Evaluation of the Science and Technology Education Leveraging Relevance (STELR) Proof-of-Concept Program

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Contents

Executive Summary ...................................................................................................................... 3
The participating schools ............................................................................................................ 3
Adoption of STELR program by participating schools ............................................................ 4
Increasing students’ engagement with science in STELR program ........................................ 4
Future study and careers in science and engineering ............................................................. 5
Teachers’ perceived benefits of Inquiry-Based Learning (IBL) in the STELR program .......... 5
Professional Learning .............................................................................................................. 5
Conclusions and recommendations ......................................................................................... 6
Recommendations .................................................................................................................... 7
Background ................................................................................................................................ 9
A declining interest in science ................................................................................................. 9
The STELR initiative ............................................................................................................... 9
Research approach .................................................................................................................. 10
Themes under investigation ..................................................................................................... 10
Methods of data collection ...................................................................................................... 11
Findings ...................................................................................................................................... 11
Students’ perceptions about the relevance of science ............................................................... 11
Changes in learning activities ................................................................................................. 13
Perceived differences in teaching approaches compared to other science topics ............... 17
Student learning in the STELR project ................................................................................ 17
Learning preferences .............................................................................................................. 21
Student engagement with the different stages of the STELR project .................................. 22
Preference for practical work in general ............................................................................... 22
Preference for practical work as part of the in-depth investigations .................................... 22
Preference for practical work as part of the samplers ........................................................... 22
Preference for the Challenge ................................................................................................. 23
Perceptions of STELR group work activities ........................................................................ 23
Use of STELR website and rooftop systems .......................................................................... 24
Future study and careers in science and engineering .......................................................... 24
Student concerns with aspects of the STELR project ........................................................... 26
Overall perception of the STELR project ................................................................. 27
Teachers’ understandings about Inquiry-Based Learning (IBL) ................................ 29
Limitations of Inquiry-Based Learning approach ............................................... 31
Teachers’ perceived benefits of IBL in the STELR program .............................. 32
Level of student engagement ........................................................................... 33
Use of the STELR curriculum resources ......................................................... 34
Renewable energy laboratory equipment ......................................................... 34
Roof-top installed renewable energy systems .................................................. 35
The STELR website .......................................................................................... 36
Curriculum document detailing a suggested teaching sequence ..................... 37
Supplementary STELR Resources .................................................................... 39
The challenge and open-ended learning .......................................................... 39
Professional Learning ....................................................................................... 40
Appendix 1 ........................................................................................................ 43
Principles of an Inquiry-Based Learning Program ............................................ 43
   Engagement of Students .............................................................................. 43
   Exploration ................................................................................................. 43
   Explanation ............................................................................................... 44
   Elaboration ............................................................................................... 44
   Assessment ............................................................................................... 44
References ....................................................................................................... 46
Executive Summary

The Science and Technology Education Leveraging Relevance (STELR) program is an initiative of the Australian Academy of Technological Sciences and Engineering (ATSE) and was designed in response to secondary school students’ declining interest and engagement in science. The STELR proof-of-concept program was developed to demonstrate the feasibility of improving students’ engagement and interest in science by providing schools with carefully-planned curriculum units and ‘hands-on’ learning resources which are aligned closely with technology that has a high degree of relevance to the lives of students and teachers. It was intended that this approach to teaching science would stimulate the interest of students and teachers in the enabling disciplines of science and mathematics.

The STELR proof-of-concept program was introduced into four Victorian secondary schools involving ten teachers and thirteen classes of Year 9 and 10 students. The program provided teachers with written curriculum materials supporting the theme of renewable energies and which encouraged an inquiry-based approach to learning. Additionally, the program included: professional development for teachers; class kits to support ‘hands-on’ experiments in the renewable energy themes of solar, wind and biofuels; the installation of rooftop renewable energy systems; and the development of a STELR website allowing access to technical information, ideas and data sharing between teachers and students and career information.

The six week teaching sequence outlined in the written curriculum materials involved a series of stages, beginning with introductory activities about energy and renewable energies. This was followed by a series of sample investigations encouraging students to become familiar with the renewable energies of wind, solar and biofuels. The third stage involved students undertaking in-depth investigations for one of the renewable energies from the previous stage. The final stage required students to participate in a group problem-solving task, called the Challenge, where students were given a specific real-life problem to solve.

The evaluation of the STELR proof-of-concept program aimed to investigate its feasibility as a strategy for: improving students’ interest and engagement in science; supporting teachers’ professional learning; establishing and maintaining professional networks; supporting inquiry-based learning with curriculum materials and resources; and improving students’ knowledge of careers and pathways in science. The process of evaluation involved: questionnaires completed by students and teachers, interviews with teachers, focus group discussions with students, professional review meetings with teachers, student work samples and observations of classroom activities.

The participating schools

There were four Victorian secondary schools that delivered the STELR proof-of-concept program in 2008. The first school was a government coeducational school located in the Geelong region. This school delivered the STELR program to three Year 10 classes and involved three classroom teachers. The second school was also a government coeducational school but located in metropolitan Melbourne. This school delivered the STELR program to five Year 10 classes and involved four classroom teachers. The third and fourth schools were also located in metropolitan Melbourne. The third school was an independent boys’ school that delivered the STELR program to two Year 9
classes with two classroom teachers. The fourth school was a Catholic coeducational school that delivered the STELR program to three Year 9 classes and involved two classroom teachers.

**Adoption of STELR program by participating schools**

Overall, the STELR program was embraced enthusiastically by both students and teachers participating in the proof-of-concept stage. In particular, teachers reported a deep appreciation for access to the ‘hands-on’ class kits and the curriculum materials that supported them. It was also noted that the renewable energy themes underpinning the STELR program were generally well supported by technology provided in the class kits, and encouraged engaging and highly relevant discussions with students during science classes.

While the STELR curriculum units and class kits were common to all of the participant schools, the program appeared to accommodate teachers’ need for flexibility in its implementation to best match the needs of individual students and their existing science programs. This flexibility was important as each of the schools participating in the proof-of-concept stage of the program had different timetable regimes and curriculum requirements. Some teachers were able to enhance and contextualise their implementation of STELR program further by including additional school resources, University mentors, guest speakers and curriculum materials they had prepared.

The STELR proof-of-concept program also planned for schools to use the rooftop renewable energy systems and STELR website within their teaching sequences. However, the evaluators were unable to make a full assessment of the impact of these as there were some delays with the installation of the rooftop renewable energy systems and technical problems with schools gaining access to the STELR website. It can be reported, however, that teachers expected these resources would have significant potential to enhance the delivery of the STELR program in the future.

**Increasing students’ engagement with science in STELR program**

It is the view of the evaluators that the STELR proof-of-concept program delivered in all of the four participant schools demonstrated a clear capacity to increase students’ participation and engagement in science classes. The online questionnaire data demonstrated an obvious strengthening of the perception that science was relevant to the students’ lives after their involvement in the STELR program. There were also similar shifts in the students’ perceptions about the usefulness of the science they learn at school. Evidence of an increased engagement in learning science was reflected in the students’ focus group discussions. The increased engagement in students’ participation was also reported consistently by the teachers, with several noting a connection between the increased relevance of the topics they were studying in the STELR program.

Much of the improvement in engagement and interest in science was attributed to the increased relevance of the renewable energy topics being covered in STELR and the increased amount of ‘hands-on’ learning the students were now participating in as part of the program. When the students were asked about differences in the way they were learning about science in the STELR program, a number of trends were observed in students’ responses to the surveys and focus groups:

- A shift away from the predominant use of text books to learn science.
- A marked increase in the number of experiments and ‘hand-on’ investigations.
- An increase in purposeful tasks involving students solving real world problems.
- An increase in the use of Information and Communication Technology to learn science.
• More scope and freedom for students to have a say in what they investigate in science and a new focus on answering students’ questions emerging from their inquiry.
• More productive class discussions and group work in STELR and less reliance on didactic methods of teacher-delivered theory.
• The teacher was seen by students as a co-investigator who participated in the inquiry with students and sometimes discovered new knowledge that even they didn’t know.

**Future study and careers in science and engineering**
While not all classes in the project undertook explicit activities involving different careers in science and engineering as part of the STELR program, the surveys and focus groups indicated there did generally appear to be an increase in students’ awareness of science careers beyond school. Trends in the survey data also indicated a positive shift in some students’ interest in studying a career that requires further study of science past Year 10.

**Teachers’ perceived benefits of Inquiry-Based Learning (IBL) in the STELR program**
The STELR curriculum document outlined the Inquiry-based Learning Principles [reproduced in Appendix 1] and the evaluators noted that, although there was some variation in adopting this approach, teachers generally placed a substantial emphasis on the need for students to investigate a topic by asking questions and undertaking research activities.

Overall, the teachers believed there were significant benefits arising from the inquiry-based approach in the STELR program. Some of these benefits included:

• A definite increase in the level of students’ engagement with the material; this included more class discussion and willingness of students to contribute to discussions as well as increased engagement in undertaking the practical activities;
• Generally fewer discipline issues with students;
• More opportunities to connect what they were learning with current issues in the media and students’ lives;
• An opportunity to undertake inquiry based learning on a much larger scale than teachers’ resources and time would otherwise allow;
• Broadening teachers’ understanding about the applications of science;
• The STELR program provides an excellent context to apply the Victorian Essential Learning Standards (VELS) in terms of links to the two Science dimensions of ‘Science knowledge and understanding’ and ‘Science at work’, as well as the Interdisciplinary Learning domains of ‘Thinking’, ‘ICT’ and ‘Thinking Processes’.
• The opportunity to work as a team of science teachers; and
• Providing students with insights into how science works in the real world.

**Professional Learning**
Most teachers who participated in the proof-of-concept stage of the STELR program reported they had attended the professional development day designed to provide ‘hands-on’ experience with the STELR equipment and an opportunity to network with other teachers delivering the program. This aspect of the program proved very popular with the teachers who generally noted they found the professional development very rewarding. They also commented that at least one additional day would enhance their professional learning further.
Teachers from all schools reported they had adopted a school team approach to support each other in delivering the STELR program. However, communication between teachers across different schools during their teaching sequences was limited to occasional emails and teachers from two schools who met during a holiday period. It was noted by the teachers that the STELR website would eventually facilitate improved communication between STELR schools.

**Conclusions and recommendations**
The STELR proof-of-concept program was developed to test the feasibility of improving students’ engagement and interest in science by providing schools with carefully-planned inquiry-based curriculum units and ‘hands-on’ learning resources which are aligned closely with technology that has a high degree of relevance to the lives of students and teachers. Feedback collected from students and teachers who participated in the proof-of-concept program throughout 2008 suggests that the unique combination and delivery of these principles provided by the STELR program has had a very positive effect on students’ participation and engagement in science.

The overall successes of the STELR proof-of-concept program were considerable and included:

- The very positive perceptions of the STELR program by the participating teachers and their students;
- An overall positive effect on the students’ participation and engagement in learning science in secondary school;
- An overall positive effect on the students’ perspectives about the relevance of science to their lives;
- An overall positive effect on the students’ confidence about their knowledge of science.
- Students and teachers reporting that there were fewer disruptions in science classes because of the students’ increased levels of participation;
- The flexible nature of the STELR program was such that it allowed teachers to adopt, modify or add to the suggested curricula and pedagogy to best meet the needs of the teachers and their students;
- The STELR program was seen as a success by the participating teachers and their students despite the limited use of the rooftop renewable energy systems and STELR website at this stage.

As a proof-of-concept program the STELR initiative delivered to the four participant schools also provided a basis for constructive feedback to inform the development of a more substantial pilot stage of the program. This feedback has been summarised below:

- The variation in teachers’ understanding and implementation of inquiry-based learning may limit the full potential of the STELR program;
- Some teachers raised concerns about the durability and safety of specific equipment to support experiments in the renewable energy themes of solar, wind and biofuels;
• Although there was generally an expectation by teachers that the rooftop renewable energy systems would enhance the STELR program, some teachers requested clear advice to be included in the STELR curriculum documents as to how their use might be incorporated into the STELR teaching sequence;

• Most teachers expected the STELR website would significantly enhance the program and their students’ learning; however the site was still being constructed even though schools had begun their teaching sequence.

• The opportunities for collaboration by teachers and students from different STELR schools were limited during the teaching periods. Several teacher felt the need for more professional development.

• The emphasis as to what students should learn by undertaking the STELR program varied across the schools.

**Recommendations**

The STELR proof-of-concept initiative was designed to test the feasibility of the program as a strategy to improve students’ interest and engagement in science. To this effect the evaluators consider that this objective has been demonstrated in principle, as is reflected in the data collected throughout the delivery of the program. The evaluators consider that the proof-of-concept program has established strong foundations for development of a more detailed pilot stage of the program and the following recommendations are offered as feedback for that purpose:

Recommendation 1: The benefits of the STELR program could be further enhanced with additional professional development for teachers aimed at building their capacity to use inquiry-based learning, particularly within the STELR curriculum resources. As a part of this professional development the evaluators recommend achieving greater clarity and consistency in the emphasis placed on fundamental energy concepts supporting the STELR project. It would be fruitful to develop formative and summative assessment resources that target students’ knowledge of significant energy concepts and are consistent with the inquiry-based framework of the STELR initiative. These are issues that would ideally be addressed as a part of a pilot stage implementation of the STELR program.

Recommendation 2: The STELR project provides opportunities for teachers to modify stages to suit their particular needs. Therefore, all stages, the introductory activities, samplers, in-depth investigations and the challenge, need to be incorporated into any final curriculum document.

Recommendation 3: The STELR laboratory equipment supplied to schools should be further examined for the need to be modified to alleviate safety and durability concerns. Alternatively, notes may be provided for laboratory technicians and teachers on various modifications possible, including the best ways for students to use the equipment. In addition, any in-person professional development sessions needs to provide sufficient time for teachers to work with the equipment.

Recommendation 4: The full potential of the STELR roof-top renewable energy systems has yet to be realised. There needs to be more planning put into generating ideas and activities to use this equipment within schools and across schools. Given the cost of installing this equipment, further thought needs to be given to how these devices might be used in science at other year levels as well.
as other discipline areas. There is great potential for using the roof-top energy systems to engage students in renewable energy and climate topics.

Recommendation 5: Given that some of the STELR proof-of-concept schools still have classes to undertake the program there is opportunity to trial the roof-top equipment with these classes.

Recommendation 6: The possible uses of the STELR website by teachers and students have yet to be fully realised – there is great potential here. There needs to be more planning to be put into generating profitable ways in which the website may be used. The uses of the website need to be embedded into the STELR curriculum document and student activities.

Recommendation 7: The revised STELR curriculum document could include material, and ideas, generated by the STELR proof-of-concept teachers. The revised curriculum document does not need to be included into the one document as there could be more than one document, for example, a student and teacher edition. In addition, curriculum advice could also be located on the STELR website.

Recommendation 8: The program would benefit greatly from exploring ways to connect teachers from different schools following any in-person professional development program. Any professional development program needs to include at least two days of in-person workshops where the teachers gain an understanding of how inquiry-based learning approaches can be applied to the STELR curriculum and gain some ‘hands-on’ experience in working with the STELR equipment. The two days of workshops might be separated by several weeks during which time the teachers might trial some of the STELR activities. At the second workshop teachers would share their experiences with other teachers.


**Background**

**A declining interest in science**

There is currently a considerable amount of national and international concern for low levels of student engagement in school science (Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008) and diminishing numbers of students electing to study physics, chemistry and higher levels of mathematics in their senior years of schooling (Victorian Parliament Education and Training Committee, 2006). The concern extends to declining numbers of post-secondary students undertaking tertiary level courses in science-related professions, such as engineering, at a time when Australia faces skill shortages in many of these professions (Department of Education Science and Training, 2006). Increasing Australian students’ participation in science, technology and mathematics education programs at all levels has therefore become a national priority if Australia is to maintain its growth and prosperity as a nation.

Research into the declining interest in science has pointed to ‘evidence of students developing increasingly negative attitudes’ (Tytler, 2007 p.7) towards science throughout their secondary years of schooling. It has been argued that the use of overly transmissive approaches to teaching science in our schools, and excessively abstract content which has limited relevance to the immediate lives of students, have been significant factors contributing to students’ negative attitudes towards science (Lyons, 2006; Masters, 2006). Strategies to address declining participation in science have therefore focused on the need to:

‘promote more varied pedagogies that challenge, support and interest students, as well as engage them with authentic and contemporary issues and problem solving in [Science, Mathematics and Technology Education] STEM, that strengthen the intellectual rigor of STEM learning and interest students in STEM content.

(Tytler et al., 2008 p. ix)

**The STELR initiative**

Within this context the Science and Technology Education Leveraging Relevance (STELR) initiative has been developed by the Australian Academy of Technological Sciences and Engineering (ATSE) as a means to address the decline in students’ interest and engagement in secondary school science. The initiative is based on two key assumptions that have been outlined in the STELR proof-of-concept program (Australian Academy of Technological Sciences and Engineering, 2008):

1. Participation rates in secondary schools enabling science and mathematics subjects are declining, leading to a shortage of scientists and engineers in the workplace, and an inadequate level of science literacy in the community.
2. Of the very many reasons for this decline, one that can be addressed by a focused efforts in the classroom is the lack of relevance perceived by many secondary school students

The initiative has adopted a strategy of developing and providing schools with carefully-planned curriculum units and resources that are based on *inquiry-based learning* and which are aligned closely with *technology* that has a *high degree of relevance* to the lives of students and teachers.
In supporting the use of an inquiry-based approach to learning (Appendix 1) the STELR program draws on pedagogical strategies that seek to go beyond the transmissive learning of abstract facts about science. The program seeks to encourage students to *ask their own inquiring questions* about a scientific phenomenon that has both meaning and purpose to them. The STELR program is therefore based on a classroom context where both students and teachers develop an understanding of and capacity to use inquiry-based learning as an effective strategy in the learning of science-related knowledge, skills and attitudes.

To provide an engaging context for the inquiry-based approach, the STELR program has been aligned with technologies that are understood to be highly relevant and meaningful to students, teachers and the wider community. This proof-of-concept program has been based on *renewable energy* which was selected by ATSE because it would:

1. be perceived by students and teachers as extremely relevant to their living circumstances today and in the future;
2. be perceived by students as potentially linked to their job prospects; and
3. provide a platform upon which formal studies in enabling scientific disciplines and science-based professions can be based.

*(Australian Academy of Technological Sciences and Engineering, 2008)*

The proof-of-concept program was implemented in 2008 with Year 9 and 10 science classes in four Victorian schools who were provided with the following aspects of STELR:

- Curriculum materials supporting the theme of renewable energy (solar, wind and bio-fuels).
- Professional development for teachers designed to support them in the use of the STELR technology and inquiry-based learning.
- Class kits to support experiments in the renewable energy themes of solar, wind and biofuels.
- Technology to support the conduct of renewable energy experiments, including: wind turbines, solar panels, a weather station, data collection equipment and data upload to the ATSE server.
- Website allowing access to: technical information, ideas and data sharing between teachers and students from different schools, careers information.

**Research approach**

**Themes under investigation**

This research investigated the following aspects of the STELR proof-of-concept program:

1. Potential for improving students’ interest, engagement and achievements in science through their participation in the STELR program.
2. Potential for supporting teachers’ professional learning, particularly their knowledge and use of inquiry-based learning and the relevant technologies included in the STELR program.
3. Potential for establishing and maintaining teachers’ professional networks and learning communities that will add capacity to their knowledge and skills.
4. Potential for the curriculum materials and resources to provide effective support for inquiry-based learning for both the students and teachers.
5. Potential for improving students’ knowledge of careers and pathways in science

Methods of data collection
Data collection to provide evidence of the impact of the STELR proof-of-concept program within the above mentioned themes included the following:

1. A total of 147 Year 9 and 10 students from the four participant schools completed online surveys before their participation in the program and then again at the conclusion of the program. The surveys were designed to investigate changes in the students’:
   a. interest in science
   b. engagement in learning science
   c. perceptions about learning science
   d. knowledge of science-related careers
2. Focus group discussions with students during their participation in the STELR program.
3. Interviews and focus group discussions with teachers during their implementation of the STELR program in schools and during their participation in professional development activities.
4. Analysis of students’ work samples and observation of STELR activities in action.

Findings

Students’ perceptions about the relevance of science
There was a noticeable shift in the students’ thoughts about the relevance of science to their everyday lives coinciding with their participation in the STELR program. This shift is captured in Table 1.1 below, and demonstrates an obvious strengthening of the perception that science was relevant to their lives after their involvement in the STELR program.

<table>
<thead>
<tr>
<th>How much do students agree with the following statement?</th>
</tr>
</thead>
<tbody>
<tr>
<td>'I think science is relevant to my everyday life'</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage (N=147)</th>
<th>Disagree</th>
<th>Agree a little</th>
<th>Somewhat agree</th>
<th>Moderately agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-STELR Participation</td>
<td>6.3%</td>
<td>4.2%</td>
<td>9.2%</td>
<td>23.3%</td>
<td>34.2%</td>
</tr>
<tr>
<td>Post-STELR Participation</td>
<td>11.6%</td>
<td>10.3%</td>
<td>21.4%</td>
<td>29.2%</td>
<td>21.4%</td>
</tr>
</tbody>
</table>

Table 1.1: Students’ perceptions about the relevance of science pre and post participation in the STELR program

There were also similar shifts in the students’ perceptions about the usefulness of the science they learn at school (Table 1.2). When asked how much the agreed with the statement ‘I think the science I am learning at school is useful to my everyday life’, the students’ responses shifted from being
distributed normally around the ‘Somewhat agree’ option, to becoming skewed towards the Strongly agree after their participation in the STELR program.

![Graph showing the distribution of students' agreement with the statement 'I think the science I am learning at school is useful to my everyday life.']

Table 1.2: Students’ perceptions about the relevance of science being learned at school pre and post participation in the STELR program

There was also strong evidence of an increased engagement in learning science that was also reflected in the students’ focus group discussions. In these discussions students frequently reported that their classes had been more focused and there had been fewer discipline problems for the teacher.

Everyone seems to be doing more science now. There is less disruption than before and it is easier to learn.
(Year 10 student)

The increased engagement in students’ participation was also reported consistently by the teachers, with several noting a connection between the increased relevance of the topics they were studying in the STELR program.

With the STELR we did cover quite a few of the social and ethical aspects of the topics as well and I personally enjoyed that quite a lot. They enjoyed talking about these issues because they are interested in the environmental issues. It really went well and the students were quite keen to contribute to the discussions and while we were doing that we didn’t have any issues with classroom management.
(Year 10 Science Teacher)

I think the content of what we were given in the STER program made it easier to engage in discussion, whereas if they were doing straight chemistry, for example, some of the students tend to switch off. It is stuff that affects them here and now and it is often in the news too!
(Year 10 Science Teacher)
Students’ responses to survey questions about their enjoyment and participation in their science classes also suggested that the STELR program had generated a positive impact of students’ participation and engagement in science classes. These trends are reflected in Tables 2.1 and 2.2 below:

**Table 2.1: Students’ enjoyment of learning science pre and post participation in the STELR program**

<table>
<thead>
<tr>
<th></th>
<th>Pre-STELR participation</th>
<th>Post-STELR participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree</td>
<td>8.9%</td>
<td>8.9%</td>
</tr>
<tr>
<td>Agree a little</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Somewhat agree</td>
<td>13.3%</td>
<td>13.3%</td>
</tr>
<tr>
<td>Moderately agree</td>
<td>28.3%</td>
<td>28.3%</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>39.2%</td>
<td>39.2%</td>
</tr>
</tbody>
</table>

**Table 2.2: Students’ perceptions about their contributions to discussions and activities in science classes pre and post participation in the STELR program**

<table>
<thead>
<tr>
<th></th>
<th>Pre-STELR participation</th>
<th>Post-STELR participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Agree a little</td>
<td>2.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Somewhat agree</td>
<td>16.1%</td>
<td>16.1%</td>
</tr>
<tr>
<td>Moderately agree</td>
<td>33.4%</td>
<td>33.4%</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>28.8%</td>
<td>28.8%</td>
</tr>
</tbody>
</table>

**Changes in learning activities**

Much of the improvement in engagement and interest in science was attributed to the increased relevance of the renewable energy topics being covered in STELR and the increased amount of ‘hands-on’ learning the students were now participating in as part of the program. When the students were asked about differences in the way they were learning about science in the STELR program a number of trends were observed in students’ responses to the surveys:

- A shift away from the predominant use of using text books to learn science
• A marked increase in the amount of number of experiments and ‘hand-on’ investigations
• An increase in the perception students were solving real world problems
• An increase in the use of Information and Communication Technology

These trends are indicated in tables 3.1 to 3.5 below, where the students were asked to respond to how often they have used different approaches to learning science before and after participation in the STELR program.

Table 3.1: Students’ perception about how frequently they read from text books to learn about science pre and post participation in the STELR program

Table 3.2: Students’ perception about how frequently they solve problems from text books to learn about science pre and post participation in the STELR program
Table 3.3: Students’ perception about how frequently they do hands-on investigations to learn about science pre and post participation in the STELR program

Table 3.4: Students’ perception about how frequently they solve real-world problems to learn about science pre and post participation in the STELR program
Table 3.5: Students’ perception about how frequently they use the internet to learn about science pre and post participation in the STELR program

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Pre-STELR participation</th>
<th>Post-STELT participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>3.62.5</td>
<td>0.00</td>
</tr>
<tr>
<td>Occasionally</td>
<td>21.8</td>
<td>6.7</td>
</tr>
<tr>
<td>Frequently</td>
<td>20.5</td>
<td>31.1</td>
</tr>
<tr>
<td>Very frequently</td>
<td></td>
<td>5.4</td>
</tr>
<tr>
<td>Every lesson</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In discussing the differences in learning activities during the focus group discussions the students indicated that:

- There were more experiments in STELR.
- There was more time to investigation in STELR.
- There was more freedom to choose what to investigate in STELR.
- STELR had more purpose, more realism.
- There was less/no bookwork but more internet based explorations in STELR.
- STELR involved answering the students’ questions rather than textbook questions.
- There was more discussion and group work in STELR and less theory and more group work.
- They were more responsible for their learning.

Sample student (S) responses to the researchers’ (R) focus group questions [T1-T9 refer to particular teacher] about learning in the STELR program included:

S: we are taking more of a leadership role and we are doing most of the work. If we need something we can go and see the teacher. [T3]
S: we seem to be taking more of the learning into our own hands. [T3]

R: what were you doing previously?
S: mostly notes. [T3]
S: a lot more textbook work [T3]

S: It used to be just text-book stuff before but now it is much more enjoyable. We have experimented with solar panels and circuits to see what works best. [T3]
S: there were more experiments? [T8]
S: [in previous science topics] you get certain stuff to do, say two periods to do it in, in this project we had longer time and you were free what you could do. [T6]
S: we had no book work or anything, no questions to answer...we could make up our own questions really. [T6]
S: there seemed to be a lot more purpose to it, than just like mixing chemicals together or something. [T7]
R: so do you see it as more relevant and realistic?
S: yeah. [T7]

S: there's more hands-on than taking notes and talking about it than all the other topics [R2]
S: I’m a theory person and there wasn’t as much theory in the topic as I would have liked. By just experimenting you are not going to expand your knowledge as much. [T9]
S: everyone seems to be doing more science. There is less disruption than before and it is easier to learn [T3].
S: there is more group work [T3].

Perceived differences in teaching approaches compared to other science topics
In describing differences in the teacher and his/her approach in the STELR project compared to other science topics the students commented:

- the teacher in the STELR program allowed the students more scope to explore their own investigations.
- the teacher was seen more as a co-investigator than the expert. The students liked being on the journey of discovery together with the teacher.

S: I think he was a little bit more lenient; he let you do what you wanted to do.
R: so in the past were the tasks more structured in that you were told to do this and this and this?
S: yeah. [T6]

R: was there any difference in the way your teacher taught this topic? [T7]
S: even through he had been trained to teach it he kind of learned with us, which kind of made us feel we went on the journey together. I think it was good in that sense.
R: so he didn’t know all the answers and neither did you and you collectively?
S: we worked it out together
R: so that was different than to other topics?
S: yeah, because generally they know what they are teaching…it’s not that he didn’t know, but he didn’t know all the answers. [T7]

R: was the type of teaching any different to what you have had in other science topics?
S: I think it’s different. When we were asked to the in-depth investigation the teacher, he was just a supervisor and looked at everyone’s work instead of teaching one particular concept to the whole class it was quite open people were free to take things their own way
R: did you enjoy that aspect?
S: It was definitely fun [T9]

R: was there anything different in this topic in the way it was taught?
S: I think it was new for the teacher. I think he also found it interesting he wanted to know if we were enjoying this. Moving around and seeing what everyone is doing seeing how things work. I think that was quite good. For the current topic he is not as interested in what we think because he’s done it so many times. Because it’s [STELR] new and interesting to the science I think it’s good. [T8]
S: The teacher was much more enthusiastic I guess it was because it was the first time he was doing it everyone was much more enthusiastic. [T8]

Student learning in the STELR project
Throughout the implementation of the STELR proof-of-concept program the evaluators used the focus groups to explicitly ask students about the concepts they had been learning in the STELR program. Additionally, the evaluators observed classes of students as they participated in both the
‘hand-on’ experiments and when they undertook the Challenge activity. Students’ work samples were also examined as they participated in the STELR activities and students were asked to discuss the concepts they were learning as a result of STELR.

There were strong indications from each of these sources that the STELR program was contributing to the development of deeper understandings about alternative energy sources. Students were generally able to articulate what they had learned that was new to them and how this had been learned as a result of STELR activities. In responding to the focus group questions, for example, most students characterised their learning in terms of a greater understanding of renewable energy devices. Representative student comments are given below in response to the researcher’s question “What have you learned from the STELR topic?”

S: how solar panels work. [T6]
S: we learned about wind turbines the number of blades effect how much electricity is produced. [T6]
S: how big and small you can get wind turbines, [their] efficiencies. [T6]
S: how much energy they [wind generators] can generate. [T6]
S: I learned about solar; that’s very cool. [T7]
R: what aspects of solar did you learn?
S: the amps and volts, sort of how many panels and what angles, series and parallel, that sort of stuff. [T7]
S: There were three groups of wind and two groups of solar we just did a few experiments to find the best efficiency of the wind turbine and solar cell. [T9]
R: what have you been learning?
S: we are learning about energy – alternative energy sources. Bio-fuels, solar power, wind power. [T3]
S: we are going to have to use them in the future so we are learning about them now.
We are actually learning how to make bio-fuels from ethanol and oil from the fish and chip shop. [T3]
S: with solar power we have been making circuits and seeing how efficient they are. They are not that efficient. [T3]
S: for wind we made a small wind turbine and measured how many blades are most efficient.
We discovered that 4 blades was quicker than 6 because 6 is heavier, takes more energy to push it around. [T3]

These themes were also reflected in the evaluator’s observations made during the ‘hands-on’ and Challenge activities, where some students also discussed their greater personal awareness of the applications of renewable energies and the significance of such concepts to the wider community.

S: the social effects of renewable energy. We came up with this thing that in Australia it is dry and arid areas and to get solar energy from these areas to urban areas may take time and more research to get full benefit of solar.
S: I did biofuels, we did a few activities. Like experiments like how to make bio-diesel; it was really interesting. I didn’t realise the [commercial] use of ethanol at the moment. I thought it was still like way off. Whereas some countries use it all the time, I found that interesting. [T7]
S: In my group we did a wind power and we looked at the shape of the blades...we found that six blades were most effective even though [commercial] wind turbines use three and we found that three blades were least effective... also looked at shape. [T8]

Evidence from the surveys (Tables 4.1 to 4.3 below) also indicated that students experienced an increase in the levels of confidence and understanding of the science they were learning in the STELR program.
Table 4.1: Students’ confidence about their knowledge of science pre and post participation in the STELR program

Table 4.2: Students’ perception about their understanding of science learned at school pre and post participation in the STELR program
However, the evaluators also observed variation in the emphasis teachers were placing on their expectations related to students’ knowledge of significant energy concepts, such as energy transformation, efficiency, and power. This variation was also reflected in students’ discussion about their learning of these concepts and appeared to have emerged from two sources:

- diversity in teachers’ understanding and expectations about exactly what fundamental energy concepts students would need to have good knowledge of for the STELR program;
- diversity in the degree that the different stages of the STELR program were implemented by individual teachers in the participant schools.

The impact of this variation became most apparent when students were participating in the Challenge, where students were expected to draw on their knowledge of energy concepts to solve the open-ended problem. Some students were able to approach the challenge with their more explicit knowledge of the fundamental concepts; however other students experienced a degree of frustration as they attempted to solve the challenge with a more limited knowledge of the energy concepts required.

The teachers and students pointed to several conceptual and process areas that students either should know before beginning the STELR project, or need to be taught in the project. These include:

- Electrical ideas of current, voltage and their relationship to power and energy in electric circuits.
- The key ideas associated with how energy is produced from renewable energy devices such as solar cells and wind generators.
- The process skills such as creating an investigable question, design of investigation, scientific testing, collection of reliable data, tabulation of data, graphing, interpreting data, etc.
The expected level of understanding of the first two points needs to be such that Year 9 or 10 students can achieve.

T4: the idea of energy at the start was fantastic, but for the rest of it I personally think that perhaps there needs to be more theory in there somehow. With IBL they have to be confident in their knowledge to try and take it further where as once we got into the solar, wind and biofuels there wasn’t really any set learning activities for them to get to learn about those particular technologies. They were doing the experiments but I don’t think many have a really good understanding of how they actually work; that’s important especially when it comes to the challenge; that’s the problem I’m anticipating later in the week (when they do the challenge) the just don’t have that really solid understand to that yet.
T4: I think it definitely has them thinking about the realities of becoming greener and how it is not as easy as just having the right light bulbs.
T3: I think they have a general knowledge of global warming but don’t understand the nuts and bolts. STELR means we can bring out the data and graphs and stuff. I think they will retain the skills with electricity and so on...we didn’t get into as much hard science as I’d hoped to. It uses different skill s that sometimes we wash over. Using graphs and maths.

The evaluators believe that STELR program would benefit greatly from greater clarity and consistency in teachers’ understanding and emphasis placed on the energy concepts supporting the STELR project. It would also be fruitful to develop assessment resources that target students’ knowledge of significant energy concepts and are consistent with the inquiry-based framework of the STELR initiative. These are issues that would ideally be addressed as a part of a pilot stage implementation of the STELR program.

Learning preferences
The students were also asked in the focus groups how they thought they best learned science and if they experienced their preference for learning in the STELR project. The preferred learning styles included:

- ‘Hands-on’ activities, including experiments and projects
- Book work that was interesting
- Researching using the internet and recording notes
- Discussion and group work

Students consistently responded that the experimental work they undertook in the STELR program was a valuable way for them to learn. They also expressed in the focus groups that they experienced much more experimental work while participating in the STELR program and that this, in particular, had a positive impact on their learning science.

S: I prefer the pracs and that, hands-on [T7]
S: I like writing in my workbook because I have a picture memory so I can remember the words I write and I also like doing hands on pracs and if I need to revise I like to write things down [T7]
S: working as a group [R2]
S: talking about it, instead of writing everything down [R2]
S: hands-on is good [R2]

The students who responded “book work” recognised that there was a distinct lack of this style in the project but recognised that this was replaced with computer work, researching on the internet. For example,
R: did you find there was opportunity to do book work?
S: there was more research on computers, heaps of work on the computers rather than the textbook; there weren't many books really. [T6]

Student engagement with the different stages of the STELR project

The STELR project had a number of distinct stages that included an introduction, sampler experiments, in-depth investigations, and the Challenge. When asked “What part of the STELR project did you like the best?”, the students responses included:

- practical work as part of the in-depth investigations;
- practical work as part of the samplers; and
- the Challenge.

Preference for practical work in general

Most students preferred practical work and students consistently cited that this as the best way in which they learn. For example,

S: I like the prac best [other students chorused, ‘yeah’] [T6]
R: why do you like prac? [T7]
S: because I'm more of a hands-on person. [T7]
S: I reckon the practical bits were the best because I sort of learnt more from them rather than the theory bits. [T6]
S: it [my learning] helped to have more hands-on. [T6]

Preference for practical work as part of the in-depth investigations

The main reason students gave for preferring practical work as part of the in-depth investigations was that it gave them ownership of the design and conduct of the investigations. There was an appreciation of the information given to complete the in-depth investigations in terms of possible avenues of research to pursue.

S: I like the prac with the wind; you could see what shape the blades work the best. I thought that was cool. [T6]
S: we had a lot of say in what we did, had a lot of control. [T6]
S: I like how we got to make our own windmill things. [T7]
S: I liked all the questions you gave in the in-depth investigations. I know you don't have to do all of them but it's kind of good to get an overall perspective. [T7]
S: in the projects we did that, designed our own prac.
R: did you enjoy that?
S: I think it was the best.
S: I liked how you designed it the way you wanted it and find out what you wanted to find out [T6]
S: I liked the research on different solar panels to get the best efficiency. [T9]

Preference for practical work as part of the samplers

For those students who preferred the samplers, variety was given as the main reason.

S: I like how at the start you get to do a little bit of very bit of the project you are not just stuck to bio-fuels or whatever, you get to do like a double period activity on each. [T6]
S: I reckon doing like doing them at the same time sort of thing, like learning a bit about wind energy and solar energy, like the prac things. [T6]
R: like the little bits of each rather than the in-depth?
S: yes. [T6]
S: I reckon the sampler because we had to try everything [R2]
Preference for the Challenge
The main reason given by those students who preferred the Challenge was that the nature of the challenge was real; that the students were given a realistic challenge to solve that has multiple solutions.

S: I like it how they have made it like a challenge, like it looks like a challenge, getting to Macquarie Island. Whereas it’s not saying, we need go a certain distance, what can you take. They have made it kind of more realistic. [T7]
S: The challenge is good because there are a lot of things that you can choose on your own; you work out what you need and the power it takes to run in the real world. [T4]

Perceptions of STELR group work activities
The group work was also identified by the students as being a very positive feature of the STELR project. Whilst there was a concern that sometimes one might have a group member who doesn’t pull his/her weight the students were in full agreement that the quality of the work by the group exceeds that of any individual. Other benefits specific to the group work undertaken in the STELR program which were seen by the students were:

- You can have someone else to bounce ideas off.
- It helps you communicate with students you wouldn’t normally communicate with.
- Sharing the work load.
- Having students with specific skills within the group.
- Sharing of information and learning from other students in a manner more in tune with them. For example, understanding from a student who speaks the same language as others in the group.
- You push each other for better quality.
- Peer learning.

R: there is a fair amount of group work in the project so do you don’t mind group work?
S: no, it’s good working with others? I find it helpful.
R: do you reckon that the group work that you did produced better quality than you would if you did it on your own.
S: yeah, much better, you tend to push more so you don’t fail the entire group. We had a group member who was really good with computers. He created a website so people could log on and we could survey people. That was really good, we got a lot of people giving comments - there were 250 or something. [T6]
S: probably, yeah it’s more easier to do in a group than individually that means you can share around the work, and you push each other. [T6]
S: yes, and also if somebody else gets it they help you because sometimes the teacher can’t explain it as well. [R2]
S: you get other opinions than just the teacher’s. [R2]
R: did you find the amount of group work beneficial or disconcerting?
S: It depends on who is in your group but it was good. It feels like what you would do if you were to become a scientist. Working with different people and sharing results working together on a common experiment. [T9]
R: was there a fair amount of group work in the project? [T7]
S: Yeah.
R: so you don’t mind group work?
S: no, but it depends on who is in your group. You always have those types of people in your class that don’t do anything.
R: but do you think that the group as a whole can produce better quality work than individuals?
S: yes. You can have someone to bounce the ideas off.
R: do you think the project makes you work with others?
S: it also helps you communicate with people you wouldn’t normally communicate with.
R: so that’s worth doing in science?
S: I reckon it is. [T7]
S: we were split into groups, like solar and wind, created a PowerPoint to explain what we have learned to the rest of the class and then each person from a different group came together to do the challenge so we had one person from biofuels, one person from wind, and that we could pool our ideas together to get a better outcome. [T7]
R: so did you think that getting information from other students was worthwhile?
S: yep, like I learned, I did solar, and when Courtney did her presentation I understood what she was talking about, she explained how you can turn food into biofuels and stuff like that, and how it can be used.
R: that’s interesting because in lots of science classroom you generally get most of the information from the teacher.
S: it makes more sense when you have someone your own age talks the same type they way you do.
S: not so many sciencey (sic) terms and that. [T7]
S: yeah, it’s good if you are not understanding I as well as you like you can ask on your friends and they can explain it to you. [T8]

Use of STELR website and rooftop systems
When asked about their use of the website many of the students commented that they were unaware of its current contents, suggesting this aspect of the program was not being fully utilised. They could access the site early in the project but they commented that site was still under construction and were unable to access it until later in the program.

S: I haven’t been on it yet. We tried to get onto for one of the questions but the computer wouldn’t let us on. [T7]
S: I had to look for the project but it had no information whatsoever as far as I could tell, look like it was still half made. It didn’t help me one bit. [T6]

The students were also asked about their use of the roof-top equipment, including the solar cells and wind turbine. Many students responded that they students were made aware of the equipment and its possible uses but data from the devices were not used much by the students.

S: we haven’t used all the materials yet but the stuff we have used has been good. [T3]

Future study and careers in science and engineering
It was observed that while all schools in the project did not undertake specific activities involving different careers in science and engineering as part of the STELR program, the surveys (Table 5.1 and 5.2) and focus groups indicated there did appear to be an increase in students’ awareness of science careers beyond school.
Table 5.1: Students’ perceptions about career opportunities emerging from studying science at school pre and post participation in the STELR program

Table 5.2: Students’ perceptions about their personal knowledge of career opportunities that require further study of science at school pre and post participation in the STELR program

Trends in the survey data (Table 5.3 below) also indicated an increase in some students’ interest in studying a career that requires further study of science past Year 10. It is important to note, however, that many of the Year 10 students were also undertaking their careers activities as a part of their schools’ subject selection process for the following year. It is possible that, in future, the STELR program could seek to capitalise on the careers opportunities that are also organised as part of schools’ career education programs.
Students contributed the following comments in focus group discussions about careers in science and engineering:

S: there's lots of jobs in solar energy...and better money for it. [T6]
S: ...I want to be a vet or forensic scientist and when I was in the project I looked into solar careers and that interested me.
S: a little bit; yeah we researched it. We didn't really look into the actual careers we sort of like what sort of things they do. [T6]

In their discussions the students suggested that the experiences in the STELR program gave them insight into what to expect in senior science studies and the role played by scientists and engineers.

R: do you think that's what scientists do, so this topic gives you some insight as to what scientists do when they actually do their science and engineering? [T7]
S: a little, it gave you the aspect like when you look at a question and you get an answer, it leads you onto another question. [T7]

S: this project has given us some insight into the types of things we would be doing if we went into science. [T9]
S: this gives you a good taste of what to expect at senior levels. [T8]
S: the open-ended investigations kind lets you experience what a career in science might look like. I think that is a good factor of the project. [T8]

R: has STELR made you want to study science more?
S: yes. I am more interested now. I would like to study psychology. [T3]

S: [The STELR project] It has made us more aware of the issues in science as well. [T3]

Student concerns with aspects of the STELR project

Whilst all students in the focus groups gave a resounding ‘yes’ when asked, ‘Overall, did you feel the STELR project was worthwhile?’ There were concerns expressed by some of the students, which
could be traced back to the classroom experiences in a few classrooms. For example, one group of students from one class felt lost in undertaking the Challenge. The students the reasons given included:

- Lack of time to complete the task.
- Lack of direction to complete the task.
- Not enough technical information needed to complete the task.

Examples of student comments included:

*S: I personally don’t think it was worthwhile doing. We studied the wind and solar then there were all these different parts to the challenge and we didn’t know anything about it and for me it got way too confusing. I didn’t understand where to go, what to do [it should be noted that the students’ teacher was away ill for three lessons].
S: we had to gather a lot more information than we already had.
S: we had a short period of time to do it in as well.
R: so were you missing more of the technical stuff.
S: yeah, there was also small stuff, like we went from Australia to Macquarie Island and it took one of my group members a whole period to find the distance because that was a key part, like how long we needed the electricity for, it took time that long just to get the distance.
R: so would you prefer to have that information already there?
S: yeah [T6]
S: Mr XXXX hasn’t been here a lot and a lot of the teachers didn’t really know what to do and we wanted to ask him questions.
R: so even though it was open-ended you needed a bit of structure to help you with that?
S: yes. [T6]

*S: I reckon the challenge is OK but we just need more help with it. [T4]*

Not all of the teachers used the experiments provided by STELR and one class in particular described their classes as having too much theory, which they felt was delivered in a boring manner.

*R: so you had a lot more theory than practical. [T6]*
*S: yeah.
R: so how was the theory delivered?
S: boring, very boring, handouts and videos, it wasn’t that interesting to learn.
R: so did you have a lot of lesson teaching from the board.
S: yeah and handouts.
R: and there wasn’t much student-directed, students exploring on their own.
S: no, about half was teacher and half was student. [T6]*

A few students also expressed concern at the level of mathematics expected in the STELR project. This view is illustrated in the following student comment.

*S: I still reckon though that some of the maths part of it can be a bit confusing at times. A few people in my class don’t really know. Like converting the volts to power can be a bit confusing.*

**Overall perception of the STELR project**

The concerns expressed by the students above were in the minority, however, and most students in the focus groups expressed quite clearly that the STELR program had a positive impact on their learning of science. This was also reflected in the students’ responses to the post STELR surveys (Table 6.1 to 6.3 below).
Table 6.1: Students’ impressions of the STELR in relation to being ‘hands-on’

Table 6.2: Students’ impressions of the STELR program in relation to learning science being interesting
Teachers’ understandings about Inquiry-Based Learning (IBL)

The STELR curriculum document (p. 4) states, ‘The teaching units exemplify contemporary, evidence-based thinking on teaching and learning including an inquiry-based learning approach’. Whilst the STELR curriculum document (pp. 8-9) outlines the Inquiry-based Learning Principles [reproduced in Appendix 1] there was a reasonable amount of variation in the teachers’ understandings of what inquiry-based learning actually is.

While most teachers emphasised the need for students to investigate a topic by asking questions and undertaking research, there were differences in:

- The teachers’ beliefs about how much ‘structure’ a teacher should provide for students to undertake inquiry-based learning;
- The emphasis to be placed on real-world applications;
- How much the students need to be ‘prepared’ before introducing a topic that is going to use IBL;
- To what extent IBL is wholly an open-ended approach to teaching and learning; and
- The correct sequencing of teacher-taught content knowledge in order to prepare students for the STELR experiments.

In some cases the teachers understood IBL to be wholly student-focused and defined as much by its opposition to a teacher-centred and textbook-driven approach. Some teachers had an understanding that IBL required adopting a balance of using unstructured inquiry and very structured classes that involved teachers delivering content to the students. Where some teachers understood that there was insufficient time to utilise the inquiry approach as intended in the STELR material, they noted they had ‘reverted’ back to giving the students the information because it was quicker.

This variation in what is understood to be IBL contributed to a range of approaches being adopted by the teachers in the process of delivering the STELR program, making it somewhat difficult to
compare the students’ experience of the STELR materials as if it were truly common. Some illustrative teachers’ comments are given below:

T1: IBL means you introduce a topic to the kids and the kids formulate their own answer to their own questions in the form of experiments.

T3: Inquiry based is...I pose a question, we brain storm it, and then they go off and find the information and we come back and debate and discuss what we have found. I don’t structure it that much. I lead them in a direction and they go off and do it. I’m trying to get away from recipe teaching. I tell them I don’t do recipe teaching any more. A bit like myth busters. I pose a problem and they come up with the answers and we all come together. A little bit of structure from me. Input from me at the start and then I’m basically like a resource. They come up to me when they are ready. They have that control.

T4: I think IBL is meant to be a very student-centred approach to learning; moving away from teachers being at the centre of the learning process I guess. Definitely trying to use real-world problems in order to build their knowledge about science in a way that is based in the theory but also being able to apply it to real examples.

T5: [With IBL] the students have an opportunity to discuss things with me and as the teacher I facilitate their learning; but ultimately I would like them to discover the concepts from their own personal experiences through the experiments and investigations. With the way I teach I do like to introduce a topic by asking what they know about it first; it doesn’t mean I’m teacher-directed, but some things are teacher directed due to activities we do at the beginning at the project. The learning is more open.

All the teachers felt they had some understanding of IBL. Some suggested they had been encouraged to use this approach during their (recent) teacher training. For example,

T7: this is my first year I guess its part of my foundation from last year from uni they really drilled home the idea of inquiry approach so it is pretty fresh...[IBL] not just simply do and then go and find out really delegating roles to students and informing them giving them a bit of scaffolding what approaches could work and then allowing them to build on some kind of understanding to develop investigate further the particular aspects we are dealing with...that’s my general understanding.

There was recognition by the teachers that the IBL approach is suited to the STELR project. The following quote from an experienced teacher who incorporates IBL in his teaching illustrates this point.

T8: What happens with this kind of teaching approach, it pushes you into trying different things. I have learnt to let kids go and watch them rise or fail. There are teachers that find difficulty in allowing students to investigate and make mistakes. This unit demands that we withdraw and allow students to see how real research is conducted, even if it means allowing students to reach some dead ends.

There were some teachers with whom IBL was not part of their normal teaching practices. For example,

T6: firstly it is probably opposite to what I have been doing. Normally I tend to when there is a difficult class behaviour wise I tend to revert to taking control of the group. My understanding (of IBL) is the kids learn through exploration and from more in group with enquiry based, yeah more of a group approach, coming up with questions that are from their point of view worth pursuing and then dividing the group into tasks getting them to do that and ending up with a group result.

The STELR project allows for a range of different teaching and learning approaches, which have been applied with success in the proof-of-concept stage of the project. Different stages of the STELR project, such as the in-depth investigations and the Challenge, lend themselves to more open-ended
inquiry by the students. However, as pointed out by the teachers, as well as the students, these stages still require some structure and scaffolding by the teacher. The other stages that involve the introduction and samplers may require more structure and direct teaching than the other two stages as they relate to students developing an understanding of key energy concepts and electrical terms and formulae. The balance of structure versus open-ended inquiry will depend on the particular style of the teacher and his/her class of students. Whilst IBL may well be understood by recent graduates to teaching through their experiences in teacher training it may not be well understood by more experienced teachers. It is for these teachers that advice as to the possible pedagogic approaches would be helpful.

Several teachers expressed a view that the IBL learning approach is time consuming with the result that not as much content can be taught compared to traditional approaches. However, such approaches do have their place for the teaching and learning of some science topics. This view is reflected in the following comment by a teacher:

T9: I think overall it has been good. The only drawback is that you don’t get through the same level of content as you would if you had a structured class so you could not do it for every kind of topic that you teach for science but there is certainly a place for it. You need two or three units like this throughout the year just to engage them so they can play around with experiments.

Recommendation 1:
Recommendation 1: The benefits of the STELR program could be further enhanced with additional professional development for teachers aimed at building their capacity to use inquiry-based learning, particularly within the STELR curriculum resources. As a part of this professional development the evaluators recommend achieving greater clarity and consistency in the emphasis placed on fundamental energy concepts supporting the STELR project. It would be fruitful to develop formative and summative assessment resources that target students’ knowledge of significant energy concepts and are consistent with the inquiry-based framework of the STELR initiative. These are issues that would ideally be addressed as a part of a pilot stage implementation of the STELR program.

Limitations of Inquiry-Based Learning approach
Some teachers felt that an IBL approach could not be applied for all units of work as it consumes more time than traditional approaches if the aim is to cover science content. The teachers also felt that IBL is more challenging for the teacher as more control is given to the students and that for some classes a greater degree of structure would be required. These views are expressed in the following teachers’ comments.

T3: I enjoy the STELR program. Got to have a teacher who is able to let things go a bit and that is a bit tiring. Not for every teacher, but it’s a great thing to help kids learn more on their own. If I had a difficult class it might be different. Would be a lot more structured for them.
T7: …in my class there are a real lot of extremely intelligent people and they can kind of look up and they work really well together and even the kids who aren’t up to the same level they work well together they kind of help each other whereas for my Year 8 class there are a lot of kids who are not where they should be and for me to [adopt] inquiry based learning it would just be, it wouldn’t work, it would probably turn into mayhem
T9: the only drawback is that you don’t get through the same level of content as you would if you had a structured class so you could not do it for every kind of topic that you teach for science but there is
certainly a place for it. You need two or three units like this throughout the year just to engage them so they can play around with experiments.

T4: IBL does take a lot of time and preparation so we don’t always have a lot of time to do that and it’s been nice to have the STELR program to assist with that.

Teachers’ perceived benefits of IBL in the STELR program

Teachers generally understood there are significant benefits to be gained by using an inquiry-based approach in the STELR program. Some of these benefits included:

- Definite increased level of students’ engagement with the material; this included more class discussion and willingness of students to contribute to discussions as well as increased engagement in undertaking the practical activities;
- Generally fewer discipline issues with students;
- More opportunities to connect what they were learning with current issues in the media and students lives;
- An opportunity to undertake IBL on a much larger scale than teachers’ resources and time would otherwise allow;
- Broadening teachers’ understanding about the applications of science;
- The STELR program provides an excellent context to apply VELS in terms of links to the two Science dimensions of ‘Science knowledge and understanding’ and ‘Science at work’, as well as the Interdisciplinary Learning domains of ‘Thinking’, ‘ICT, and ‘Thinking Processes’.
- Opportunity to work as a team of science teachers; and
- Providing students insights into how science works in the real world.

T2: With the STELR we did cover quite a few of the social and ethical aspects of the topics and I personally enjoyed that quite a lot. They enjoyed talking about these issues because they are interested in the environmental issues. It really went well and the students were quite keen to contribute to the discussions. T1: and while we were doing that we didn’t have any issues with classroom management. We did have some issues with different types of classroom management in other areas of the STELR program however.

T1: I think the content of what we were given in STELR made it easier to engage in discussion, where as if they were doing straight chemistry, for example, some of the kids tend to switch off. It is stuff that affects them here and now and is often in the news.

T3: The STELR program is definitely very different; it is a much bigger project than we would have time to develop as teachers; it’s been good to have something that is a lot larger than we would be able to do; IBL does take a lot of time and preparation so we don’t always have a lot of time to do that and it’s been nice to have the STELR program to assist with that.

T5: The kids loved it and the teachers liked it. The teachers are already talking about changes for next year. They wouldn’t do that if they weren’t interested.

T3: I hadn’t done anything on biofuels before so I had to learn a lot about Biofuels; making the blends up; measuring the energy; building wind turbines. I had done a little on solar panels before but the STELR had a lot more than I had done previously.

There was some variation in teacher’s confidence that the STELR approach was leading to students developing better understanding of the concepts in science. A significant part of this variation may also be due to the different approaches to STELR being used as well as the different cohorts of students involved in the program:

T4: Yes they definitely see relevance in the topics. I’ve had two different classes and they only started having those light bulb moments when we started the challenge. They had done all of the focus projects

32
and they were starting to apply that to a real life situation. They were starting to realise how little energy that these renewable resources actually make for them and how difficult it is going to be on a large scale. They were building boats that needed 20000 Watts and realised that a solar panel makes 170 Watts. They were figuring that out and it was good to see them making that connection.

T5: The idea of energy at the start was fantastic, but for the rest of it I personally think that perhaps there needs to be more theory in there somehow. With IBL they have to be confident in their knowledge to try and take it further where as once we got into the solar, wind and biofuels there wasn’t really any set learning activities for them to get to learn about those particular technologies. They were doing the experiments but I don’t think many have a really good understanding of how they actually work; that’s important especially when it comes to the challenge; that’s the problem I’m anticipating later in the week (when they do the challenge) they just don’t have that really solid understanding to that yet.

Level of student engagement
A recurring finding coming from both the teachers and students was the increased level of engagement had by the students in undertaking the STELR project. There were many reasons given to explain this. These included:

For the students:

- A match with their preferred ways of learning, which included hands-on activities, open-ended task that involve student and design of investigations, avenues of discussion of real problems and group work.
- The enthusiasm of the teacher and his/her interest in what the students were doing.
- The teacher was seen as a co-investigator rather than the expert with all the facts.

For the teachers:

- The stimulus material, such as the DVD ‘An Inconvenient Truth’.
- Discussion of current issues in the media and their relationships to the students’ lives.
- Practical ‘hands-on’ activities.

The universal appeal in the STELR project lay in the fact that each student and teacher found some aspect that benefited them. These aspects did not come from the same stage. Each stage was mentioned by the students/teachers. Whilst some classes didn’t complete all stages (for example, most of the introductory stage and/or the challenge) for various reasons (the main reason being time constraints) there was evidence that other classes engaged heavily with these stages.

Some more teachers’ comments include:

T6: the Al Gore movie ‘the inconvenient truth’ certainly got a lot of interest happening. That was good...I did that activity with the bouncing balls looking at the energy transformations and, what was it, the efficiency we had 6 different types of balls and the kids did that really well and that was an inquiry based thing because they were just given the direction an energy input initially but they had to run with how they were going to investigate it them selves and they came up with a butcher’s paper thing with their results and it was quite good.

T7: yes I think so [a greater student engagement]. Yesterday I did the solar sampler and done a wind sampler. And I expressed to them they need to take ownership of this and the importance of it and how much they can get out of it even if they don't like certain aspects of science this is something they can really look into and I also told them how much time I put into setting up things and they seemed to get into it, taking pride in their work; even the kids who tend to let things go by are really seemed to get stuck in I don’t know really which variable is the point at which they decide its good.
T9: I put a question to them, “You’ve been doing this unit for about three weeks now it’s fairly open-ended you can see we don’t have a set method, discussion, conclusion, methods like we do for a lot of experiments do you like this?” About two thirds of the boys said they actually like it. I think overall it has been good.

Recommendation 2:

The STELR project provides opportunities for teachers to modify stages to suit their particular needs. Therefore, all stages, the introductory activities, samplers, in-depth investigations and the challenge, need to be incorporated into any final curriculum document.

Use of the STELR curriculum resources

The STELR curriculum resources consisted of:

- Renewable energy laboratory equipment (for example, low capacity cutaway photovoltaic systems and wind turbines);
- Roof-top installed renewable energy systems (for example, wind turbine, solar panel and weather station) connected to a computer with interactive teaching software, rechargeable battery and refrigerator; and
- STELR website; and
- Curriculum document detailing a suggested teaching sequence.

Renewable energy laboratory equipment

The wind generators and solar panels were used extensively, and successfully, by the students in the sampler and in-depth investigation stages of the STELR program. Modifications were made to different items, such as wind generators (protective housings) and solar panels (glued to boards with connecting wires sockets), to enhance their durability and allow students to readily collect data. In addition, everyday items, such as soft-drink cans, were modified and used in the bio-fuel investigations as a safety measure.

There was some concern by the teachers in the students using the spirit burner equipment to conduct their bio-fuel investigations. Three teachers did not allow students to undertake the bio-fuel sampler investigations. They felt that there was too much of a safety risk.

T8: I’m not comfortable running the three samplers at the same time; biofuel needs to be done separately. With wind and solar there are lots of things going on and with spirit burners I feel that is a recipe for disaster.

T6: The biofuels [investigations] is just an accident waiting to happen.

The teachers who did allow students to conduct the bio-fuels investigations commented that they felt the need to spend more supervisory time and provide more restrictive guidelines for students than they gave for the other investigations.

T5: The fuel burners are more dangerous than Bunsen burners – the cap is too loose. We had three groups (solar, wind and biofuels). I spent most of my time with the Biofuels.

T7: For the bio group I kept close because I hadn’t done it before. But now I have done it would be happy next time for them to go off and use the spirit burners and things like that.
The teachers and their laboratory technicians spent a considerable amount of time testing and modifying the equipment, and trialling the activities so as to allow the smooth running of the investigations.

T3: The resources are excellent. The equipment has been fantastic. Some of the more high-tech stuff the kids wouldn’t see unless they had it in their home. Being able to touch it and see what happens. We haven’t used the weather station as much as I like. Yet to figure out to use them well. But the small kits stuff has been great.
T5: We got all of the equipment provided and that’s been really great; the stuff that’s on the roof I haven’t incorporated at all as there is nothing at all in the teachers notes about how to incorporate that so I haven’t used them; we’ve been talking about them a little but it would have been nice to use that stuff in a meaningful way; it is all set up but it wasn’t put into the course in any way; I think that stuff could be useful but they need to find a way of implementing it into the course really;

The teachers expressed a view that at the STELR professional development day more time may have been given to working with the equipment as they found that extra time at school, often between lessons, was used playing with the equipment. The teachers also would have liked to have known how the equipment might have been used in teaching the STELR topic. However, the teachers felt that this was hurdle type learning experience so that this problem wouldn’t arise in teaching the STELR project in following years.

T2: At the XXX school...we didn’t have much time to work with the equipment...I would like to have more time to look at the equipment, but when the kids do it in class you get a much bigger perspective. When there are 25 students using the equipment you get to see what goes wrong... Perhaps seeing others using it in a class would be useful.
T1: Before each class I would try to set things up before hand and have a play... Because we were the first group to get through we had some teething problems. The equipment...you can see how it could be used and how it should be used, but you need to see the teaching of it as well – but there is the learning of the teacher as well and I guess that the teacher needs to learn how to use it teaching.
T9: The teething problems that we have had are probably the sort of problems you would have when you introduce any new unit because I’m not sure what the teaching is. So I’m learning it as the students are learning it and naturally, you can’t teach it as well. Next year or the year after when we repeat, it will be much easier.
T4: I hadn’t done anything on bio fuels before so I had to learn alot about Biofuels; making the blends up; measuring the energy; building wind turbines. I had done a little on solar panels before but the STELR had a lot more than I had done previously.

Recommendation 3:

Recommendation 3: The STELR laboratory equipment supplied to schools should be further examined for the need to be modified to alleviate safety and durability concerns. Alternatively, notes may be provided for laboratory technicians and teachers on various modifications possible, including the best ways for students to use the equipment. In addition, any in-person professional development sessions needs to provide sufficient time for teachers to work with the equipment.

Roof-top installed renewable energy systems
The roof-top installed renewable energy systems have yet to reach full functionality in the proof of concept schools. This is one of the main reasons why the use of this equipment was not used in the teaching sequence by any of the schools.
Whilst the teachers believed the teaching sequence they experienced could run successfully without the need for the roof-top equipment they felt that such equipment would provide enhanced student engagement to the topic. However, the teachers felt that curriculum materials need to be written to facilitate the use of the roof-top systems.

T5: We need to write material that can use these devices. We need to write activities within the module otherwise no one will use it other than pointing out to students that we have them in the school. We need some concrete activities so that the teachers and students feel confident in using them. We would definitely use it when rolled out.

T4: We got all of the equipment provided and that’s been really great; the stuff that’s on the roof I haven’t incorporated at all as there is nothing at all in the teachers notes about how to incorporate that so I haven’t used them; we’ve been talking about them a little but it would have been nice to use that stuff in a meaningful way; it is all set up but it wasn’t put into the course in any way... I think that stuff could be useful but they [curriculum writers] need to find a way of implementing it into the course really.

Recommendation 4:

The full potential of the STELR roof-top renewable energy systems has yet to be realised. There needs to be more planning put into generating ideas and activities to use this equipment within schools and across schools. Given the cost of installing this equipment, further thought needs to be given to how these devices might be used in science at other year levels as well as other discipline areas. There is great potential for using the roof-top energy systems to engage students in renewable energy and climate topics.

Recommendation 5:

Given that some of the STELR proof-of-concept schools still have classes to undertake the program there is opportunity to trial the roof-top equipment with these classes.

The STELR website

The STELR website was not used by any of the schools in their teaching sequences. A principal reason was that the website was not functional until several weeks into the sequence. In addition, as late as July 29 (STELR Review meeting), teachers reported problems gaining access to the website from their school location despite clear evidence of accessibility at the meeting location (ScienceWorks, Spotswood).

The website can provide significant scope to enhance the STELR program both from within the community of schools undertaking the program to publicizing the STELR program to non-participating schools. The website can act as a repository for additional resources, such as case studies of commercial renewable energy project, as well as a space for sharing information, such as roof-top renewable energy systems data from each of the participating STELR schools. The website can provide tutorials for use by students in such areas as using spreadsheets to create graphs or calculating power output. The website could display exemplary student work to illustrate what could be achieved; it could also provide teachers with technical details and hints on using the STELR equipment or some PD modules in areas such as inquiry-based learning.
Recommendation 6:

The possible uses of the STELR website by teachers and students have yet to be realised – there is great potential here. There needs to be more planning to be put into generating profitable ways in which the website may be used. The uses of the website need to be embedded into the STELR curriculum document and student activities.

Curriculum document detailing a suggested teaching sequence

The curriculum document detailed a suggested teaching sequence of six weeks involving four stages:

1. Introduction to global warming and energy concepts (6 lessons).
3. In-depth exploration modules (6 lessons).
4. Design challenge and evaluation (6 lessons).

There was significant variation in the time take by schools to complete the teaching sequence, ranging from 5/6 weeks up to 10/11 weeks, as well as the stages and the activities within the stages. Whilst there was a suggested period of time of six was given to complete all stages all proof-of-concept schools were unable to do this. The two schools that finished within the six week period did not undertake the last stage, the design challenge and evaluation, not did they complete all the introduction activities. There where two schools that completed all stages and most activities described in the STELR curriculum document. These schools took considerably longer time than the suggested six weeks. One school took 8/9 weeks, whilst the other school took 10/11 weeks.

The decision to carry out some activities and not others stemmed from the teacher’s particular focus to teaching the topic and students’ prior experiences. For example,

- Teacher 1 showed the students all of the video ‘Inconvenient Truth’ whilst others, like teacher 2, only showed snippets.

  T7: we watched the whole inconvenient truth just because they seemed to not know a lot about global warming and so I stopped it and discussed.

  T5: Inconvenient Truth was only as a stimulus for discussion and only parts of it. It was one of many resources that we have been using. I only showed snippets for discussion, we didn’t see the whole thing. There are other resources that the kids could use – the articles, for example, I found from the Age.

- Some teachers did some work with students in relation to careers in science and engineering through either discussing possible career paths with students in class discussions or giving students a task of researching career paths in specific renewable energy areas. Other teachers, like teacher 8 didn’t do any work with the students in relation to career paths in science and engineering.

  T8: my kids, who they are, who their parents are, know where they are going and I don’t need to teach that. I don’t need to spend anytime at all on careers really.

- Some teachers, like Teacher 8, had more of a process focus to the teaching sequence whilst others, like Teacher 2, had more of a concept focus, particularly to the early stages of the STELR program. Teacher 8 completed only parts of the introduction stage whilst Teacher 5 completed most parts of this stage.

  T8: I liked the way in which it completed our scientific method approach that we started at the beginning of year 9. At the start of Year 9 we teach them certain skills about how science works and this [STELR] is
a perfect example of using those scientific principles and applying them with alternative energy ideas. I was very pleased with the way this worked.

T5: then we started to go through the teacher materials there was a lot of stuff there and people were saying, ‘what am I going to teach, how am I going to teach this material?’ So I sat back and thought of what concepts what things do I want the kids to get out of this? And what’s the best way of producing the information. And we really enjoyed looking at the concept of energy, the toys, the efficiency of a bouncing ball – that was one of the best experiments I couldn’t get them out of the room at the end of the lesson, same for the other teachers.

• Some teachers (Teachers 3 and 8) advocated for less time to the introduction and sampler stages of the STELR program so that more time could be given to the in-depth investigations and challenge stages. However, other teachers (Teacher 3) saw great benefit for student learning and engagement through undertaking the introductory activities.

T3: there is way too much introduction stuff, I want to spend more time on the in-depth investigations or the challenge stages. Suggest that the tasters, samplers and introduction should be 1.5 weeks maximum. Because setting up experiments, taking measurements and writing them (samplers), that’s a very slow process for Year 10s. With the energy concepts as they are doing the experiments you are reinforcing the concepts so I think the introduction section is a bit long.

T8: overall we are really happy with the whole project. We are happy how it dovetails into our current course. There could be less time for the unit – 5 weeks will be sufficient. We have other things we want to do with the students to keep them busy.

T5: ...we also investigated the toys and discussed the carpenter with the hammer and nail. The kids used the sample of the Sankey diagram – they preferred the Sankey to the graph. They felt they understood that better and that’s how they wanted to describe the energy concepts and the transformations that were occurring. This worked really well and the kids looked at different scenarios and they looked at surfaces for the ball to bounce and they had to infer come up with a question. And they loved it.

• There should be the possibility for more scenarios for the challenge. Teachers and students could them choose a scenario that best matches their interest. The teachers and students felt that more structure and advice was necessary for the students to successfully complete the Challenge.

T10: They [students] are still unsure about the challenge and I’m not sure if they will be able to relate the energy stuff to this challenge. I think it is a bit too open ended and too many components...I would simplify the challenge a bit more by giving them more information; like where they are going and how long it takes to get there – so they are spending more time on using the knowledge they have learned.

Collectively, all the Proof-of-Concept teachers found benefit in all stages of the STELR project. However, in separate school groups they varied in what they thought was beneficial to teach in the project. It would therefore be difficult to recommend cutting back on any of the stages. The teachers in the Proof-of-Concept program made decisions to utilize those parts of the STELR program that suited their needs. The STELR program should then be seen as a flexible program.

T4: The other issue is that there was so much packed into the course that I couldn’t have had time; we’ve had to cut stuff out.

A key finding is that most teachers felt that to effectively teach all stages of the STELR curriculum a lot more time is required than the recommended six weeks. This was in spite of the fact that the roof-top equipment and the STELR website were not incorporated into the teaching of the topic. Therefore, any use of these would extend any planned teaching sequence.

Several teachers found the STELR curriculum document too bulky and suggested that a separate teacher and student edition be published.
T4: it would be really great is there was a student booklet and a teacher booklet prepared for STELR because we had to spend a lot of time preparing notes and things; They need something like to help them keep up with everything.

T8: what we did was photocopy the student friendly sections and leave out the teacher advice. However, I would still re-jig it; I want it to be more cohesive. Some early pages could be assigned to setting up the problem, then some exploring, and by developing the earlier findings, just like we have used the booklets here at school.

R: so what would be different in the teacher copy? What sort of added stuff would you have in there?

T8: I would like to see teacher advice to how to set up the class among other things. I would like to see a description of the philosophical approach to the topic. For many it may be new for them.

T5: it would be really great is there was a student booklet and a teacher booklet prepared for STELR because we had to spend a lot of time preparing notes and things; They need something like to help them keep up with everything.

Supplementary STELR Resources
The teachers incorporated other resources to enhance the STELR program. These included:

- Peer mentors, who were undergraduate students from LaTrobe and Melbourne Universities. They were seen as helpful in assisting students, particularly in the conduct of the biofuels investigations and electric circuitry.
- A guest speaker involved in the solar industry in the research and development side. Apart from providing expert advice about solar energy the speaker informed students about careers in the solar energy industry.
- Production of curriculum material such as:
  - Stimulus material in PowerPoint form to engage students in the Challenge. Also, guiding notes and other resources to assist them in completing the challenge.
  - Information in PowerPoint form to provide as to the operation of the roof top systems.
  - Worksheets and activities designed to reinforce key electricity concepts.

Recommendation 7:
The revised STELR curriculum document could include material, and ideas, generated by the STELR proof-of-concept teachers. The revised curriculum document does not need to be included into the one document as there could be more than one document, for example, a student and teacher edition. In addition, curriculum advice could also be located on the STELR website.

The challenge and open-ended learning
The open-ended learning required for the challenge revealed some very different student and teacher experiences for this part of the STELR program.

Some teachers placed a low-level of importance on the Challenge and noted they were rushing through this part of the program. Other teachers understood that this was a significant aspect of the project and required the students to engage deeply with the tasks required.

The open-ended nature of the Challenge provoked different responses from teachers when asked about how they used this approach and how students responded to it.
Some teachers suggested their students were not really well prepared for the open-endedness of the Challenge and sought to provide more structure to assist their students. These teachers also indicated that the Challenge had exposed gaps in the students’ conceptual knowledge about energy, making it more difficult for them to complete the tasks.

Some teachers noted they would like to provide more of the basic Challenge information for the students so as to allow the students to focus on the application of their knowledge.

T5: *when we had our initial discussion [about the challenge] things were highlighted to me that they didn’t understand. So I had to put a few things on the board and they copied that down. I think they have found it a bit too open ended and requires the teacher to think about how best to use the time when they are having trouble. I found there wasn’t enough structure. I think the topic of the challenge was good and the scenario was pretty good. I have set some roles for them in the challenge, but wasn’t included in the materials. In the end I’ve added a fair bit more to the challenge to help them.*

T6: *they are still unsure about the challenge and I’m not sure if they will be able to relate the energy stuff to this challenge. I think it is a bit too open-ended and has too many components. I would simplify the challenge a bit more by giving them more information; like where they are going and how long it takes to get there – so they are spending more time on using the knowledge they have learned.*

T3: *some students can cope well – they are students who have the skills and love working on their own and do well anyway. Don’t have problems with those students. Low-end students need a lot more structure and help with the work – more structure. Middle students can go either way. I did find some weaker students did well. One, for example, had the task of data recording and presenting the data as PPT. He was a success story. Maths wasn’t great, but he became much more interested. Some kids like maths, and STELR has parts that suit them. There are other parts that suit other kids’ interests as well.*

T4: *they are only half way through the challenge. But the biggest implication is they are realising what it is going to mean to switch over to these renewable energy sources; they are not as efficient at producing energy as the ones we have currently but how important it is that we make that change somehow.*

The teachers reported that the students responded differently to the open-ended nature of the challenge. Students who were performing generally well in science anyway seemed to enjoy the in-depth nature and self-directed nature of the challenge. Other students, who had struggled with science in the past, reported they were very frustrated by the challenge and wanted the teacher to provide much more ‘structure’ to help them complete the challenge in smaller steps. These students noted that the experiments were more ‘motivating’ for them because they knew what they were required to do.

*S: The challenge is good because there are a lot of things that you can choose on your own; you work out what you need and the power it takes to run in the real world.

S: I think the experiments are good but this [challenge] is not as motivating? They [experiments] have more structure and you know what you have to do and that. With this there is a lot more things you have to think about and half the class aren’t really working well at all. [the experiments are] clear-cut and telling us exactly what we have to do. Like this [challenge] needs more structure, like one lesson for working out the appliances and one lesson for a different bit; breaking it down into different bits so we know what to do.*

**Professional Learning**

There was also some variation in teachers’ access to the professional learning supporting STELR. Most of the teachers reported they had attended the PD day designed to provide hands-on experience with the equipment and that they found this very useful.
T4: the most useful thing about the PD was when we went through the booklet and looked at exactly what we were meant to do; we had a little bit of a talk as a faculty beforehand so we knew we were going to look at solar and bio fuels but I had no idea what we were going to do with them until I went to that day.

T6: The teaching approaches I think also there was a bit of a run-through on that inquiry based stuff, that was good; just asking other people who have been involved in the program was good.

Teachers from all schools reported they had a team approach to support themselves as science teachers and were more likely to share what they had learned.

T6: they [the school] have started what we call professional learning teams and this particular team there are something like six Thursdays one hour after school where these teams meet so myself and the other teachers [second STELR teacher and other Year 9 science teacher] have got together and said lets get together devote time to this task. First we set up the work station and we have spent time looking at the wind and the solar student stuff and how we are going to do that and tomorrow after school for another hour we will be looking at the next step three groups going at the extended task and how we are going to do that.

It was noted by most teachers, however, that an additional PD day would have been helpful, and that seeing the equipment in action with 25 students in the class was the most effective way to learn how to use the resources in this context.

T4: It is important that we do get to do that hands-on experience so we can anticipate what is going to happen in the classroom.

Teachers from the proof-of-concept schools had asked for the development of a teacher resource and a student resource because they were finding the amount of preparation time for STELR very difficult to sustain over a long period of time. They suggested such an approach would also assist in the provision of more ‘basic knowledge’ for the students and help them with the sort of ‘structure’ they needed to undertake IBL. This point also seemed to reflect the teachers’ differences in understanding IBL.

It was also observed by one teacher that the other teachers who tended to use more teacher-centred methods had tended to become overly reliant on her for professional learning and the preparation of teaching resources to support the STELR program.

T5: It’s also ok if you are confident in teaching physics, but I’ve found some teachers weren’t confident in physics and they struggled. So I came up with the approach where I made suggestions to them about how I’m teaching it and they found that helpful. They appreciated that and we would have a weekly discussion about what was useful; what was lacking in the materials and so on. With STELR we have been meeting more regularly than usual but I have found that while some of the teachers have become less and less dependent, two of them have become more and more dependent on me.

Several proof-of-concept teachers made the point that there was a strong collaboration between the teachers in planning and reflecting on the experiences had in teaching the STELR project. However, at this point in time there was no connection with any of the other schools in the STELR project.

The two review meetings were quite profitable in terms of sharing of ideas and experiences.

The following teacher comment gives useful advice for future schools wanting to run the STELR project.
T3: if a school is taking STELR on board without someone who is right into it they will need to learn as a team of teachers. They will need a day on what the project is about, how to use the equipment hands-on, and some mentoring in the school.

Recommendation 8:

The program would benefit greatly from exploring ways to connect teachers from different schools following any in-person professional development program. Any professional development program needs to include at least two days of in-person workshops where the teachers gain an understanding of how inquiry-based learning approaches can be applied to the STELR curriculum and gain some hands-on experience in working with the STELR equipment. The two days of workshops might be separated by several weeks during which time the teachers might trial some of the STELR activities. At the second workshop teachers would share their experiences with other teachers.
Appendix 1

Principles of an Inquiry-Based Learning Program
(Adapted from a draft by the Science by Doing team)
http://www.sciencebydoing.edu.au/

Engagement of Students
An inquiry based approach starts with engagement of the students prior to explaining. This serves several purposes:

• provide a conflict between prior learning and the new more scientific understanding - such conflict will lead students to ask questions
• get students’ attention and focus
• elicit and assess prior knowledge [students may have naïve conceptions or misconceptions]

During this stage, students:

• ask questions
• show curiosity
• show interest

During this stage, teachers:

• create interest
• generate curiosity
• raise questions
• elicit responses

Exploration

During this stage, students:

• ask questions
• hypothesise
• work without direct teacher input [but are guided]
• gather evidence
• record and organise information
• share observations
• make evidence based claims
• draw conclusions
• work cooperatively and / or collaboratively

During this stage, teachers:

• encourage students to work cooperatively and / or collaboratively
• observe and listen as students interact
• ask thought provoking questions
• allow students time to puzzle through and to explore
• act as a facilitator and / or a consultant
• create a climate where students “want to know and “want to learn”

Explanation
During this stage, students:

• draw on experiences to offer ideas and explanations in his / her own words
• uses evidence to support ideas
• critically appraise explanations
• listen critically and respectfully to others
• reflect on and assess their own understanding
• produce multiple representations of concepts.

During this stage, teachers:

• elicit the students' explanations of concepts, definitions of words
• ask for evidence and clarification
• formally provide definitions, explanations and new labels
• use students’ experiences to build new concepts
• assess students’ developing understanding of concepts
• provide opportunities for students or represent their ideas in a variety of formats.

Elaboration
During this stage, students:

• apply scientific terms, definitions
• apply understandings to new contexts
• use previous information to ask questions, propose solutions, to make decisions and design investigations
• draw reasoned conclusions from the evidence
• check for understanding with their peers.

During this stage, teachers:

• expect students to use appropriate scientific terms, labels and definitions
• expect students to use their understandings from explanations
• remind students of alternatives
• ask question such as “What do you think?” “Why do you think that?”

Assessment
During this stage, students:

• demonstrate their understanding of the ideas and concepts
• answer open-ended questions
• evaluate his / her own progress
• ask questions
• participate in peer assessment.

During this stage, teachers:

• elicit or diagnostically assess students’ prior knowledge and understanding
• explicitly develop the language of science and mediate where students have conflict in their understanding
• use formative assessment or assessment of learning throughout a unit of work to evaluate student understanding, to provide feedback to students and to direct the learning program
• use summative assessment to identify the students’ congruence with the new understandings.
• use conceptual mediation to overcome and reconcile misconceptions
• use a variety of assessment strategies.
References


