second year, found that crayfish burrows were less frequent in areas that were depleted of man ferns. One of the recommendations based on a whole series of evidence, not just man fern distribution, was that replanting of man ferns might be beneficial in encouraging crayfish burrows. (There is some evidence in research literature to say that man fern roots from part of crayfish diet). Immediately after this was submitted to council*
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they did their own study and supported this. Only now, 10 years later do we see crayfish numbers starting to improve along this creek.

Sometimes if students have gotten up to speed with a body of information they may do a variety of projects in that area. For instance we've had one student take this approach when working on carbon sequestration. Out of personal interest she had read all of the Garnaut reports and the IPCC reports on climate change and she then undertook a project on evaluating Tasmanian eucalypts as a means of carbon sequestration. She moved on and used algae as a means of carbon sequestration in marine environments and in her third year she looked at no-till methods of farming as a means of carbon sequestration in soils and pasture land in Tasmania. She's had three really enlightening and successful projects on the same topic. We have had another pair of students undertake multiple projects into eutrophication in freshwater systems due to fertiliser run-off and due to introduction of ducks at a reserve. They are proving that once you get up to speed in one area it's silly to lose it.

Ann emphasised the advantage of linking this work with community science resources, and over the years has developed many contacts:

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 Hobart, 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 Dept. of Primary Industries or Waterwatch Tasmania, 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 6 students.

Ann talked about the need to mentor teachers who become involved in investigative projects.

One of the biggest challenges is mentoring teachers. We have been developing material to support them. It's quite daunting for a teacher having 16 or more different projects going with a class at the same time. The sort of PD necessary to support this is difficult to come by. UTAS scientists go round to schools to help. That's the difficult area – building teacher confidence. Even now, after many years of involvement within our school, some teachers find the process daunting.

She listed the characteristics of a teacher who can run open investigations successfully:

• Need a strong background and good knowledge of contemporary science – reading magazines and journals to be up to date in science.
• Interpersonal skills and the capacity to provide challenge and support to individual students
• Capacity to multi task – hands-on management
• Enthusiasm for learning with students, interest and tenacity

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.

The interaction of the BHP and state awards with curriculum

There are three senses in which the BHP and state awards interact with curriculum. As has been described elsewhere in the report, open ended science research is given a significant
Students as scientists: The impact of the BHP Billiton science awards

boost when it is explicitly mandated in the state curriculum. This has been the case in Tasmania and in NSW. The inclusion of open ended research in some senior syllabi, such as in science courses in Queensland, in the International Baccalaureate, or in the Tasmanian Environmental Science course, provides an impetus for entries in the competition. It is hard to say whether these decisions have flowed from the existence of the awards schemes, but anecdotally there are cases in the authors’ experience where curriculum designers with a history of commitment to these awards have successfully argued for their embedding in curricula. Apart from this possibility, there was evidence in the interviews that the existence of a culture of open science investigative work, and documentation of how to go about it, was invaluable in supporting the curriculum change in Tasmania. Similarly, a quote from a teacher in the ACT demonstrates the same trend:

Anecdotally, I can say that schools that have embedded research investigations in their curriculum fare much better than schools that include this as an “extra”. By embedding this in the curriculum, this type of investigation is seen as being part of the overall program and not an “add-on”, thus not being seen to onerous on teachers. It also exposes more students to the “scientific method”, thus given all students access to research investigations of this calibre. (Teacher award winner 2)

The second sense in which there is an interaction between the awards and curriculum is where schools who are committed to this sort of work and who have a history of involvement in the awards, build both the competition and the skills training supporting it, into their scope and sequence.

The awards have influenced the scope and sequence and supported science as a priority. (D, Tas. primary teacher)

There were a number of instances of this happening described in the interviews. These include the Moriah and Redeemer case studies, but also primary and secondary schools in both NSW and Tasmania. In one primary school, the running of open investigations and award entry was part of a 10 year professional development plan to raise the quality of science teaching and learning:

You might say it has been an interesting ride, with the professional development that we started with in the school right back in 2000, which followed a number of surveys and test of students’ scientific ability and different aspects, and then all of that data was talked about and at a staff meeting we worked out our three phase plan of what we were going to do to turn things around. And it has worked very well…. So 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 10 year initiative. (Teacher award winner 5)

In these schools as with a number described in the section above, the awards scheme and science investigative work have been conceptualised within a curriculum context that aims at engaging students with more open inquiry approaches to science, and to support teachers to do this.

The third sense in which the awards interact with curriculum is through individual teacher change due to involvement with the awards. In some cases, as with Redeemer below, participation in the awards and commitment to student investigations was claimed to be a natural consequence of a culture within the school of student centred, supportive pedagogies. In other cases the causal arrow seemed to point from the awards to the classroom practice:
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(It changes your teaching) in direct proportion to what you put in. The more I do the more I change the way I teach. It has changed my approach to the syllabus putting more emphasis on group learning. (L, NSW secondary teacher)

It made me change my pedagogy. I had to meet the requirements of the curriculum but needed to engage the kids. All of them do the scientific enquiry unit for a third of the year. (H, Tas. secondary teacher)

It has major impact on me as it ensures that I teach the areas they need, for example experimental method, report writing, etc. The competition focuses my mind on these things. (A, NSW secondary teacher)

Part of the issue, however, with changing practice through these awards, is the need to support teachers in their professional learning.

I do a lot of professional reading and also have an open door policy in my classroom. I would welcome PD in the skills required for this approach to learning. (L, NSW secondary teacher)

One award winning teacher reported on the rich and varied forms of professional development taken by teachers at her school to help them develop skills to better assist students-including:

accessing the afternoon session with Bright Minds at the UQ, attending a district teachers network meeting regularly, two of the science team have done a week’s medical research in Ian Fraser’s lab, working with scientists who come to the school, having a scientist in residence every year and participating in the Scientists in Schools program (Teacher award winner 5)

The enthusiastic teacher

One thing that comes across in the teacher interviews is the commitment and enthusiasm of the teachers who are involved in the STA and BHP Billiton award scheme. These are teachers who expend a lot of energy in supporting students in open investigations and in encouraging and supporting other teachers to work in this way also. In cases of schools where there was a history of award activity, individual teachers had been highly influential in creating a culture within the school of pursuing new science knowledge, and building expertise and a network of alliances within the scientific community to offer support in this.

For those schools with sporadic involvement in the BHP Billiton awards, in which we might have expected to find sporadic commitment to the ideals of science investigative research, again we found committed teachers with strong beliefs in these ideals. The difference between these schools lay perhaps in the lesser history of involvement or the school or community context. Nevertheless these teachers had also shown exemplary involvement with students and other teachers over a number of years.

Of course this is a selected sample we are dealing with. In the case of Tasmania the teachers were selected by recommendation after a poor response to the call for interviews. However, the NSW teachers were approached using a representative random sampling approach for those schools with nominated students, and the stories were similar. In both states we were talking with teachers who had been principally involved in the BHP awards at their schools. In each case we found teachers who had been actively promoting a way of doing science, to students and teachers, which is out of the ordinary.

At the higher commitment end of the interviewed teachers, including a number of BHP teacher awardees, their stories are remarkable, as illustrated by the two case studies. They had
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been influential beyond their own schools in supporting science investigation work in their region (Ann) and in local primary schools (Stuart).

Thus, it seems clear that a major achievement of the award system has been the encouragement and support of innovative and talented teachers of science who represent an important aspect of science – the research enterprise – in local schools.

The following case study of Stuart Garth at Redeemer Baptist School demonstrates the effect that one teacher can have on many students’ experience of science. Stuart’s story is a powerful reminder of the importance of teachers in students’ lives. It is also interesting in the insight it provides into the many ways in which a teacher supports students in lifting standards of research work. These particularly include his critical role in supporting students find questions and frame the approach to their investigation, his energy and organisation in linking students with local science professionals, and the moral stance he adopts in focusing on questions of social import. It will be argued later in this report that the experience of people like Stuart needs to be captured in framing professional learning materials for teachers embarking on this work.

<table>
<thead>
<tr>
<th>Case study of Stuart from Redeemer Baptist School: Supporting students to do quality research</th>
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<tbody>
<tr>
<td>Stuart Garth teaches at Redeemer Baptist School, a K-12 school with an impressive history of successful BHP Billiton awards. He started two decades ago as a young teacher of science, becoming interested in using video as a resource for teaching, and his students entered STS in the video category. A student winning first prize spurred him into involving his own and other classes in the school by visiting classes and promoting creative writing, photography, and science research.</td>
</tr>
<tr>
<td>These other categories are easier than investigative work – the beauty is you can have a lot of people go through. It also caters for creative kids.</td>
</tr>
<tr>
<td>He was able to use his video skills to help with video based research analyses. His school won a prize and by the end of the 1990s he was sending multiple projects to BHP Billiton. He identified factors that improved standards in the school as including the state curriculum changing to include research projects, a rubric being developed by an education academic on what characterises good research, and:</td>
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<tr>
<td>A team of students being sponsored to go to the US - that changed projects a lot and created incentive. It resulted in a shift in emphasis towards research and the quality improved.</td>
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<td>In 1999 I worked with a kid who looked at the dangers of heat in a car. It was a huge study. It would have taken about 6 months. .. He was selected to go to Singapore. He was on Totally Wild ... on national TV... We've never really looked back since then. ... Once you've got the idea that doing a good project requires time. ... we can do something that will actually help society. He designed a device that you put in a car that works on a thermostat that once you get to a certain temperature the fans come on inside your car. It was a prototype. It provided a model for research projects – what is possible, what is inspiring.</td>
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<tr>
<td>Another kid looked at a ground effect plane – an engineering sort of guy who built his own tools. He won the Young Scientist of the Year Award in 2000.</td>
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<tr>
<td>The school teaches the scientific method as part of their curriculum. In preparation for the awards, Stuart hands out a 20 page booklet to students, including examples of projects from past years. Students choose projects but he provides support: &quot;I've got an idea for your project&quot;. He opens up the school labs till 6 pm one day a week - “near the deadline I have 20 to 30 kids at a time”.</td>
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Deakin University, February 2010
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 microorganisms 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.

Stuart talked about the need for nurturing and the fact his school ”is not an elite school but a caring school. You need to support and mentor students”. In keeping with this 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". He described a project a student had done on deep vein thrombosis. 'We rang hospitals... dealt with the ethics aspects ... the first company we rang lent us a $60,000 ultrasound. I picked it up, dropped it off’

Stuart described how: 'I've got a boy with a massive project on luminance contrast. He designed 48 eye charts ... the project built on a previous project looking at colour luminosity.' He described the student as previously not successful or motivated academically.

I asked year 10 kids. I had this kid who was ... not really interested in school work. Plays computer games. For some reason he thought ... hey, this is a chance to do something in my life. He did a paper run for six months to come up with money to construct these eye charts ... designed an algorithm... put it into standards and he’s come up with a new Australian standard with his name on it. The standards committee has passed it. I had to ring up the standards guy to convince him that the science has been done. He’s now fired up .. in all subjects. He’s taking 3 sciences next year. People come to me and say ‘this guy’s totally changed’. I've got many stories like that although this one would be hard to beat.

Stuart described the long term impact of projects on the students including changes in direction:

I've had many kids have come to me to collect anything they've done on their science projects because when they go to university a lot of them have interviews ... and it's been their science project in year 7 which has got them into their course because they haven’t had the marks to get in. I've had 4 or 5 like that. I've had so many students gone on to do science. I would say that in about 70% of the cases the science project and the work I've done with them has triggered a change for directing them into science. Some would have done it anyway, but if it wasn’t for the culture of our school around science a lot of kids wouldn’t have ventured into the area. I'm confident about that. I entered an award earlier this year and I sat with the headmaster and went through (the records) - he did a survey of our history.. During the last five years, on average, 76% of the HSC cohort complete at least one Science subject - In addition, in 2009, 70% of all university courses offered to Redeemer's HSC cohort were science-based courses. He couldn’t believe it.

Some of Stuart’s and others’ work at the school has involved whole class projects. Again, he has been influential in generating the idea:

I had my whole class looking at light pollution for the NATA Young Scientists Award 2009. We were involved in the CSIRO "Scientists in Schools" program. We were lucky to get an astronomer – Spanish – doing research on galaxies. He's blending radio with light astronomy. He said to the teachers .. when he first arrived and got off the plane and looked at the sky he just cried ... it was black. He said
‘we need to preserve out skies’… I came up with the idea in the shower from an Earth Hour program about light pollution. It coincided with the visit from the astronomer. I talked to the class about a few ideas and they chose that one. One of the kids had the idea about a website. So we ended up with developing a website… we publicised it… we ended up over 12 weeks with 3555 measurements. Mainly from the class – but they emailed their relatives from all round the world. We set up the website. We made a magnitude chart by eye. Not using any instrumentation… we made 16 charts of the Southern Cross and Vega. What you can see with different levels of light pollution. I really wanted them to have the ideas. We spent a lot of class time working in groups and put together the class project. I had different kids in charge of different areas. Names of website, 300 word summary. One girl was a map coordinator, another boy and girl were internet data entry officers and when the kids made a measurement they’d ring them up. It was great. We took out first place.

Stuart described the prevailing pedagogy in the school, that ties in with their science research culture: There’s a lot of our teachers who use collaborative work, for instance the technology teachers. The teachers are closely knit. That makes it easier to take up and manage science projects.

Stuart discussed the effect on students of being involved in the research projects:

The big impact is on their ability to communicate. Firstly writing reports is not an easy thing. It takes a lot of time generally for instance I take a student and we might work with them on the Aim. I sit down with them and workshop and they go home and write it up. For instance with the people who go to the BHP Billiton Awards, I get them to talk in front of the class and school and give them practice at talking under pressure to other people. Because they have to talk to judges. I get them to talk to a couple of the English staff. They’re very helpful. They give them advice like ‘you’re spending too long getting to the main point… you need to capture attention’. The ability to communicate is huge. All the kids who have gone to the US are excellent communicators (but) not naturally. (Doing the project) has really helped their communication abilities. They go to university and are really confident. Talking to lecturers. I see a change in individuals – definitely. I’ve had ESL kids going to the US representing Australia. Report writing is also important. Being able to email a company for advice. Once they get past that they’re ok communicating with specialists.

Linking with the scientific community

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, to bring authentic science practice into the classroom in the guise of scientists and a variety of science professionals who help students with their projects.

At the moment I’m having a scientist come. I’m doing a unit on marine issues and I’m just bringing a scientist down as part of the Scientist is Schools program and I’m bringing her into the classroom and so all these things help. Go hand in hand. (D, Tas. primary teacher)

The Department of Education ‘My Science’ program for primary schools in Western Sydney; they have scientists and secondary teachers go in to be mentors for kids working on a project. For instance scientists in R go three times, sparking ideas, then visit a month later to help refine and a third time when they’re doing their report. (S, NSW secondary teacher)

The more active teachers (see the Moriah and Redeemer case studies) had cultivated over the years many contacts, even partnerships with the scientific research community and with local science professionals who supported their work with students.
Dealing with student diversity

As discussed in sections above, some of the teachers described the difficulty for many students in doing open ended investigations, and for some this way of working was best for able students. However, many teachers had worked on ways of successfully involving all students in investigative work. One teacher talked of the different levels of CREST as being useful for this purpose.

Lots of students will do the CREST award- but there is the difference between levels e.g. finding what keeps the flower alive the longest and investigating pod use and impact on hearing – looking at frequencies …- I put a great deal of effort into this report - The students would easily have put in 100 hours each for a silver award. I don’t have this time to give all my students. It can be very stressful for some students to give them such open ended tasks.

The CREST is quite good as an encouragement in Year 7 but the gap between the bronze and the silver CREST is very big. The silver CREST- you are looking at candidates for BHP finalists whereas you are not really doing that for the bronze CREST; you are preparing them for the science fair- and all you get is a certificate that says you’ve done it - yet some of these that going to the science fair are quite interesting and original. For instance a student was sailing at the time … so did the data collection while sailing- Can I do something on coral bleaching?- Good report – but not .. (of silver standard). (Teacher award winner 3).

This same teacher talked about the value of the research competitions for all students, and the skills that are needed:

For all abilities- encourage every child, but it is also a lack of imagination, sometimes really brilliant students when they have to organise themselves they are not so good. It is more than just being clever it’s having imagination and organisational skills; it is more than that. (Teacher award winner 3)

One teacher award winner (6) described the diverse characteristics of some of the students involved:

I teach gifted students- so it gives me the opportunity to extend them without them thinking that we are doing extra work. They love the hands on aspect.

The finalist this year had a learning difficulty with reading and interpreting questions under exam conditions… she didn’t think of herself as very smart. She loved the research project because her difficulty did not impact on her ability to do the research and she was very surprised she was so successful. Kids get so much personal reward and confidence.

In year 10, it is not always the strongest science students who do well, because they need good organisational skills and good literacy skills. Some students who do well are not necessarily from the science background - commonly students with traditional strengths in humanities can get a lot out of the investigations.

I do find that kids that are good at science love it immensely, but it’s the kids on the fringes of the science classroom - they actually do get engaged- because it is their work and they take that ownership. (Teacher award winner 6)

Another teacher talked about structuring different levels of participation, in striking a balance between inclusion of all students and support of the science enthusiast:

It’s compulsory to participate in the science curriculum but there are lots of voluntary aspects that they can participate in, such as the science clubs -which children can attend after school. Entry into the school competition is not compulsory but it has a high rate of entry. They can choose to do a long term investigation and then just put it in the expo part
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and not as a contestant, and that encourages some children who are hesitant and think they wouldn’t be good enough to at least put work in and they are on display Then the entry into the Queensland competition and the BHP Billiton is voluntary but they are already selective – they go in, but have to be selected at each stage. (Teacher award winner 5)

Two teachers made comments about the awards helping to address the gender imbalance in science – with girls leading and being successful in competitions.

**Supporting teachers to become involved**

**Factors affecting the participation of teachers**

It needs to be noted that the data for this study comes only from people who have chosen to engage with this activity. There is clearly a need when addressing factors which affect the participation of teachers to listen to the voices of those who are not yet involved. However some points made by those interviewed should be recorded.

Where the curriculum of the state or the school does include student engagement in science research projects, there is pressure on teachers to participate. The science coordinator in a Sydney school made this point while acknowledging that ‘some do it better than others’. Again, there were cases identified where an enthusiastic teacher was able to win over colleagues and involve them in the activity. However, even there some of the factors which limited teacher participation were identifiable. It was recognised that the initial step is a large one, with the task becoming easier as time progressed. Further, there is not always the professional support available which could help teachers take the first steps. Relevant professional development was advocated as one means of addressing this issue. A particular group identified as people with a special need for such professional development were those teaching ‘out-of field’ whose initial education did not give them the relevant background, and hence the confidence, to tackle this sort of activity with students.

The science teachers all know about it (the BHP Billiton Awards) but most of them don’t get off their backsides and enter. They fall down on the doing. Lots have been doing the same thing for 20 years. It takes an effort to get started but then it gets easier and easier. (H, Tas. secondary teacher)

There is currently not much PD opportunity that is available. There are lot of teachers teaching science and maths out of field and there is a need for PD. (H, Tas. secondary teacher)

The new courses for Years 11 and 12 have an investigative component - at least 20% comes from an investigation. Teachers are scared of it - something that is very time consuming and because kids are doing individual work you have to develop the management skills of being able to keep the kids on track and organised, which can be a bit intimidating. (Teacher award winner 6)

**Strategies for enlisting and supporting teachers**

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.

Not so many teachers have been doing investigations but over the past few years the curriculum has been formalised with investigations an important part of the outcomes so we are delving more and more into investigations. It’s growing each year. And it’s grown into where teachers are now confident to take their class in science investigations.
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. (M, Tas. primary teacher)

And on an approach to supporting teachers:

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, Tas. primary teacher)

A number of the teachers interviewed spoke of both the difficulty their colleagues sometimes had in embracing open investigative projects in their classrooms, but also the enthusiasm of others of their colleagues. They talked of the enlisting of teachers’ commitment over time and of strategies such as visiting classes to encourage student participation, providing supporting documentation such as descriptions of the stages of an investigative project or examples of projects from previous years. In some cases they offered support to teachers through working with them in classrooms and modelling how to support students. 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. A number of interviewees argued that the multiple categories of many of the state awards was a way of enlisting teachers’ commitment who did not have the energy or commitment to open investigations. They saw a need for such strategies to get teachers up to the high bar represented by open investigations.

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 (see the Moriah case study) and standards build by virtue of teachers and students being exposed to the projects from more experienced schools.

In only one case was a formal professional development approach used, run by the Queensland STA. This was reported to have been successful for primary teachers. While clearly there is a need for professional development of teachers, in the main this seems to have occurred informally, in a school setting, drawing on the expertise of teacher enthusiasts.

The feedback from award winners of the importance of professional learning opportunities lends support to the need to better equip teachers to assist students undertaking scientific investigations. This could be through professional development opportunities in each state and could include:

- encouraging award winners to share their understandings;
- sharing all the important background knowledge that has been built up over many years of entering, providing instruction on organisational approaches, links to curriculum, Q &A sessions, getting help from parents, scientists and others;
- building networks to support teachers who are new to the process.

The advantage of promoting the awards scheme through targeting teacher professional development in open ended investigations are that it:

- acknowledges the importance of the teacher in the success of students’ projects;
- acknowledges the importance of teachers in promoting and developing school culture of competing in awards schemes.;
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- acknowledges that teachers and schools often do not have the necessary skills to be able to assist students with open ended investigations. (Taking into consideration the shortage of qualified teachers of science and the number of teachers teaching science out-of-field.) The professional development opportunities may help to provide teachers with necessary skills and be a step towards making the awards fairer;
- invests in the teaching profession with the objective of promoting science as an important means of answering significant questions facing the world and promoting careers in science.

The teacher awards

The BHP Billiton Science Teacher Award is one of the most prestigious awards for science teachers. Receiving the award provides opportunities for networking and professional learning. The prize associated with the award has changed over time, and now provides travel, accommodation and meal costs for teachers attending the BHP Billiton Science Awards and any international competition.

Teacher Award-Melbourne Award Ceremony trip

While all the award winning teachers appreciated the profile and recognition the national award afforded, there were differing opinions about the usefulness and appropriateness of the prize. The trip to Melbourne or overseas was mostly commended as a valuable prize because of the professional learning it provided in assisting them to help their students.

I have won another award and there is always money for the school or money for me which was fine, but I guess I would never have thought of going to the international science fair myself- even though I had money could use, from a Peter Doherty award for PD. I looked around Australia for PD that I could use it on, but this sort of put it in my lap. But I am so glad because it was probably the best PD I’ve ever had. (Teacher award winner 5)

I found it eye-opening to come down to the luncheon and see what was being produced from around Australia. It was really, really mind blowing and to be able to talk to some of the teachers and students from the other schools was very interesting. It gave us a lot of ideas as to what we could do and how our students compared to other students and how we could expand. (Teacher award winner 6)

There is a big step-up from state to national and going to Melbourne this year made me realise… .. We were standing there looking at the other projects and we were blown away. So it’s really helped me this year to know that that’s the standard. (Teacher award winner 7)

The rewards of the trip to Atlanta … just to see what the international engineering and science fair was like, and the quality of the work, to have a chance to talk to Nobel Laureates. It was just the ultimate and I have been able to bring a lot of that back because I run conferences for teachers. I have had three conferences since I came back last year run for teachers across our region. (Teacher award winner 5)

Fantastically nice to network and see what people are doing around the country. The thing that struck me was the quality of the science awards and that was quite wonderful, and it was nice to mix with people from industry as well. I don’t know if I enjoyed that because my background is science and I am comfortable in that area as well- coming from a science education officer background. (Primary teacher award winner 4)

The teacher part of the awards is also important. Teacher quality and interest and engagement is important. I went .. it was an amazing experience. Meeting other teachers
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and seeing how they manage their students and talking to them about logistics. I’m a better director of projects because of this. (A, Tas. secondary teacher)

However there are also constraints on a classroom teacher- leaving students and responsibilities for others to cover. Interviewees also expressed some dissatisfaction with the restrictions in the type of prize offered.

The presentation was at the beginning of the year- and it was difficult to take time off. I don’t know if it is worth the break. It was at the end of week 2 and the time missed (with classes getting longer) was greater time and it is really bad to be away from your classes at anytime.

There was a $10,000 prize in the past. Other possibilities could be sponsorship for CONASTA as well as going to Melbourne. I know it’s a big thing going to America but you actually are on duty chaperoning students and I just felt that it’s always nice to get an award.

The characteristics of the Award winning teachers

The stories of the award winning teachers are those of inspirational and strategic teachers who have introduced innovative ways of engaging students in science through open ended investigations.

- All the award winning teacher teachers interviewed for this study had expended time and effort - selflessly - well beyond the normal teacher’s workload.
- The teachers were humble and commonly did not seek out recognition or awards yet they did seek out the competitions and awards for their students and believed the recognition was important. The national status of BHP Billiton awards scheme was considered important and significant.
- Many teachers were active in the professional organisations. The teachers acted as mentors to students and staff, often providing leadership and professional development. In this way they were leading change in the way science is taught in their schools.
- The teachers worked over many years to change practice. Some examples of these changes include:

  the use of “Biomimicry” in the classroom and allowing the students to imitate nature by designing models that perform a specific task. My Year 8 students undertook this open-ended task (Teacher award winner 2)

  Looking at black fellow / white fellow science (Teacher award winner 4)

  We wanted to go into Nanotechnology with our year 7’s and…, I was able to establish contact in Georgia at the Georgia institute of technology and we have been able to access materials from them. (Teacher award winner 5)

It is interesting to note that some of the award winning teachers have qualifications that make them well suited to managing the demands of the BHP Billiton Science Awards scheme –for example, a Masters degree by research. One of the award winning teachers was a scientist who became a scientific education officer and is now a teacher whose experience clearly demonstrates the power of a scientist leading science investigations in her classroom:

  I share with them my background and take in scientific papers, shown them different spiders and caterpillars that have been named after me – Like this is what you can actually do………share aspects of indigenous knowledge. (Primary teacher award winner 4)
There were strong links between the Teachers Awards and the Students Awards with most award winners involved helping students and other staff with the state awards.

The effect of the awards on teachers who receive them

There is a high recognition of the awards in school, by colleagues and the community. The teachers interviewed describe their personal and institutional recognition a result of receiving the award:

Upon receiving the award, all teachers and students have had an interest in the Awards. The whole school community, students, parents, teachers and the many partners we have established from the wider scientific community, celebrated the Award. Awareness of the award was raised via staff meetings, promotion in the school newsletter/website, parents and students sending me congratulatory letters/cards. Students have also wanted to know more about the teacher and the student awards and how to access the award, The local newspaper celebrated the award, as did other print media such as the Herald/Sun, Australian Teacher, Shine, AEU, NEOS KOSMOS and a Greek newspaper in Athens (Teacher award winner 2)

It definitely has raised an interest with students and I find myself discussing science issues with more students both within the classroom and in corridors and the schoolyard! (Teacher award winner 2)

The BHP Billiton/CSIRO Award has provided me with an opportunity to grow both personally and professionally. I have been able to share in my experience not only with the teachers at my school, in the state and nationally, but also with teachers on an international level. (Teacher award winner 2)

I found it eye opening to come down to the luncheon and see what was being produced from around Australia. It was really, really mind blowing and to be able to talk to some of the teachers and students from the other schools was very interesting – it gave us a lot of ideas as to what we could do and how our students compared to other students and how we could expand. (Teacher award winner 6)

The recognition has led to changes in recipients such as career pathways, their leadership position, and their profile in the school. For the school the recognition the teacher receives can lead to a change in enrolments and the focus or priority areas of the school.

It is not surprising that the excellence of the award winning teachers has commonly been recognised by other awards schemes including the Prime Minister’s Award for Excellence in Science Teaching, the Doherty Award for excellence in primary and middle school science and the Eureka prize. In addition to the professional learning opportunities from the BHP Billiton award, the teachers had commonly experienced other valuable professional learning experiences.

I am going to Singapore for a conference next week to present paper. Sponsored position by CSIRO. I went to the 2009 Greenhouse conference as a spinoff of this award. I have been involved in a sustainability project. It was really nice to be at a high level conference, reinvigorated the need for scientific education in primary. (Teacher award winner 4)

I was invited to help review the IB curriculum for science which goes to about 700 schools around the world. As a results of that they produced a book called Teachers Resource manual with examples of marked work and what was really flattering was work by my students went into that book. (Teacher award winner 3)

I… attended a nanotechnology conference…seeing what they are doing, seeing the equipment, and just the nature of it. So I brought that back and generated one particular piece of work that we did, looking at what was simply nanotechnology and what the scale
of it and examples of how it is being used, .. to produced nanoproduct and then we looked at the impact of it on society, and looked at it from both the positive and negative point of view …. That flowed onto other teachers who modified it for their own use but certainly it influenced what they were doing. (Teacher award winner 1)

All the award winning teachers acknowledged the national recognition and profile afforded all of the BHP Billiton awards: Receiving the Teachers Awards had helped them in various ways such as in job applications, it had brought status to the school, and was a welcome recognition of their efforts.

The judges commented that, interestingly, most teachers do not find the awards act as a reward mechanism in a direct manner, rather in an indirect way. They find their rewards through the recognition of their students’ achievements, the increased visibility of science in the school, the overall impact within the school of a ‘Science Award winner’. They relate the Science Awards to their personal experience of working with open-ended investigations with students and the value of that to their teaching.

**The effect of the teacher awards in promoting quality teaching**

Through the teacher awards the recipients took advantage of opportunities to improve the learning situations at their schools, for example:

- one recipient became aware of programs such as Scientists in Schools and so initiated it at her school,
- another took the opportunity to forge links with a school in USA whilst on the overseas trip as part of the award, and now her school works with them on a nanotechnology project,
- another described how her confidence had been boosted by the formal recognition,
- another explained how she was exploring the ways of teaching the less able students - though a staggered approach to investigations.

**Economies of scale - taking advantage of multiple science programs**

The award winning teachers who were interviewed had a good understanding of the sponsored science programs, recognised their value and had taken advantage of other relevant activity running in their state, informing their students and the staff of available opportunities to maximise their advantage. This strategic use of programs enhanced the opportunities for students to:

- showcase their work,
- present investigations in multiple formats,
- build their confidence.

There are constraints with the suitability and availability of programs, nevertheless the awareness of available programs is the point. Table 27 presents examples of teachers building synergies across multiple programs.
The table below presents the interactions between multiple programs and the BHP awards submitted by different states.

<table>
<thead>
<tr>
<th>Program</th>
<th>Comment by Teacher</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Tasmania Science Investigation Awards</td>
<td>It is more like a real science conference- where the students present a poster (Teacher award winner 1)</td>
<td>Tas</td>
</tr>
<tr>
<td>Working with scientists</td>
<td>Yes, I have introduced working with a Scientist to mentor and assist students with their scientific investigations (Teacher award winner 2)</td>
<td>All</td>
</tr>
<tr>
<td>Genetics competition</td>
<td>the genetics competition when the students started by writing an essay which was on contemporary genetics research and an application that had legal and ethical aspects  (Teacher award winner 3)</td>
<td>ACT</td>
</tr>
<tr>
<td>Attend public lecture</td>
<td>Students go to two public lectures and write them up, with reflection their learning (Teacher award winner 3)</td>
<td>ACT</td>
</tr>
<tr>
<td>Eureka awards</td>
<td>One of the BHP Billiton Student award winners came second in one of the Category’s in the Eureka awards (Teacher award winner 5)</td>
<td>Qld</td>
</tr>
<tr>
<td>Working with scientists</td>
<td>Through UQ I now have one of my past students – he is in the last few months of his doctorate. (Teacher award winner 5)</td>
<td>Qld</td>
</tr>
<tr>
<td>Working with past students through UQ</td>
<td>Working with scientists- they come into the school (Teacher award winner 5)</td>
<td></td>
</tr>
<tr>
<td>Scientists in resident</td>
<td>We had a scientist in residence every year The teachers claim the best PD they ever have is when the scientist in residence.... (Teacher award winner 5)</td>
<td></td>
</tr>
<tr>
<td>NATA Young Scientists Award</td>
<td>One of our students came third in the National Association of Testing NATA and they run a young scientists program and she won $ 2000 worth of science equipment for the school and it arrived last Friday so everyone is excited. (Teacher award winner 5)</td>
<td>Qld</td>
</tr>
<tr>
<td>Scientists in school/CREST awards</td>
<td>Enrolled the Scientists in Schools program- working with a scientist from CSIRO- support them doing CREST awards. (Teacher award winner 5)</td>
<td>WA</td>
</tr>
<tr>
<td>Learning links –at UWA</td>
<td>Linking to other competitions –learning links program with UWA supports students to enter competitions. We have powerful plants and that's a learning links program with plant energy biology. (An ARC centre of excellence). (Teacher award winner 6)</td>
<td></td>
</tr>
<tr>
<td>Science education at UWA</td>
<td>Science Education at UWA is running a mini conference for students at the end of the year where students present their own research work – for Year 10 only - building communication skills and confidence and realising that real science not just in laboratory but being an effective communicator those students</td>
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An organisational perspective

The interviews with the national organisers of the BHP Billiton Awards indicated that the Awards scheme had impacted on them both personally and professionally. They felt that they were making a contribution to the continuance of science. They commented on the visibility of science in schools, general population, and the value of open-ended investigations. They used words like ‘inspired, passionate, involvement’ to describe the teachers they met. As one said, “Teachers are outstanding, you can’t help but be inspired. Their passion is humbling”. They also talked about seeing how science was being played out in schools and the value of rewarding teachers’ good work and students’ efforts. All were amazed, time and time again, by the quality of science produced by children. As indicated by the interviews, they commented that “you can see what kids are doing and what they can do”. “We are constantly amazed at kids’ efforts and the value of open-ended investigations. It is very rewarding”.

Views from the state awards organisers

Interviews were also conducted with the state organisers of the BHP Billiton Awards. The general sense from the interviewees is that currently the process works well. With the states doing the preliminary selection, CSIRO Education is freed up to take on the national judging of Finalist Students and Finalist Teachers.

The guidelines provided to the students and the teachers provide the state organisers with sufficient detail to make informed decisions.

Judges’ views of the BHP awards

Judges of student awards.

A number of those who have acted as judges for the student awards were also interviewed. The judges commented on the fact that the students were engaged with topics of personal interest and that their passion for their topic came through in both their written reports and their discussions (for finalist students). Students had selected their own topic, developed the research proposal and project and had complete ownership of their learning. One judge commented that it was “quite an honour, representing CSIRO” in the judging of students’ work. He was amazed at the quality of students’ work, particularly the high-end entries. The projects displayed “impressive scientific research, networking and collaboration and much out-of-hours work on the part of the students”. The finalists were chosen based on how they excelled above the rest. Some factors demonstrated in the students’ work included the impact of the science on society, their lateral thinking capacity and the use of “cutting edge” science.

All judges noted that students’ projects demonstrated creativity. One judge commented that “their report log books often indicated the progression from the initial vague ideas through to engagement, persistence, empowerment through knowledge, and then to them being experts in their field”. Again, all judges stated that the log books should, and do, mirror the detail of the project and often serve to clarify processes, networking and the support people.

For some students, report writing can be a challenge and the report can often highlight what level of additional support the individual student receives from others. From about Year 9 the
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report writing is significantly improved as students become more familiar with the format of reports.

Judges made the point that generally speaking, the students who make it through to the finalist awards are academically advanced with a passion for science. However one judge pointed out that this is not always the case:

Sometimes students who enjoy the ownership of a project, whether it is science or something else, will also outshine others.

The science camp for student finalists provides opportunity for them to know the judges, and other students. The atmosphere is very positive and allows students to talk about their projects and relate to others with similar interests. As one judge stated, “The students feel that they are being treated as special. They are able to relate to others who are interested in their science projects”. It is very affirming of their science. The process undertaken across the camp, coaching them in presenting their projects as well as ways of presenting the key information onto posters, also allows students to develop communication skills.

Judges of teacher awards.

Interviews were also conducted with those who formed the national judging panel for the BHP Billiton Teacher Awards. After selection from the state awards, teachers have to undertake a video-taped interview session with the panel. The panel asks a range of questions to develop deeper understandings of the teacher’s capabilities.

1. Can you briefly explain your contribution to open-ended investigations? Please give an indication as to how long you have been involved in these activities. How does this contribution express itself in terms of student learning outcomes?
2. How do you incorporate cutting edge science into your classes in ways that are stimulating for students, and relevant to their learning?
3. What do you think are the key factors in initiating then maintaining the motivation and energy of students in open ended investigations, particularly classes of students with different abilities? How do you stimulate students to engage in higher order thinking and work?
4. How do you encourage students to become more scientifically literate, and to be more globally aware and responsible?

About your leadership

5. How do you promote interest in science both inside and outside the classroom? As a leader, have you been able to advocate for science in a way that has resulted in positive change? (i.e. increased profile or resources)
6. How do you share your expertise and resources related to open ended investigations with other teachers, your school community, and your wider professional community, so as to enhance the quality and effectiveness of science education?

About you personally

7. What are the personal characteristics that help to make you an effective teacher? How do you measure your success?
8. Can you describe one thing in your teaching career that has brought you the most satisfaction?
9. In your view, what qualities, experience and skills do you have that would make you a good chaperone to take student to ISEF?
10. What benefits do you think you will gain from attending ISEF and how would you share these with others on your return?
11. Is there anything else you would like to tell the panel?

Judges commented that the initial process of selection was through the criteria that teachers responded to in their applications, however “...it is difficult to judge the quality of the applicants and their professional practice and knowledge just from the application”. Some of the judges had interactions with some of the teachers previously through the state awards or through CREST, although this wasn’t common. Normally, they relied heavily on the interview to help distinguish between the outstanding applicants. As one judge indicated, “The interview gives opportunities for the competencies to be fleshed out”. Sometimes it was possible to get a glimmer of teacher quality by the standard of the students’ projects, the variation in projects and in the nomination of the teacher by the school. Teachers who are nominated must have at least 50% classroom teaching. Once nominated, they cannot be re-nominated for a further three years.

How is the quality of the applicant measured? As one judge stated, “With great difficulty!”. The teachers undertake a one hour interview. As well as the interviews, teacher finalists have to present themselves and their work to the other teachers. The judges must all be in agreement about who they think is the overall winner. Up until now there has not been any disagreement within the judging panel about who is the best teacher finalist.

In considering the answers given at the interview, the panel look at a number of factors:

- The contribution of the teacher over an extended period of time – cumulative
- Involvement with the state science teacher association
- Involvement with curriculum development at local or national level
- Discussion and understanding of pedagogy – breadth and depth of knowledge
- Networking (provides a strong confirmation of practice)
- Providing PD/mentoring to others
- Encouragement of students to undertake open-ended investigations, use of ‘cutting-edge science topics’
- Activity in science in the community
- Linkage with universities/industry partnerships
- Relevance of science in real-world
- Ability to promote science as an Australian ambassador.

Most teachers selected by their state as finalists for the BHP Billiton wards will not only receive their state science teacher’s award, but they will be entered into other awards such as the Oliphant Award (SA) or the Prime Minister’s Science Teacher Award.

For the judges, evidence for change in teachers’ practice came from knowing teachers outside the Finalist awards but through the process of the awards scheme. Some of the judges had been involved in the science teacher associations, CREST or teacher professional development and had spent time with teachers in training them in understanding open-ended investigations. From this contact, they were able to indicate that they had seen considerable change in teachers’ practices. Most teachers involved in these professional learning opportunities went on to undertake the BHP Billiton awards scheme for their students and themselves.
Organisational issues

Several of those from the management group commented that whilst the Science Awards celebrated science, there was still much to do. Many science teachers felt unable to do open-ended investigations due to management issues. These may or may not be related to student behaviour. Rather they could be about how to actually manage 20 individual science projects. Sometimes the teacher needs support to take up the opportunity to introduce open-ended investigations.

One judge stated that all comments relating to the science awards needed to be qualified by the fact that she only saw the top level applicants. She wanted to ensure that the information she gave was interpreted in that light and that she couldn’t comment on the qualities of the many teachers who didn’t quite make it.

There was an unstated implication for broadening the award scheme. A number of the teacher award winners, some of the state organisers and also some teachers made explicit comment on the high standards and selective nature of the awards. There was not an explicit objection to this, and indeed these high standards and the profile that attracts many of the entrants figured prominently in the arguments put as to the effectiveness of the awards. However, the question of balancing this against a need to provide incentives for many to participate and recognition for a spectrum of entrants, was raised frequently. This would seem to be an argument for looking carefully at the balance of the award scheme and its STA and CREST feeder schemes.

A similar point was made with respect to the teacher awards. Several of the judges commented on the award not really being the motivating factor for the teachers. As one judge commented “most teachers measure their own success by the success of their students”. There was mention of the fact that to be considered, teachers needed to agree to be interviewed, to go to Melbourne, and to chaperone an international trip. This places restrictions on who can be a nominee. One state organiser questioned the concentration of funding into high profile events and a few recipients. Again, this needs to be balanced against an acknowledgement of the power of such events to galvanise publicity and enthusiasm.

Conclusions and Recommendations

Comment on sampling

Before presenting the conclusions and recommendations a comment should be made about the sampling for this study. In planning the study it was decided to focus on those who had an intimate knowledge of the state based and in-school activity leading up to the Awards and the Award processes themselves. The team did not seek the opinion of people critical of the awards form an ‘outside’ perspective. There are people who are sceptical about such activity for a number of reasons: those who are committed to a view of science education which means induction into the knowledge of the concepts and theories of science and see no importance in students experiencing how science works as a research enterprise; others who are suspicious of any involvement of corporations in the education of students; others who believe involvement in such activity places too great demands on teachers, and so on. The existence of people with such views is acknowledged but it was decided that they would not be of great assistance in finding answers to the questions posed for this particular study. In a sense, the appropriate response to such critique is to explore the effectiveness of the Awards.
in enhancing the science education of Australian students. This is what the study has attempted to do.

The sampling procedure was not without its difficulties due to a number of factors such as the timeline of the study and the time of the year at which the study was conducted. However, the study team found those contacted were pleased to participate. It needs to be noted also that those interviewed were not uncritical in their comments. They acknowledged the difficulties experienced in initiating and managing student science research projects and some presented alternative views on the Awards themselves. The sampling procedure was designed to allow triangulation as interviews were conducted with students, teachers, organisers, and judges.

On reflection, if time permitted it would have been of value to interview two other groups whose views are important in this area. One such group is the people from outside the schools such as the scientists who it has been shown contribute significantly to the success of the scheme at the grassroots level. The other is the school leadership group as they see the activity within the total life of the school.

**The awards as a network**

One cannot consider the impact of the BHP Billiton Student Awards separate from the extensive organisation and activity for which the Awards provide the ‘final step’. The study has revealed the significant impact of this whole enterprise on what happens in classrooms, homes, and communities across Australia so it is impossible to talk simply about the impact of the Awards without considering the whole. What has been revealed is a total scheme which has had a very significant positive impact, not just on students’ understanding of and commitment to the study of science and the pursuit of science based careers, but also on curriculum, teacher pedagogy, and linkages between schools, the families of the students, the scientific community, local and state and territory wide groups of science teachers, and local communities.

In framing the conclusions, and recommendations, it is important to keep this network of interconnections in mind. The recommendations will therefore deal with the teacher and the student awards as such, the relationship between the BHP Billiton awards and state awards, the support and development of teachers, the relationship of teachers and students to the scientific community, and the overall aims of the awards.

**The effectiveness of the awards**

There is clear evidence of the impact of both the student and teacher awards in inspiring and sustaining quality practice in science education in Australian schools. The student awards:

- Have appropriately rewarded students engaged in high quality scientific research work, through the judging and award process, the camp, and international experience;
- Have had both symbolic and practical effects in encouraging teachers and students to engage in substantial investigative project work;
- Have underpinned a substantial increase in the standards of student investigative work in schools, particularly in pockets of excellence where committed teachers have galvanised local activity;
- Have raised the standing of the state science teacher association awards by virtue of acting as a layer encouraging excellence in student science research work;
- Have encouraged, in schools involved in the awards, substantial partnerships between schools, teachers and students and the scientific community;
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- Have provided a means, through the partnership with CSIRO and the state science teacher associations, for the scientific community in Australia to recognise and celebrate the quality work being done by science teachers and students in schools;
- Have recognised and rewarded science-committed students engaged in scientific research work but also have opened up pathways to engage previously uncommitted students in independent scientific research work and in schooling more generally; and
- Have, on the balance of a substantive body of anecdotal evidence, increased the number of students engaged in science related courses and careers.

The teacher awards:

- Have recognised and rewarded committed and truly inspiring teachers of science; and
- through these teachers have contributed to improving the practice of science teaching and learning in Australian schools, and Australia’s profile and links internationally.

Recommendation 1

That BHP Billiton continues to support the BHP Billiton science awards through partnership arrangements with CSIRO and the Australian Science Teachers Association.

The Student Awards

A number of informants pointed out the very high standards of the awards and the high bar they represented for students. This high standard, together with the public and national nature of the awards, is a major strength and needs to be retained. However, a concern of both the awards and the teachers involved in them is the promotion of student investigative work in schools, and ways in which teachers and students can be supported to ‘get onto the page’ in this challenging area. This is the issue of high profile reward approaches versus grass roots encouragement, which BHP Billiton is no doubt already aware of.

The channelling of the awards through state award system works to addresses this issue since:

- Many students are recognised and rewarded through these awards beyond the BHP Billiton nominees;
- The existence of the CREST bronze awards was cited by a number to have provided a means of encouraging teachers and students to become involved in investigative work with its focus on group research and broad recognition;
- The existence of different categories of awards such as photography, modelling and creative writing allowed teachers and students an outlet to be involved in different ways of thinking about and communicating science that catered for a variety of student interests and strengths and was less demanding of teachers.

However, there were still some issues. Not all states have the same category structures with NSW for instance narrowing its focus to research projects. There was some concern about how to match the award structure to the different sizes of the states. There were comments on the timing and method of communication to nominees and winners.

Recommendation 2

That BHP Billiton discuss with CSIRO and ASTA how the nature of the STA and CREST and BHP Billiton awards can best be aligned to meet the twin demands of reward of excellence and grass roots support and encouragement of investigative work, and how the nature of the
different levels of award and their communication to students can be most effectively managed to strike the best balance between these competing demands.

The Teacher Awards

Each state Science Teachers Association can nominate an award for a teacher each year. One limitation is that the nominee must be willing to attend the Melbourne function and chaperone students on the trip if they win the national award, however, not all teachers nominated are evidently willing to make this commitment and so do not accept the nomination. The ASTA funding is dependent on the finalists agreeing to the commitment. A question was raised about the difficulty of the smaller territories providing competitive names each year in comparison to the larger states where there may be many teachers each year with a claim to recognition.

It may be advantageous for BHP Billiton to offer support for an additional level of teacher awards to increase recognition of the many teachers engaged in significant classroom innovation associated with the award schemes. These could be presented at the state association level as a way of acknowledging the efforts of individual teachers, and/or school teams, with award winners and multiple quality entries. This could potentially include quality work in categories other than research investigations. Similarly, certificates could be made to schools acknowledging a large number of entries by a school, recognising this as an expression of school priority. States with large populations could take advantage of such awards to offer additional recognition.

Recommendation 3

That BHP Billiton consider expanding the teacher award scheme to give recognition to a greater number of teachers at state level for their involvement with quality student work in the awards schemes.

Aims of the BHP Billiton Science Award Program

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<tr>
<th>Table 28: Proposed changes to the statement of aims of the BHP Billiton Awards</th>
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<tr>
<td><strong>Current statement of aim</strong></td>
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<tr>
<td>To improve student communication skills through preparation of reports, posters and dialogue with judges.</td>
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<tr>
<td>To increase the number of students continuing science at a senior level.</td>
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<tr>
<td>To improve the view that primary school students have of science.</td>
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<tr>
<td>To increase the number of students choosing to study science at tertiary level and/or take up careers in science and engineering.</td>
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In considering the aims of the BHP Billiton science award scheme in framing this evaluation study it became clear that some of the aims do not reflect the real work the awards are doing to encourage quality practice in science in schools. It is recommended that the aims of the Program be revised to reflect the findings of this study within broader consideration of what is known about effective science education. Table 28 sets out both the present and the proposed statements of aims.

**Recommendation 4**

*That a revised set of aims for the BHP Billiton Science Awards Program be adopted.*

### Additional opportunities and recommendations

In addition to recommendations specifically dealing with the operation of the awards, the experience of students, teachers, schools and state associations involved in science investigation work, described in this report, suggests some substantial possibilities for improving the teaching and learning of science more generally. In particular, there exists in these case studies and teacher accounts of science investigative work, the suggestion of directions for science education that would bring the experience of school students closer into alignment with contemporary practices of science. The study demonstrates the potential of investigative work to capture the challenges and excitement of working with science ideas in novel situations. This is of particular relevance issue currently, with the emphasis in the Australian Science Curriculum on inquiry and investigative work.

It is acknowledged that there are a number of parties who might see themselves as having a mandate, and the potential to contribute to building on the work described in this report. These include education systems (Government, Catholic, and Independent), CSIRO Education, the Australian Science Teachers Association, and state associations (STAs). It is not appropriate for the report authors to make pronouncements about how this responsibility might be shared or carried out. However, the report findings identify opportunities, with appropriate leadership, for building on current experience within the State STA and BHP Billiton awards to develop a more vibrant school science curriculum generally. The following recommendations focus on these opportunities.

### Curriculum

The report reveals that across the states and territories there are varying provisions and encouragements for teachers to include science research activity in the formal curriculum. Where there is explicit reference to investigative outcomes in the curriculum this has led to an
increased commitment of teachers and schools to this activity. Conversely, the existence of the award schemes has supported the introduction of such curriculum outcomes. There was concern expressed by a number of teachers that the Australian curriculum in science needs to support the possibility of this student science investigation activity that is in the best cases based strongly in local contexts. Science inquiry skills is one of the three strands of the Australian curriculum, as is ‘science as a human endeavour’, and contemporary science is a major focus. It would therefore seem as if the sort of work represented in this study should find a powerful place in the new curriculum. However, moves towards testing and uniformity may reduce the likelihood that open investigations are explicitly included.

Opportunity and recommendation 1

That action is taken to ensure that the national curriculum for science includes at least freedom, but hopefully also encouragement, for locally relevant science research projects to be part of the normal classroom program for all students during the compulsory years of schooling. The substance of this study provides a powerful set of arguments for so doing.

Teacher Professional Development

The study has shown that teachers of science can find the demands of open investigative work daunting, so that there is a need to find ways that can apply at a system wide level of supporting and encouraging teachers to commit to this sort of work. The study also identified that there is a lot of expertise locked up in the teachers who have been successfully engaged in this sort of activity for some time but often with little encouragement for the expertise to be shared. Within some states there have been steps to facilitate the sharing of this expertise through professional development programs, and some of the award teachers have been involved in PD activities. The study data suggest that a more sustained and widespread professional development approach involving the sharing of existing expertise would be welcomed. There is increased urgency to this call when it is recognised that there are many teachers taking science classes who are not formally qualified as science teachers and are teaching ‘out-of-field’. In considering such provision attention would need to be given to ensuring that all teachers, including those in remote areas and those teaching science out-of-field, will have access to such professional development.

Another potentially useful approach could be the development of a teachers’ resource kit which could include stories of past winners, both teachers, students and school stories, resources such as templates for writing up a scientific report, useful web-links, timelines that other schools use, advice on necessary paper work, deadlines etc. A number of the teachers interviewed had developed versions of such a kit. Such a resource kit could be used in conjunction with the professional development approach described above.

Another approach to developing grass roots support has been the instigation of local science fairs which encouraged networks of interested teachers and allowed for recognition of student work at a level below that required for the state or national awards, but which had the effect of starting activity down this track and exposing teachers and students to the standard of work that can be achieved. This seemed a particularly effective approach in rural areas.

Thus far, the BHP Billiton award scheme has approached the aim of encouraging uptake of inquiry pedagogies and student engagement through encouraging and profiling quality work. However, if the significant blocker to the growth of open investigations is the lack of confidence and experience of teachers, there exists the opportunity to make use of the expertise and resources that have now built up under the award schemes to develop a system level professional development initiative.
Opportunity and recommendation 2

That steps be taken to initiate and co-ordinate moves for a professional development approach and provision of resources to encourage and support teachers to become involved in open research investigative work. The development of such an approach might involve:

- A national conference / workshop where teachers with expertise in running investigative work, can share resources and ideas and develop a strategy for a national approach to professional development.

- The development, possibly in partnership with state STAs, of a professional development resource package for teachers of science to engage their students in investigative work.

- The development, again possibly in partnership with state STAs, of curriculum resources to support the structured introduction of science inquiry skills, based on the experience of teachers and schools involved in the award schemes.

- Support to organise local science fairs as feeder events into the state and national awards, as a strategy for setting up networks of teachers focused on science inquiry.

Science teaching as a career option

The study uncovered significant concern, particularly in rural Tasmania, about the lack of qualified science teachers able to effectively support student science investigative work. This included an increasing number of instances of science being taught by teachers ‘out of field’. This shortage of qualified science teachers, especially in rural areas, is of increasing concern in Australia. Given BHP Billiton’s aim to improve the teaching of inquiry science and investigative science as curriculum improvement approaches, it would make sense to explore how the award system could be adapted to support the attraction of more qualified scientists into teaching. Ian’s case study provides an interesting model of a talented science student seeing teaching as a worthwhile science career, and Ann’s and Stuart’s case study provides powerful illustrations of the rewards available to teachers who combine strong science knowledge and skills, pedagogical skills, and vision.

Current data suggest that little attention is paid to presenting teaching as one of the possible career options for students such as those who enter the competition and who like and are competent in science. Encouraging students to consider science teaching might be done through the device of representing outstanding science teachers at the BHP camp, having them speak at the awards, or shaping the running and promoting of the teacher awards to present science teaching as a challenging and rewarding career.

Opportunity and recommendation 3

That relevant bodies will explore ways to use the award scheme to encourage quality students and science graduates to consider science teaching as a career option, as an important contribution to raising the quality of science teaching in Australian schools.

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Contribution of people from outside the school systems to science education

One of the important findings of the study is the extent to which people from outside the school systems contribute to the success of the student science research projects in many schools. Whilst the teachers play the major role in mentoring the students they acknowledge that often the work that the students do moves beyond their expertise and that the students get a great deal of assistance from people outside the school. The range of expertise upon which the students draw is considerable and includes scientists, technicians, farmers, etc. The contribution of these people to the success of the program has become very evident to the researchers and it is proposed that ways should be found to formally recognise this contribution. Such recognition might include the presentation of a prize at the state award ceremonies or even through the local school council.

Opportunity and recommendation 4

*That some form of recognition be given to people from outside the school system who contribute so much to the learning of school students through their science research projects. This could be done as part of the state award systems.*
Appendices

Appendix A: Instruments used in the evaluation

Online survey questions

To be included …

Questions of teachers of award nominees

Participation: School/teacher factors
- Do you and/or your school have a history of encouraging students to enter science research competitions?
- Is participation in science research competitions seen as something for students with special interests and abilities or for a larger pool of students?
- Would you please describe your involvement with students who have entered science research competitions?
- What is the extent to which others on the school staff are or have been involved?

Participation: Student factors
- What motivates the students to enter science research competitions?
- What sort of students have enjoyed participating in these competitions? Is it always the same ones who enjoy science classes?

Impact on students’ understandings and attitudes
- What do you see as the outcomes for students in participating in science research competitions?
- What evidence is there that participation in science research competitions impacts on
  - students’ investigative skills?
  - students’ appreciation of the nature of science?
  - students’ communication skills?
  - students’ engagement with science?
  - students’ views of school science and science more generally?
- What aspects of the participation impact most significantly on students:
  - doing the research project itself,
  - reporting of the project,
  - participating in an across-schools competition,
  - achieving success in the competition,
  - participating in the BHP camp (where applicable),
  - or some other aspect of it?

Impact on curriculum and pedagogy
- Do the science research competitions relate to the school’s science curriculum? How?
- In what ways has involvement with student research competitions impacted on
  - your own or other teachers’ pedagogy and assessment practices more generally?
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- your own and other teachers’ attitude towards open ended science investigations?
- perceptions within schools concerning the value of such activities?

**Impact on science enrolments**

- What evidence is there that participation in science research competitions impacts on enrolment patterns in school science, students’ career intentions in relation to science, or numbers of students enrolling in science related tertiary courses?

**Awareness of Awards**

- What is the level of awareness of teachers and students of the BHP Billiton awards?

**Other**

- What else would you like to say about this topic?

**Teacher award winner questions**

**Nomination**

- You were nominated for this award by a colleague from the state association/CREST.
- Who nominated you for this award?
- Why were you nominated?
- What special things have you done to promote science education in your school, and the community and in science education?
- What drives you to do this work? What do you think are the benefits for students?
- As an award winner you would have had the opportunity to attend the BHP Billiton Science Awards Presentation Day in Melbourne. Did you attend this event?
- Can you describe the conference and the experience?
- What impact has it had on your teaching?
- What were the best aspects of this event? Any problems or suggestions for improvement?

**For National Winners Only (2007-9)**

- As part of your award you had the opportunity to attend an overseas ISEF conference Did you take this opportunity? Where did you go?
- Can you describe the conference and the experience?
- How has it impacted on your teaching?
- Has it changed your view of school science?
- How many students did you accompany?
- What were the best aspects of this event? Were there any issues for you? Any suggestions for improvement?

**Characteristics of the Teachers Award**

- What do you see as the best aspect of this award scheme?
- What do you see as problem aspect of this award scheme?
- **Impact of being an Award Winner**
- How has receiving a Teachers Award impacted on: your teaching? your career?
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- How has the Teachers Award been acknowledged or recognised by colleagues, school, profession?
- Are you still involved in the open-ended investigations at your school? How?
- What have you learnt from your experience as a recipient of the Teachers Award?
- Have you implemented changes to the way science is taught at your school as a result of your experiences associated with receiving the teacher award?

Colleagues and School
- How did your school and colleagues impact on your receiving the award?
- Do you and/or your school have a history of encouraging students to enter science research competitions?
- Would you please describe your involvement with students who have entered science research competitions?
- What is the extent to which others on the school staff are or have been involved?
- What motivates the students to enter science research competitions?
- What sort of children have enjoyed participating in these competitions? Is it always the same ones who enjoy science classes?

Impact on students’ understandings and attitudes
- What do you see as the outcomes for students in participating in science research competitions?
  - What evidence is there that participation in science research competitions impacts on students’ investigative skills and their appreciation of the nature of science?
  - What evidence is there that participation in science research competition impacts on the students’ communication skills?
  - What evidence is there that participation in science research competitions impacts on students’ engagement with science?
  - What evidence is there that participation in science research competitions impacts on students’ views of school science and science more generally?

Impact on curriculum and pedagogy
- Do the science research competitions relate to the school’s science curriculum? How?
- Has involvement with student research competitions impacted on your own or other teachers’ pedagogy and assessment practices more generally?
- Has involvement with science research competitions impacted on your and other teachers’ attitude towards open ended science investigations?
- Has involvement with science research competition initiatives impacted on perceptions within schools concerning the value of such activities?

Impact on enrolments
- What evidence is there that participation in science research competitions impacts on enrolment patterns in school science?
- What evidence is there that participation in science research competitions impacts on numbers of students enrolling in science related tertiary courses?
- What evidence is there that participation in science research competitions impacts on
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students’ career intentions in relation to science?

Awareness of Awards
- What is the level of awareness of teachers and students of the BHP Billiton awards?

Other
- What else would you like to say about this subject?

Interview questions for students

Year/s you entered the science research competition?

Year level when completing your project?

Were you a finalist?

<table>
<thead>
<tr>
<th>1. How you became involved:</th>
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<tr>
<td>1.1 How did you become involved in the BHP Billiton awards?</td>
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<tr>
<td>• Was it a school project?</td>
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<tr>
<td>• Did someone at the school encouraged you to enter the competition but not as part of school science?</td>
</tr>
<tr>
<td>1.2 Who encouraged you to do the investigation, and enter the competition</td>
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<tr>
<td>1.3 How many from your school entered? How many got prizes/became finalists?</td>
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<tr>
<td>1.4 How many times have you entered?</td>
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<table>
<thead>
<tr>
<th>2. Description of your investigation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Can you tell me about your experimental investigation?</td>
</tr>
<tr>
<td>2.2 What did you find out from doing your investigation?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Description of the experience: (investigation/competition)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 What methods of science did you use in your investigation- what about it was how you think scientists work?</td>
</tr>
<tr>
<td>3.2 Did anyone help you with your experimental investigation? How?</td>
</tr>
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<table>
<thead>
<tr>
<th>4. Evaluation of the experience: (investigation/competition)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Did you enjoy the experience of completing the investigation, taking part in the competition, and being an award winner</td>
</tr>
<tr>
<td>4.2 What did you learn about science from doing the investigation and being a finalist/award winner?</td>
</tr>
<tr>
<td>4.3 What did you learn most from?</td>
</tr>
<tr>
<td>4.4 To what extent has your involvement in the competition improved your confidence in talking about science with other people? (consider the report, presentations, meeting other people)</td>
</tr>
<tr>
<td>4.5 What did you find interesting:</td>
</tr>
<tr>
<td>• your investigation (question, methods, people, reporting (written/oral))</td>
</tr>
<tr>
<td>• researching individually or as part of the school (Did you enjoy researching by yourself, being part of the school group?)</td>
</tr>
<tr>
<td>• participating in this science competition (conducting the research, getting an award)</td>
</tr>
</tbody>
</table>
| • meeting people throughout the competition: scientists, other students from other
4.6 In what way does the science you experienced through the science research competition compare to the science you do in school?

5. Effect of the experience:
5.1 Will you choose some science subjects in Years 11 and 12? Which? Has your involvement in the BHP awards contributed to this choice?

5.2 What do want to do after you leave school? Has this been influenced by your experience of science through the Award scheme?

5.3 In what ways has the experience of being involved in the science research competition influenced your attitude towards science?
   • Do you think of science any differently because of it?
   • Would you feel the same about science if you had got an award/not got an award?

5.4 Would you enter the science research competition again? Any ideas about what you would do? Would you recommend to others to get involved in the scheme? What sort of students would you recommend this to?

Interview questions of Teacher Judges

1. Could you please describe your experience of being involved in the BHP Billiton award scheme?

2. How did the experience of acting as a judge impact on you personally or professionally?

3. Would you please describe your involvement with teachers nominated for the awards, who have students entered into the science research competitions?

4. What key things were you looking for in teachers when making your judgements?
   How did you measure the quality of the teacher applicants?
   • professional knowledge – supports and extends students
   • professional practice- effectiveness, innovation(cutting edge, student competencies)
   • professional attributes – collegiality, mentoring

Can you give representative examples of each of these

What weighting is attributed to each of the selection criteria on the teacher’s application?

5. Can you talk about the quality of the teacher practices you came across in judging the awards. Do you think the awards attract and reward genuinely high quality science teaching practices?

6. From your discussions with or knowledge otherwise of the teachers, what is your sense of what impact the Science Competition has had on them professionally – relating to a change?(9)
   • pedagogy and assessment practices
   • attitude towards open ended science investigations
   • perceptions within schools concerning the value of such activities?
   • self esteem or encouragement to pursue these types of activities

7. Can you describe this further, possibly giving examples of how the awards have acted as a stimulus to the teaching of science open ended investigations or inquiry based pedagogies more generally?
Interview questions of Student Judges

1. Could you please describe your experience of being involved in the BHP Billiton award scheme- what has been your involvement with students who have entered into the science research competitions?

2. In judging the entries or discussing the projects with students, can you gain a sense of how the participation in the Science competition has impacted on them? Can you provide any examples that might illustrate or provide insight into:
   - The quality of the science that students display in these projects
   - The level of innovation or creativity or science investigative skills that are displayed
   - Improvement in science skills or understanding that may have been a result of the awards
   - Improvement/confidence in communicating science ideas
   - Student understanding of the nature of science
   - Student engagement with science,
   - Attitudes to science,
   - Effects on their aspirations to continue with science, or more generally on enrolment patterns (secondary or tertiary science)??
   - The types of students that are involved in these awards – are they science enthusiasts? Are they necessarily strong students academically (Not sure how they could make this judgment)? Was it evident they got a lot of support from school or from home?

3. When talking with students, do they mention whether this type of science is unusual in their school, or if it has caused any changes to their teachers’ practices?
   - Pedagogy and assessment practices
   - Attitude towards open ended science investigations

4. When talking with students, do they mention perceptions within schools concerning the value of science competitions?

5. Are the students aware of the nature (size, importance) of the BHP Billiton Science Awards?

6. Do the students mention other aspects of the science competition not mentioned already? (eg prizes, esteem, international aspects)?
### Appendix B: Students’ descriptions of their STA/CREST award investigations

<table>
<thead>
<tr>
<th>Earth science</th>
<th>I investigated fossil records in the ACT to try and find a variety of fossils and what the ACT was like. I found out that some millions of years ago, the ACT was an underwater sea where trilobites and brachiopods lived.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>It was an investigation in to the pH of soil from various locales. We expected to find a relationship between vegetation density and the neutrality of the soil but this was not always the case.</td>
</tr>
<tr>
<td>Fossil density</td>
<td></td>
</tr>
<tr>
<td>Environment and renewable energies</td>
<td>I conducted an investigation into the effectiveness of water storing crystals and soil wetting agents. I found that the use of water storing crystals reduced the amount of water required by plants by up to 80% when used in conjunction with a water moisture meter to check that plants are truly dry.</td>
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<td></td>
<td>I wanted to investigate the effects of industrialisation on Currumbin Creek. The Creek originates at the top of the mountain and gradually passes through more industrialised locations. My results confirmed that increased industrialisation correlates with increased pollution, as confirmed by several scientific tests.</td>
</tr>
<tr>
<td></td>
<td>Which one? Several were investigating pollution in creeks, found there was pollution. One was investigating the chemicals in cigarette butts and how fast they are ‘leeched’ to the environment, I found that they contained some fairly nasty chemicals, which were lost fairly quickly.</td>
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<tr>
<td></td>
<td>We wanted to see if we could improve the amount of power from a solar cell by tracking the sun. We found that it increased the power output by 43%.</td>
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<tr>
<td></td>
<td>I was testing which mulch absorbed the most liquid. I expected the thick mulch but I was wrong.</td>
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<tr>
<td></td>
<td>Does tracking the sun with a solar cell give more energy than staying still? We found a 43% improvement</td>
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<td></td>
<td>how different conditions such as salinity and temperature affected sedimentation and colloids in water</td>
</tr>
<tr>
<td></td>
<td>My investigation was based on eutrophication, namely how the water plant duckweed absorbed varying levels of nitrate. I found that duckweed could be used to remove nitrates from waterways, which is essential to waterway health.</td>
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<td></td>
<td>I researched whether or not willows affected the quality of water in rivers. I found that they did slightly as they slowed the flow of the water.</td>
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<td></td>
<td>Was there enough renewable energy in my local area to power my house, yes if i had a big enough system but costs of purchasing system were prohibitive</td>
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<td></td>
<td>I wanted to find out whether the maximum temperature weather forecasts of the BOM (Bureau of Meteorology) for the Australian Capital Cities were accurate over a yearly period. I found out that their predictions were within 3 degrees of the actual temperature 93% of the time, and were perfectly predicted (0 degree error) 27% of the time.</td>
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<tr>
<td>Biological science</td>
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<td>-------------------</td>
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<td>Our investigation was on how our actions speed the normally natural process of Global Warming and how that, in turn, affects The Great Barrier Reef and the environment as a whole. During our investigation, we increased our knowledge of the process or coral reef bleaching (etc.) and we also learnt new and interesting pieces of information as well. We also found out ways to help save the environment and, most importantly for our investigation, The Great Barrier Reef.</td>
<td></td>
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<tr>
<td>We investigated the heating and cooling rates of the Greenhouse Gases, CO2, Methane and Nitrous Oxide. We did find that over only a period of 30 mins that CO2 did not cool down as fast as our control, Air.</td>
<td></td>
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<tr>
<td>to observe different feeding patterns of parrots and if they had different diets, i.e. niche segregation</td>
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<tr>
<td>I wanted to find the resting and exercising blood pressures of women in all ages and the difference between the two. I found out exercising blood pressure is always higher then resting.</td>
<td></td>
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<tr>
<td>I wanted to determine if basil and/or mint essential oils were an effective larvicide of Ochlerotatus notoscriptus, a common Gold Coast mosquito. The results of my investigation were inconclusive, however, it is recommended further experimentation be undertaken under more controlled conditions.</td>
<td></td>
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<tr>
<td>I wanted to test the theory of the power of the pyramids and whether they kept food preserved</td>
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<tr>
<td>1) Genetic background and inheritance of hand dominance (left/right handedness) and its links to laterality, to determine any trends (e.g. gross motor, fine motor skills) in left handed and right handed people, esp. in coordinating their opposite hand. - Blood Type and Personality, to determine any links between different blood types and personality types and traits. As a result, there was a distinct relationship between certain blood types and individual traits.</td>
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<tr>
<td>We wanted to investigate the effects different foods have on a type 2 diabetic compared to a non diabetic. We discovered sweeter and fattening foods have the biggest impact on diabetics.</td>
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<tr>
<td>I wanted to find out the effectiveness of salt as a preservative, but not just on meat products. I tested with meat, bread, cheese, oranges and potatoes. I found that salt effectively preserves meat, cheese, potato, oranges and bread. All food items were edible after 1 and a half months of preservation.</td>
<td></td>
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<tr>
<td>i wanted to find out how soft drinks affected tooth enamel and why some were worse than others.</td>
<td></td>
</tr>
<tr>
<td>finding out :if mosquitoes were attracted to the scent of banana. found out: indecisive, experimental method needs to be improved</td>
<td></td>
</tr>
<tr>
<td>Effect of caffeine on the performance of swimmers. I believed that it would have a positive effect on the individual swimmers. However, I discovered that the caffeine had a positive effect on some athletes and a negative effect on others. When it had a negative effect, it caused the swimmers to lose the efficiency in their stroke. I needed more trials, (the number of trials and try some programs in different strokes), and subjects to be able to investigate further.</td>
<td></td>
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<tr>
<td>I wanted to find out if the colour of bird seed affected how much of the bird</td>
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</table>
seed was eaten.

We were studying if meditation and yoga help your concentration, which it did to most of the students apart from 1 or 2 in a class of 20.

In 2009 the project was on the truth about school bags because peers at school were giving me a hard time when I used a trolley bag instead of a backpack.

Our investigation was called 'Bubble Busters', and in this investigation we searched to find whether bubble gum really does take 7 years to digest through our bodies. This myth is not true.

We did an investigation if kids remembered better from manga (Japanese comics) or just reading plain texts. We found out that there was no difference from being able to remember any of the information that was given.

does red bull really give you wings? We discovered in the short term it does boost alertness, but then a low occurs.

we looked at whether the drink red bull lived up to the claim that it is an energy drink and can 'give you wings'

The link between the consumption of different dosages of coffee and the short-term memory ability of the individual

The aim of our investigation was to find out how long marine invertebrates could survive in a bucket of sea water, before the dissolved oxygen ran out. From this we then formulated an equation which could determine how long certain marine invertebrates could survive in a certain amount of water at a certain temperature. This equation was made for 5-6 such animals.

The growth difference between soil and hydroponic grown plants. We found out that Hydroponics grew faster

2004 - I looked at orchids growing on a 6 acre block of land and I investigated and correlated which environmental aspects benefitted or inhibited orchid growth/health. 2006 - I grew different microbes in agar plates and investigated the efficacy of radiata pine sap as both an antibacterial and an antifungal and compared the effects to current products on the market

Experimental Research into which leaf from different plants would be more suitable for biomass

Physics

I wanted to find out the efficiency of a solar panel system for the home. I found that in order to draw as much power as is currently needed, the system needed is vast and cost prohibitive.

Jugs- which ones best for pouring?

Friction on various surfaces

To find out the magnitude of lift on different types of airfoils

My partner and I built and calibrated a device that measured the colour of different surfaces. This device specifically measured the difference in luminance between two surface. This has a huge application to the building industry where the standards specifies a certain amount of luminance difference between two surfaces to allow people with vision impairments to navigate around buildings with a degree of safety.

My experiment was to judge the tensile strength of various fabrics including
<table>
<thead>
<tr>
<th>Chemistry</th>
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<tr>
<td>denim, cotton, wool, poly-fleece etc. My results were to be expected, denim came an outstanding first with cotton a distant second.</td>
</tr>
<tr>
<td>We looked at the motion of the swing, and changing the centre of gravity and how it effects the motion. We found that the centre of mass had a big impact.</td>
</tr>
<tr>
<td>We wanted to find out what colour water evaporated fastest and slowest out of red, blue, yellow and clear. Blue evaporated fastest and clear evaporated slowest.</td>
</tr>
<tr>
<td>My investigation was, does the mass of an arrow affect its trajectory and penetration ability? The results were that the mass of the arrows did affect the trajectory. The mass also affected the penetration ability but the composition of the arrows also had a large affect.</td>
</tr>
<tr>
<td>What temperature water is it best to make tea with. I found out that the hotter you make the water the more strong your tea will be. So it all comes to whether you like tea strong/hot or not/warm.</td>
</tr>
<tr>
<td>We were investigating if mp3 players can cause noise induced hearing loss. We found that they have the capacity to and that through a survey a proportion of the population was at risk.</td>
</tr>
<tr>
<td>I completed two different EEIs. One was a physics investigation looking at the resonance of rosalu piano wires to develop an understanding of how a piano goes out of tune. The other investigation was into the effects of caffeine on the human heart using daphnia, where it was found that certain levels of caffeine can cause cardiac arrest.</td>
</tr>
<tr>
<td>If the colour of sparklers can be changed and no</td>
</tr>
<tr>
<td>The investigation was to find which cleaning agent was most affective. We investigated this by growing mould.</td>
</tr>
<tr>
<td>1. Whether I could make effective coloured sparklers (fireworks); I was able to make crude sparklers which had sparked well and gave off colour. 2. Make good chemical cold-packs; yes, good at becoming cold but could not maintain cold.</td>
</tr>
<tr>
<td>I wanted to find out whether musicians can hear higher frequencies than non musicians. My results proved that musicians can hear higher frequencies and those who listen to loud music have worse hearing than those who don't</td>
</tr>
<tr>
<td>Boyle's law: Investigation that pressure x volume = constant(t) Implosion: we conducted an experiment enabling a tin can to implode, by use of vacuum.</td>
</tr>
<tr>
<td>I wanted to find out how fast different woods would burn. I found that the more dense woods took longer to burn than the less dense ones.</td>
</tr>
<tr>
<td>Factors affecting the rate of rusting on iron nails. I found that salt water does significant damage to nails, particularly nails on roofs.</td>
</tr>
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